Systematic Consumption Risk in Currency Returns*

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May 2016

Abstract

We sort currencies into portfolios by countries' past consumption growth. The excess return of the highest- over the lowest-consumption-growth portfolio — our consumption carry factor — compensates for negative returns during world-wide downturns and prices the cross-section of portfolio-sorted and of bilateral currency returns. Empirically, sorting currencies on consumption growth is similar to sorting currencies on interest rates. We interpret these stylized facts in a habit formation model: sorting currencies on past consumption growth approximates sorting on risk aversion. Low (high) risk-aversion currencies have high (low) interest rates and depreciate (appreciate) in times of global turmoil.

JEL Classification Numbers: E44, F31, F44, G12, G15

Keywords: foreign exchange,uncovered interest parity, carry trade returns, consumption risk, asset pricing, habit model

*We would like to thank John H. Cochrane, Adrien Verdelhan and Angelo Ranaldo for very helpful discussions and comments. We are also grateful to seminar participants at the University of Zurich, the CESifo Money Macro and Finance conference 2013 in Munich, the 3rd Banca d'Italia Workshop on Foreign Exchange Rates, and the SNB-UZH workshop 'Asset Prices and Exchange Rates: Macroeconomic and Financial Perspectives'.

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1 Introduction

In this paper, we provide evidence that currency returns reflect cross-country differences in consumption risk. We do so by sorting currencies into portfolios based on countries' consumption growth over the last four quarters. High-past-consumption-growth currency portfolios pay consistently higher excess returns than low-past-consumption-growth currency portfolios. A consumption carry factor that reflects the return of going short on currencies of low-past-consumption-growth countries and long on currencies of high-past-consumption growth countries explains the cross-section of currency returns in a sample of 29 countries over the period 1990 – 2015. We call this factor the consumption carry factor and denote it by $\text{HML}_{\Delta c}$.

In recent years, the idea that movements in currency prices can be explained by the trade-off between risk and return has gained renewed attention and considerable empirical support. At a general level, a couple of conditions need to be fulfilled for currency returns to reflect a compensation for some form of macroeconomic or financial risk. First, currencies that pay high returns on average must perform relatively badly in bad times, whereas currencies that pay low returns on average must perform well in bad times. Second, currency returns must reflect cross-country differences in the exposure to common (global) risk, because only global risk will be priced in integrated world capital markets. Lustig, Roussanov, and Verdelhan (2011) show that currency returns are well explained by a two-factor model in which the first factor is the average return on the dollar vis-à-vis all other currencies, and the second factor is the spread in returns between a portfolio of high-interest-rate currencies and a portfolio of low-interest-rate currencies. As the latter factor, which is a carry trade factor and denoted HML_{FX}, pays off badly in crises, differences in the exposure of high- and low-interest-rate currencies to this factor can explain a substantial fraction of the variation in the cross section of interest-rate-sorted currency portfolios. Verdelhan (2011) extends this framework to the pricing of bilateral exchange rates and argues that differences in the exposure to a (level) dollar factor are also a key element of the systematic variation in exchange rates. Ranaldo and Soderlind (2010) find that so-called ‘safe haven’ currencies pay relatively high returns precisely when foreign exchange market volatility increases, whereas the returns from ‘investment currencies’ are low in times of high foreign exchange market turbulences. Menkhoff, Sarno, Schmeling, and Schrimpf (2012a) add to these findings by showing that a foreign exchange volatility innovation factor rationalizes the spread in returns of interest-rate-sorted currency portfolios. Together, all these results suggest that the returns obtained from holding particular currencies or currency portfolios compensate an investor for global market risk.

While these studies provide compelling evidence for a risk-return trade-off in foreign exchange markets, they propose financial factors as an explanation for currency returns. Hence, they do not fully answer the question whether these risk factors truly reflect macroeconomic and, in particular, consumption risk. Another strand of the literature has recently begun to address this issue. Lustig and Verdelhan (2007) argue that an extended version of the consumption-based capital asset pricing model (C-CAPM) with Epstein–Zin preferences and a durable consumption good can explain the cross section of interest-rate-sorted currency portfolios. Sarkissian (2003) explores a version of the C-CAPM with incomplete markets, finding that the cross-sectional variance in consumption growth rates helps explain currency returns. Colacito and Croce (2011) show that a version of the long-run risk model by Bansal and Yaron (2004) explains currency movements quite well, and Verdelhan (2010) shows that consumption habits can explain the cross section of currency returns. Hassan (2013) uses a model with non-traded goods to illustrate that larger countries pay lower interest rates and, by the failure of UIP, lower expected returns because they insure people’s consumption against worldwide consumption shortages.

The analysis in this paper positions itself between these two strands of the literature. We follow the first strand and construct a simple pricing factor that is based on sorting currencies into portfolios according to *ex ante* observable characteristics. This approach allows us to discuss the determinants of currency returns under as few theoretical assumptions as possible — in particular, we do not have to specify strong restrictions on preferences. We follow the second strand of the literature, however, by focusing on consumption fluctuations as a driver of variation in currency returns. Linking these two approaches allows us to determine the structure of consumption risk priced into currencies directly from the data without having to confront particular moment restrictions that specific versions of the consumption-based asset pricing model may impose on the data.

Specifically, we sort currencies into portfolios based on countries' past consumption growth. Currencies of countries with higher past consumption growth consistently pay higher returns than currencies of countries with low consumption growth, and the spread in these returns is well explained by the consumption-based carry trade return factor $\text{HML}_{\Delta c}$, which equals the difference in returns of the high and the low-consumption-growth currency portfolios.

In its ability to price exchange rates, the consumption carry factor $\text{HML}_{\Delta c}$ compares favorably with a range of financial risk factors that have recently been proposed, notably with the interest rate carry factor HML_{FX} proposed by Lustig et al. (2011). $\text{HML}_{\Delta c}$ is also successful in pricing the interest-rate-sorted currency portfolios used elsewhere in the literature. In addition, we show that $\text{HML}_{\Delta c}$ also prices individual currency pairs in a framework in which individual currency betas vary as a function of past consumption growth.

It is *not* our objective in this paper to argue that $\text{HML}_{\Delta c}$ outperforms extant financial pricing factors. Consumption is much more infrequently and noisily measured than financial variables such as interest rates. Hence, *a priori* we would not expect a factor that is based on measured consumption to outperform financial factors. Bearing this in mind, we argue that it is still a very interesting exercise to see how far we can go by sorting on measured consumption growth instead of interest rates. Our contribution, therefore, is to establish a novel stylized fact: information about past consumption growth helps price currency returns and it does so almost as well as information embodied in interest rates: sorting currencies on interest rates is practically equivalent to sorting them on past consumption growth and $\text{HML}_{\Delta c}$ prices currency returns practically as well as HML_{FX} .

To understand this stylized fact, we find it instructive to take guidance from a consumption based model with habit formation in the mold of Campbell and Cochrane (1999) and Verdelhan (2010). In this model, consumption is the true source of variation in national discount factors. But the model also implies that sorting currencies on past consumption is equivalent to interest rates, consistent with what we find in the data. These features make the habit model an attractive starting point for understanding why cross-country differences in past consumption growth matter for currency returns.

In a model with habit formation, sorting currencies on past consumption growth is very similar to sorting countries by their surplus consumption ratio and, therefore, by their degree of risk aversion. Countries that recently have experienced a series of high (low) consumption growth rates have high (low) surplus consumption ratios and therefore a low (high) degree of risk aversion. In complete financial markets, exchange rate changes are determined by differences in countries' marginal utility growth . Because, in the habit model, marginal utility in high-risk-aversion countries is more sensitive to global consumption shocks than in low-risk-aversion countries, optimal risk sharing requires that currencies of countries with high (low) risk aversion appreciate (depreciate) in times of global downturns, transferring purchasing power to the more risk averse country. This implies that the high average returns paid by currencies with high past consumption growth compensate investors for the risk of a large depreciation during global downturns. When interpreted in the context of the habit model, our $\text{HML}_{\Delta c}$ factor therefore reflects the spread between the return of low- and high-risk-aversion currencies. Because higher (lower) risk aversion leads to higher (lower) precaution and therefore to lower (higher) interest rates, in this model, sorting currencies on past consumption growth is therefore akin to sorting on interest rates. We show that a realistically calibrated version of the habit model with a global consumption growth shock can broadly replicate the empirical findings that we present in the main part of the paper.

The paper is organized as follows. The next section further connects our empirical approach and the previous literature. Section 3 defines currency returns and discusses the formation of portfolios based on past consumption growth. Section 4 describes the data set used in the empirical analysis, and Section 5 presents the empirical results. In Section 6, we interpret our empirical results in the context of a version of the Campbell and Cochrane (1999) habit model. Section 7 presents an overview of some robustness checks, and Section 8 concludes.

2 Related literature

Starting with Fama (1984), a large literature has documented the resounding rejection of uncovered interest parity (UIP) in the data. In fact, there is considerable structure in this rejection: currencies of countries with high interest rates do not depreciate as much as would be implied by UIP. This UIP puzzle, along with the finding by Meese and Rogoff (1983) that exchange rates are hard to predict out-of-sample, gave rise to a large empirical literature on exchange rate modeling. It is probably fair to say that much of this early literature was rather skeptical with respect to risk-based explanations of currency returns. Engel (1996) and Lewis (1995) provide useful surveys. During the last decade, the notion that currency returns, just like those of other assets, could be determined by risk premia has gained renewed attention and — probably because of the availability of more, better and larger data sets and theoretical advances in asset pricing theory — is continuing to gather empirical support.

A valid explanation of the UIP puzzle in terms of risk premia would require that investment in currencies with high interest rates — which promise high returns on average — would deliver especially low returns in bad times for investors. If this was the case, carry trade profits would just compensate an investor for risk that he exposes himself to when holding particular currencies. Empirically, however, it is challenging to identify risk factors, and especially macroeconomic risk factors, that would drive currency risk premia.[1] In this respect, an important contribution is the study by Lustig and Verdelhan (2007). As interest rates seem to predict currency returns, Lustig and Verdelhan sorted a wide cross section of currencies into portfolios according to their interest rate differentials with the US. Portfolios are rebalanced every period such that the first portfolio always contains the lowest-interest-rate currencies and the last portfolio always contains the highest-interest-rate currencies. Sorting currencies into portfolios eliminates currency-specific components of returns such that sharp estimates of the risk–return trade off of currency investments are obtained. Eventually, Lustig and Verdelhan (2007) show within the framework of consumption-based capital asset pricing models that the growth rate of durable and nondurable consumption expenditures, as well as the mean return of the US stock market, are helpful in explaining currency portfolio returns.

In a subsequent study, using a data-driven approach in the spirit of Fama and French (1993), Lustig, Roussanov, and Verdelhan (2011) find that the currency portfolios themselves contain information to explain the cross section of portfolio returns. Lustig et al. (2011) identify two factors that together account for most of the variability in the cross section of currency portfolio returns. The first factor, which they coin the 'dollar risk factor', is the average return that an investor gains by borrowing in US dollars and investing in equal weights in all currencies available. This dollar-specific factor acts as a level factor for portfolio returns. The second factor equals the return that a global investor gains by going short in the low-interest-rate currency portfolio and long in the high-interest-rate currency portfolio. Lustig et al. (2011) denote this carry trade factor HML_{FX} . While profitable for most of the time, such a carry trade strategy yields low returns during times of global turmoil, which implies a negative HML_{FX} factor. As expected returns increase

[1] Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011) find that traditional risk factors do not explain currency returns and attribute the forward premium to peso problems.

monotonically from low to high interest rate currency portfolios, and because the covariation of portfolio returns and HML_{FX} is higher, the higher the interest rates of a particular currency portfolio are, HML_{FX} qualifies as a slope factor for currency portfolio returns. Closely related to these results, the study by Menkhoff, Sarno, Schmeling, and Schrimpf (2012a) concludes that a factor that measures news in global foreign exchange market volatility decisively explains the returns to carry trades. High expected carry trade returns can be rationalized within standard asset pricing models, because these returns turn especially low during times of high foreign exchange market volatility surprises when investors particularly fear losses. Brunnermeier et al. (2008) uncover another link between the performance of carry trades and market volatility. According to their reasoning, a sudden increase in stock market volatility (as measured by the CBOE's VIX) could cause a decrease in risk appetite and funding liquidity, which then makes investors unwind their carry trades. An orchestrated sellout of investment currencies depreciates their prices all the more such that unexpectedly low returns to carry trades are realized. In accordance with this interpretation, Ranaldo and Soderlind (2010) find that currency market volatility has a nonlinear effect on currency returns. In particular, Ranaldo and Soderlind show that it takes a high currency market volatility to affect, for example, the CHF/USD exchange rate, but exchange rate reactions are then particularly strong. Christiansen, Ranaldo, and Soederlind (2011) demonstrate that the exposure of currency returns to the US stock and bond markets varies as a function of foreign exchange market volatility. Mancini et al. (2013) show that liquidity is a priced factor in currency returns.

Our paper is related to a number of recent studies that have started to link the carry trade to observable macroeconomic fundamentals. Jorda and Taylor (2009) show that the profitability of currency carry strategies can be improved by using macroeconomic conditioning information such as deviations from purchasing power parity. Their fundamental carry strategy leads to a higher Sharpe ratio and less negative skewness of returns relative to the conventional carry strategy. Nozaki (2010) reports similar results for a fundamental strategy in which the investor goes long in currencies that are undervalued relative to some simple model of the equilibrium exchange rate and short in overvalued currencies. Such an investment strategy leads to a much lower Sharpe ratio than the typical carry trade strategy, but it outperforms carry trades in times of high market turmoil. Habib and Stracca (2011) examine what country characteristics determine the safe haven status of a currency. In a large cross section of developed and emerging economies, they find that the only variable that robustly predicts whether a particular currency is a 'safe haven' against global volatility risk is a country's net foreign asset position. Hassan (2013) observes that it is large economies that systematically pay low interest rates leading to persistent violations of UIP. He interprets this stylized fact using a model with non traded goods, in which large countries' bonds endogenously are better hedges against global consumption risk than small countries' bonds because they insure a larger fraction of world consumption against idiosyncratic consumption slumps.

Our analysis is also closely related to Menkhoff, Sarno, Schmeling, and Schrimpf (2012b) who sort currencies into portfolios based on a range of macroeconomic fundamentals, such as past GDP growth, past money growth or the deviation from a Taylor rule. They find that past macroeconomic fundamentals have significant predictive power for currency returns. Our approach is similar in that we sort on a particular macroeconomic characteristic — past consumption growth. However, different from Menkhoff et al. (2012b), we use spreads between high consumption growth and low consumption growth portfolios as a pricing factor.

Hence, while a number of studies document a role for macroeconomic fundamentals in explaining momentum or predictability in currency returns, none of them has moved on to examine the pricing power of such fundamentals-based risk factors. Also, to our knowledge, none of these papers have used business cycle frequency movements in consumption as conditioning information in constructing such a carry factor, as we do here. As our results are obtained without particular restrictions on preferences (as is usually the case in consumption-based asset pricing models) they provide independent evidence that the heterogeneity in past consumption movements is priced into currencies.

In the next section, we present a foreign exchange investment strategy that is directly based on the cross-sectional distribution of consumption growth rates. This allows us to unveil a direct link between patterns of international consumption co-movement and returns to investment in the foreign exchange market.

3 Forming currency portfolios based on past consumption growth

This section first introduces notation concerning currency returns. Then, we discuss how to form currency portfolios based on cross-country differences in past consumption growth rates. Eventually, we introduce the consumption-based carry trade factor $\text{HML}_{\Delta c}$ and discuss its statistical properties.

3.1 Currency returns

From the perspective of a US investor, the gross excess return of investing into the currency of a foreign country k is given by

$$RX_{t+1}^{k} = \frac{(1+i_t^k)}{(1+i_t^{US})}\frac{S_t^k}{S_{t+1}^k} \tag{1}$$

where S_t^k denotes the current spot price of one US dollar measured in units of currency k and i_t^k denotes the one-period risk-free rate of interest in currency k at time t. An increase in S_t^k indicates a depreciation of currency k against the US dollar. Except in times of high market turmoil and at very high frequencies (see for example Baba et al. (2012)), covered interest rate parity holds such that the interest rate differential between two currencies equals the forward premium,

$$F_t^k(1+i_t^{US}) \quad = \quad S_t^k(1+i_t^k). \tag{2}$$

F_t^k denotes the forward price of one US dollar to be delivered in period $t+1$ measured in units of currency k. Taking logs and substituting equation (2) into equation (1) yields the following approximate equation for currency returns[2]

$$\begin{aligned} rx_{t+1}^k &= i_t^k - i_t^{US} - \Delta s_{t+1}^k \\ &= f_t^k - s_{t+1}^k \end{aligned} \tag{3}$$

where, henceforth, $rx_{t+1}^k = RX_{t+1}^k - 1$ denotes the (net) excess return on investment in currency k. This is the return that a US investor obtains from buying currency k in the spot market today and selling it forward. Under uncovered interest parity, rx_{t+1}^k should be equal to zero in expectation. However, the failure of the uncovered interest rate parity relationship has been documented widely in the literature: currencies that trade at a forward discount, i.e. currencies that pay higher interest rates than a given base currency because $f_t^k - s_{t+1}^k > 0$, typically do not depreciate as much as would be implied by uncovered interest rate parity. Hence, borrowing in low-interest-rate currencies and investing in high-interest-rate currencies generates positive expected excess returns. Conversely, currencies that trade at a forward premium tend to generate negative expected returns. The observation that expected returns from currency investment are not zero forms the point of departure for the analysis in this paper. We argue that positive expected currency returns compensate investors for systematic cross-country differences in consumption risk.

[2]Using forward prices instead of interest rate differentials to calculate currency excess returns has a number of advantages. In particular, problems concerning the correct matching of maturities for interest differentials are avoided. Also, the forward returns are implementable at rather low trading costs, and investors hardly expose themselves to counter-party risk (King et al. (2011)).

3.2 Consumption-growth-sorted currency portfolios

Portfolios formed with respect to past consumption growth rates reveal a stable pattern in currency excess returns: currencies of countries with higher past consumption growth promise higher excess returns than currencies of low-consumption-growth countries, and, while relatively high on average, carry trades that borrow in low-consumption-growth currencies and lend in high-consumption-growth currencies perform especially poorly during times of global turmoil when investors might particularly fear losses.

At the beginning of each new quarter, we sort currencies into n portfolios based on the associated countries' consumption growth rate over the preceding four quarters, such that the first portfolio always contains currencies of countries with the lowest n-tile of past consumption growth rates, and the last portfolio always contains currencies with the highest n-tile of past consumption growth rates.

Table (1) shows descriptive statistics for $n = 5$ portfolios formed out of a sample of OECD countries over the period from 1990 to 2015. A detailed description of the data follows in the next section, and details on the composition of the portfolios are given in the Appendix. Average returns increase with average past consumption growth. The table shows that investment in the portfolio of the highest-consumption-growth countries yields average annual returns of about 2.9 percent, whereas the portfolio of currencies of the lowest-consumption-growth countries only yields an annual return of -0.3 percent. High-consumption-growth portfolios also have higher Sharpe ratios than low-consumption-growth portfolios. These results suggest that cross-country differences in past consumption growth are an indicator of the differences in the risk exposures of currencies.

The key element of asset pricing is that there are states of the world in which investors particularly fear losses. We argue that a factor that indicates that such bad states have occurred is given by the difference between the return of the high-consumption-growth portfolio and that of the low-consumption-growth portfolio. Hence, this factor — which we refer to as $HML_{\Delta c}$ or as the ‘consumption-carry factor’ — is the cross-country average return that a global investor obtains when she borrows in the currencies of countries with the world’s lowest consumption growth and invests in the currencies of countries with the world’s highest consumption growth.

The last column of Table (1) shows that this carry trade returns of 3 percent a year, with a Sharpe ratio of 0.25. The empirical analysis of the next section will reveal that this $\text{HML}_{\Delta c}$ factor explains the cross-sectional difference in expected portfolio returns to a considerable extent and that it is globally priced.

The second last column of Table (1) shows descriptive statistics for $\overline{\text{rx}}$, which is the average return that an investor achieves by borrowing at the beginning of each quarter in US dollars and investing in equal weights into all currencies available in the sample over a holding period of one quarter. Lustig et al. (2011) call this factor the ‘dollar risk factor’, because it captures the idiosyncratic (country-specific) component of an investment strategy that funds itself in dollars and goes long in the cross section of all other currencies. At each point in time, the dollar risk factor therefore essentially captures the average rate of depreciation of the dollar against all other currencies. As this dollar factor is important for the level of all dollar-denominated returns, it is important to include it in all our pricing exercises below. However, because of its country-specific nature, we do not expect that this US dollar factor can explain the cross-sectional difference in the returns of different currency portfolios. As argued by Lustig et al. (2011), it should therefore not be globally priced. This means that there should be no differences across currency portfolios in the exposure to this factor.

Conversely, we will show in the next sections that the $\text{HML}_{\Delta c}$ factor is globally priced — that is, we will show that it prices the cross section of currencies exactly because currency portfolios have different degrees of exposure to it.

A couple of remarks on the procedure for sorting currencies into portfolios based on past consumption growth rates are in order. First, it is important to recognize that, over time, currencies change portfolios, reflecting countries' changing position in the cross-country distribution of consumption growth rates. This is the essence of forming portfolios: the fact that individual currencies may change portfolios reflects the fact that they may not have a fixed exposure to the risk that we wish to price. This may imply that individual currencies do not have a constant beta with respect to the risk factor $\text{HML}_{\Delta c}$. However, as we will show, and as has also been emphasized by Lustig and Verdelhan (2007) and Lustig et al. (2011), portfolios of currencies do have a constant beta with respect to the risk factor $\text{HML}_{\Delta c}$.[3]

Second, we focus on consumption growth over the past four quarters to build currency portfolios, instead of consumption growth rates at the highest available (i.e. quarterly) frequency. This reflects the recent focus of the literature on the role of low- to medium-frequency components in consumption for asset pricing. For example, quarterly consumption data might be a very noisy measure of true consumption, so that averaging consumption growth over several periods could provide a better approximation of the ultimate consumption risk that investors care about.[4] Alternatively, investors might have a preference for an early resolution of uncertainty, so that small but potentially very persistent movements in long-term consumption growth carry a much higher risk price than short-term fluctuations in consumption.[5] Finally, building growth rates over one year im-

[3]Note that the approach of building portfolios is also robust to missing data: for some countries, available consumption series do not span the whole sampling period, for other countries, forward exchange rates became available only in the late 1990s, and euro countries are excluded from the sample after they introduced the common European currency.

[4]Within the framework of the basic consumption-based capital asset pricing model (C-CAPM), Jagannathan and Wang (2007) show that the fourth quarter to fourth quarter consumption growth rate is a powerful pricing factor, and Parker and Julliard (2005) find that the covariance of returns and consumption growth across the 25 Fama and French (1989) portfolios explains the difference in expected returns observed in the US stock market extremely well, if consumption growth is measured over the quarter of the return and many following quarters. Lettau and Ludvigson (2001) reason that consumption should react predominantly to permanent shocks in wealth, such that the consumption-to-wealth ratio (cay) is unaffected. Fluctuations in cay therefore signal transitory variation in wealth (i.e. future returns), which implies that cay is a powerful pricing factor for asset returns.

[5]In the long-run risk models introduced by Bansal and Yaron (2004), consumption growth follows an ARMA(1,1) process with a slow-moving permanent component, such that shocks will affect consumption at a very long horizon. As agents dislike such long-run risk, a highly volatile consumption-based discount factor results, which has the power to explain observed asset returns.

plicitly also deals with seasonal effects present in some of the consumption growth series.

3.3 The consumption carry factor $\text{HML}_{\Delta c}$

This section discusses the consumption carry factor $\text{HML}_{\Delta c}$ in more detail and sets it in relation to other pricing factors that have been proposed in the literature. Table (2) presents key statistics for $\text{HML}_{\Delta c}$, as well as for other factors: the mean return of the consumption-carry strategy is close to 3.0 percent per year, and the Sharpe ratio is around 0.25. These figures are both smaller than the respective values for Lustig, Roussanov and Verdelhan's (2011) forward-discount-based carry trade strategy HML_{FX} which, calculated using quarterly data, pays an average annual return of around 5.1 percent with a Sharpe ratio of 0.29. The correlation of the two factors is highly significant, though at 0.48 not perfect. Figure (1) plots $\text{HML}_{\Delta c}$ against HML_{FX} and shows that the two factors are generally very highly correlated. This is true during most periods of global turmoil such as the Euro crisis of 1992, the Mexican Peso crisis of 1994, September 11 2001 and the Bear Stearns bankruptcy in August 2007 but also during more tranquil periods. One reason why the two factors are not perfectly correlated is that they do not strongly move together during the Lehman shock in 2008, whereby the consumption-based carry trade strategy provided distinctly less volatile returns than the forward-discount-based carry trade strategy. This, however, may not be surprising: given that the consumption-based strategy is a function of consumption growth over the last four quarters, sorting on past consumption growth is much less sensitive to sudden gyrations in interest rates that occur during a global crisis than is sorting on current interest rates. Conversely, countries with sudden idiosyncratic crises (such as Island during the 2008 crisis) may have high interest rates but sudden consumption busts. Against this background and taking account of the likely noise in quarterly consumption data, it is remarkable how close sorting on past consumption growth comes to sorting on interest rates when it comes to pricing the cross-section of currencies — as we document in the remainder of the paper.

Consistent with this, $\text{HML}_{\Delta c}$ is also correlated with another return-based factor that has proven successful in pricing currencies, the global exchange market volatility factor suggested by Menkhoff et al. (2012a). Conversely, our consumption carry trade factor is virtually uncorrelated with the more traditional pricing factors motivated by the (consumption based) CAPM, such as world average consumption growth, the global stock market returns as measured by the MSCI world index or the cross-country variance of consumption growth rates (Sarkissian (2003)).

4 The data

The data set used in this analysis includes time series for private final consumption expenditure as well as spot- and forward exchange rates for a cross-section of 29 OECD countries which are Australia (AUD), Austria (ATS), Belgium (BEF), Canada (CAD), Czech Republik (CRK), Denmark (DKK), Estonia (EEK), France (FRF), Germany (DEM), Greece (GRD), Hungary (HUF), Iceland (ISK), Ireland (IEP), Italy (ITL), Israel (ILS), Japan (JPY), Mexico (MXN), Netherlands (NLG), New Zealand (NZD), Norway (NOK), Poland (PLN), Portugal (PTE), South Korea (KRW), Sweden (SEK), Switzerland (CHF), Spain (ESP), United Kingdom (GBP), United States (USD), and the Eurozone (EUR). Quarterly consumption growth rates are sourced from the OECD national accounts database; growth rates are measured over one year, that is, consumption is compared to consumption of the same quarter of the previous year. Starting from daily midpoint quotes, spot- and three month forward exchange rates correspond to averages over the last ten trading days of each quarter. We think that this choice is robust to end-of-month effects that might be present in exchange rates on the one hand side, but does not blur variation in exchange rates on the other hand side. Our analysis however is robust to the use of daily end-of-quarter quotes or quarterly average quotes. For each country/currency, data is included in the analysis only when all, consumption growth rates, forward- and spot exchange rates are available: for some currencies, forward quotes are only available starting in the mid 1990s', whereas other countries drop out of the sample when they introduced the euro. The analysis in this paper covers the period from the first quarter 1990 to the fourth quarter in 2015. The appendix presents more details for the data.

5 Empirical results

5.1 Pricing currency returns

The price of an asset equals its expected discounted payoff. This price reflects the systemic component of risk associated with a particular asset, which is determined by its exposure to a set of common risk factors. As carry trades are a zero-net-investment strategy, if the law of one price holds, the return on each portfolio j, denoted by rx^j_{t+1}, must satisfy

$$0 = E(M_{t+1} rx^j_{t+1}) \tag{4}$$

where M_{t+1} denotes the stochastic discount factor that prices the payoffs denominated in US dollars. We assume that the stochastic discount factor M is linear in the pricing factors

$$M_{t+1} = 1 - b' f'_{t+1} \tag{5}$$

where f_{t+1} denotes a matrix of risk factors containing the different factors in its columns, and b is the column vector of factor loadings. Equation (4) and (5) imply that

$$\begin{aligned} E(rx^j_{t+1}) &= -\left(cov(M_{t+1}, rx^j_{t+1}) var(M_{t+1})^{-1}\right)\left(var(M_{t+1}) E(M_{t+1})^{-1}\right) \\ &= \beta^{j\prime}\lambda \end{aligned} \tag{6}$$

where the column vectors β^j contain regression coefficients that are obtained by running time series regressions of portfolio returns rx^j on the factors of the stochastic discount factor. The market price of risk λ mirrored by each factor can be estimated by running a cross-sectional regression of expected portfolio returns on β^j. Substituting the expression for the stochastic discount factor (5) into the Euler equation (4) yields the following alternative expression for the expected returns of currency portfolio j

$$E(rx^j_{t+1}) \quad = \quad cov(f_{t+1}, rx^j_{t+1})' b \tag{7}$$

where $cov(.)$ denotes the column vector of covariances of the individual elements of f with rx. Hence, the market price of risk λ and the factor loadings b are related by $\lambda = var(f_{t+1})b$ where $var(.)$ denotes the covariance matrix of f. The factor loadings b are estimated by a cross-sectional regression of expected excess returns on the covariance between returns and factors.

Our objective is to show that $HML_{\Delta c}$ prices currency returns. We therefore specify the stochastic discount factor as

$$M_{t+1} = 1 - b_{\overline{\text{rx}}} \cdot \overline{\text{rx}}_{t+1} - b_{\text{HML}_{\Delta c}} \cdot \text{HML}_{\Delta c,t+1}$$

At this stage, our justification for this choice is purely empirical. Very much as in the case of the interest-rate sorted portfolios of Lustig et al. (2011), a high-minus-low factor appears as a natural starting point for pricing currencies, since it spans much of the cross-sectional variability in returns. Indeed, as can be seen from Figure (2), $\text{HML}_{\Delta c}$ is highly correlated with the second principal component of the five consumption-sorted portfolio returns. This allows us to interpret $\text{HML}_{\Delta c}$ as a global slope factor that determines return differences in the cross section of currency excess returns.

As a second factor, we include the return to a US investor who owns an equal-weighted portfolio of the cross section of all currencies. As shown by Lustig et al. (2011), this factor, referred to as $\overline{\text{rx}}$, captures base-currency-specific (here: dollar-specific) influences on the cross section of currency returns. It is therefore a base-currency specific factor and acts as a level shifter for all dollar-denominated returns. In keeping with this notion, it is highly correlated with the first principal component of the returns on our six portfolios, see the first panel of Figure (2).

Time series regression

A factor mirrors global risk if differences in expected returns across portfolios can be explained by differences in the extent to which portfolios load on this factor. We obtain the loadings or βs on the risk factors $\overline{\text{rx}}$ and $\text{HML}_{\Delta c}$ by running the following time series regression separately for each currency portfolio j.

$$rx_{t+1}^{j} = a^{j} + \beta_{\overline{\text{rx}}}^{j} \cdot \overline{\text{rx}}_{t+1} + \beta_{\text{HML}_{\Delta c}}^{j} \cdot \text{HML}_{\Delta c,t+1} + \varepsilon_{t+1}^{j} \tag{8}$$

Figure (3) plots the estimate of $\beta_{\text{HML}_{\Delta c}}^{j}$ for each currency portfolio j against its mean excess return. The low-consumption-growth portfolio pays the lowest returns on average, and its correlation with $\text{HML}_{\Delta c}$ is relatively low: in bad times, when $\text{HML}_{\Delta c}$ declines, this portfolio still performs relatively well and thus shields an investor's income stream against low returns. In contrast, the return of the high-consumption-growth portfolio covaries more strongly with $\text{HML}_{\Delta c}$. Indeed, the estimates of $\beta_{\text{HML}_{\Delta c}}^{j}$ increase almost monotonically from low- to high-growth portfolios, which implies that currencies of countries with higher past consumption growth are more exposed to risk mirrored by $\text{HML}_{\Delta c}$.

Table (3) presents the results from estimating equation (8). All portfolios but one load significantly on $\text{HML}_{\Delta c}$ while the constants (α^{j}) are insignificant in all regressions. The observation that portfolios of currencies of countries with relatively high past consumption growth pay relatively high returns on average, together with the finding that high-consumption-growth currency portfolios covary more strongly with the consumption carry trade factor, implies that $\text{HML}_{\Delta c}$ explains the cross-sectional difference in expected portfolio returns: high-growth-currency portfolios pay higher expected returns because they perform badly exactly when $\text{HML}_{\Delta c}$ is low, which is in bad economic times when investors are especially concerned that their portfolios do not perform badly. The dollar risk factor $\overline{\text{rx}}$ on the contrary does not account for the difference in returns across portfolios, because all portfolios load on it with a roughly equal estimated coefficient $\beta^{j}_{\overline{\text{rx}}}$ of about one. This suggests that $\overline{\text{rx}}$ is indeed a local factor that accounts for shifts in the average level of US-dollar denominated returns that the investor obtains from investing in foreign currencies during any given quarter.

Cross-sectional regression

While $\beta^j = [\beta^j_{\overline{\text{rx}}} \quad \beta^j_{\text{HML}_{\Delta c}}]'$ measures the exposure of each currency portfolio j to the proposed risk factors, $\lambda = [\ \lambda_{\overline{\text{rx}}} \quad \lambda_{\text{HML}_{\Delta c}}]'$ is commonly interpreted as the price of risk. In equation (6), λ corresponds to the ratio of the variation of the stochastic discount factor and its expected value. We follow Cochrane (2005) (Chapter 13) and estimate equations (6) using GMM.[6] Inference is based on a Newey and West (1987) covariance matrix estimator with an optimal lag length set as suggested by Newey and West (1994). As expected, Table (4) reveals that the dollar risk factor $\overline{rx}$ is not priced. The price of the consumption carry trade factor $HML_{\Delta c}$ on the contrary is significantly positive, and it amounts to 320 basis points per annum. This implies that an asset with a β of one earns a risk premium of 3.2 percent per annum[7], and equation (6) indicates that currency

[6]Using GMM to estimate the price of the risk factors $\lambda = (\lambda_{\overline{\text{rx}}}, \lambda_{\text{HML}_{\Delta c}})'$ implies that two sets of moment conditions are evaluated at the same time: those that generate the regressors β and those that generate the cross-sectional regression coefficients λ. In contrast to a two-pass estimation procedure, where an estimate of λ is obtained by running a cross-sectional regression of expected asset returns on the βs that were obtained previously by running time series regressions as specified in equation (8), using GMM has the advantage that the covariance matrix between the two sets of moment conditions takes into account that the βs are estimated coefficients as well. This leads to larger standard errors for the λ coefficient estimates.

[7]As the risk factor $\text{HML}_{\Delta c}$ is a linear combination of the returns of two test assets, it has a time series regression β of one on itself. Hence, the price of risk λ should equal the mean of $\text{HML}_{\Delta c}$, which holds true in our estimation exercise.

portfolios with a higher $\beta_{\text{HML}_{\Delta c}}$ pay higher expected returns.

To test whether the consumption carry trade factor $\text{HML}_{\Delta c}$ helps to price the currency portfolios given the presence of the other risk factor $\overline{\text{rx}}$, we focus on the asset pricing model in discount factor form given by equation (7). We estimate the vector $b = [\; b_{\overline{\text{rx}}} \quad b_{\text{HML}_{\Delta c}}]'$ together with the covariance of factors and portfolio returns using GMM. We find that the estimate $b_{\text{HML}_{\Delta c}}$ is positive and significantly different from zero at the five percent confidence level, whereas $b_{\overline{\text{rx}}}$ has no significant impact on the discount factor of US investors. This result confirms the conjecture that the consumption carry factor $\text{HML}_{\Delta c}$ mirrors global risk, whereas the dollar risk factor $\overline{\text{rx}}$ does not. It is consistent with the prediction of models in which the investor's utility is increasing and concave in consumption, which produces a high intertemporal marginal rate of substitution when consumption is low: in bad times for investors, the consumption carry trade factor $\text{HML}_{\Delta c}$ is low, which together with a positive $b_{\text{HML}_{\Delta c}}$ implies a high discount factor M — see equation (5).

Regarding the fit of the model, Figure (4) plots the average returns of the consumption-growth sorted currency portfolios against the returns predicted by the model. The model explains the returns of the five currency portfolios well: the p-value of the pricing error test amounts to 70%-79%, which implies that we cannot reject the null that the pricing errors from the cross-sectional regression of mean currency portfolio returns on the βs equal zero.

These results suggest that $\text{HML}_{\Delta c}$ captures global risk in the world cross section of currencies. In the next section, we examine whether $\text{HML}_{\Delta c}$ prices a cross section of test portfolios that have been sorted by forward discounts (as in Lustig et al. (2011)) and compare the pricing power of the consumption carry factor to that of two other extant factors, the Lustig et al. (2011) HML_{FX} factor and the Menkhoff et al. (2012a) foreign exchange volatility innovation factor, which have both been constructed from purely financial information.

5.2 Forward-discount-sorted currency portfolios and further risk factors

The consumption carry trade factor $\text{HML}_{\Delta c}$ can reflect global, systematic risk in the cross-section of exchange rates only if it explains the returns on any set of currency portfolios. Initiated by Lustig and Verdelhan (2007), the most commonly used test assets in the current literature on currency pricing are forward-discount-sorted currency portfolios. The results presented in Table (5) suggest that the consumption carry trade factor prices this cross section of test assets as well, and that it compares favorably to other risk factors proposed by the literature.

In Table (5), the test assets are five currency portfolios that have been constructed for each quarter by sorting the currencies of the OECD data sample on their forward discount relative to the US dollar observed at the end of the preceding quarter. Descriptive statistics for these forward-discount-sorted currency portfolios are provided in Table (A.1) in the Appendix. Using this set of test assets, we estimate the price of the consumption carry trade factor $\text{HML}_{\Delta c}$ to be 624 basis points a year, and it is significantly different from zero at the two percent confidence level.

The second and third columns of Table (A.1) show estimates of risk prices and factor loadings for two further risk factors; namely, for the Lustig et al. (2011) HML_{FX} factor and the Menkhoff et al. (2012a) foreign exchange volatility innovation VOL factor. We have constructed both risk factors as described in the respective papers using the quarterly data of the OECD sample specified in Section (4). Both risk factors, HML_{FX} and VOL, are able to price the quarterly forward-discount-sorted currency portfolios.

In Table (6) we compare the estimated betas for the forward-discount sorted portfolios that we obtain from each of these three models. The betas on $\text{HML}_{\Delta c}$ are increasing in the forward discount and all but one of them are significant while the α^j are almost all insignificant. This is the same pattern that we obtain when we use HML_{FX} and VOL as pricing factors. This suggests that $\text{HML}_{\Delta c}$ captures much of the pricing power of these two factors also on the forward-discount sorted portfolios.

5.3 Horse race between pricing factors

In this section, we run a horse race between the three foreign exchange risk factors $\text{HML}_{\Delta c}$, HML_{FX} and VOL. The test assets are five forward-discount-sorted currency portfolios plus our previous five consumption-growth-sorted currency portfolios.

In Table (7), the panel on the left shows the estimated price of risk λ for the three foreign exchange risk factors when included jointly in the stochastic discount factor together with the dollar risk factor $\overline{rx}$. Testing for $\lambda^i = 0$ in the beta representation of the asset pricing model $E(rx^j) = \beta^{j\prime}\lambda$ amounts to testing whether the factor f^i is correlated with the true discount factor (see Cochrane (2005)). The table reveals that both carry trade factors, the consumption based carry trade factor $\text{HML}_{\Delta c}$ as well as the forward discount based carry trade factor HML_{FX}, are significantly priced when considered individually. But they are also both significantly priced when included jointly as pricing factors, suggesting that both reflect priced variation in the stochastic discount factor.

The relationship between the risk price λ and the factor loadings on the discount factor, b is given by $\lambda = var(f)b$. As the foreign exchange risk factors $f = (\overline{\text{rx}} \quad \text{HML}_{\Delta c} \quad \text{HML}_{FX} \quad \text{VOL})'$ are correlated (see Table 2), testing for $\lambda = 0$ does not answer the same question as testing for the joint hypothesis $b = 0$. The parameters b of the stochastic discount factor $M_{t+1} = 1 - b' f_{t+1}$ capture whether a factor is marginally useful in pricing assets, given the presence of the other factors. In Table (7), the panel on the right reveals that our consumption carry trade factor is a highly significant pricing factor given the dollar factor $\overline{rx}$. However, both $\text{HML}_{\Delta c}$ and the forward-discount-based carry trade factor HML_{FX} turn insignificant when included jointly into the stochastic discount factor: the correlation of HML_{FX} and $\text{HML}_{\Delta c}$ is such that it becomes impossible to distinguish their marginal contribution to M_{t+1}. Likewise, $\text{HML}_{\Delta c}$ and HML_{FX} remain significant in a pairwise comparison with VOL, but all three pricing factors turn insignificant when included jointly. These results confirm that our consumption carry trade factor $\text{HML}_{\Delta c}$, the Lustig et al. (2009) forward discount based carry trade factor HML_{FX}, as well as the Menkhoff et al. (2012a) currency market volatility factor VOL all qualify as global risk factors, whereby they suggest that these factors reflect the same kind of global risk.

To conclude, $\text{HML}_{\Delta c}$ successfully prices the cross section of consumption-growth-sorted and forward-discount-sorted currency portfolios. Thereby, $\text{HML}_{\Delta c}$ compares well with other pricing factors that have previously been suggested in the literature. We explicitly do not claim that we 'beat' these other factors. Rather, $\text{HML}_{\Delta c}$ seems to capture the same information as HML_{FX}. Importantly, however, our factor differs from HML_{FX} and other previous factors in that it is constructed based on past macroeconomic fundamentals — specifically on consumption growth rates. This suggests that international differences in medium-term consumption growth are informative with respect to the risk exposure of a country's currency to global shocks, and that they can help explain *why* HML_{FX} is successful in pricing currencies.

5.4 Explaining bilateral currency returns

Our results so far show that there are systematic differences in the exposure to the consumption carry factor across currency portfolios sorted on different criteria — interest rates and past consumption growth — and that these differences are priced. By contrast, individual currencies will not generally have a fixed, time-invariant exposure to the global factor: because currencies change portfolios over time, their exposure to the consumption carry risk factor $\text{HML}_{\Delta c}$ will in general be time-varying as well. However, because we observe that the expected returns of high-past-consumption-growth currency portfolios covary more strongly with $\text{HML}_{\Delta c}$ than expected returns of low-consumption-growth currency portfolios, a country's past consumption growth rate should pin down its exposure to $\text{HML}_{\Delta c}$. This reasoning allows us to price individual currency pairs using a β-representation in which the β is a time-varying function of the consumption growth differential between the country of which the US investor holds currency assets and the US. This motivates the panel regression

$$rx^k_{t+1} = \alpha^k + \gamma_1(\tilde{c}^k_t \mathrm{HML}_{\Delta c,t+1}) + \gamma_2\tilde{c}^k_t + \gamma_3\mathrm{HML}_{\Delta c,t+1} + \gamma_4\overline{\mathrm{rx}}_{t+1} + \varepsilon^k_{t+1} \quad (9)$$

where k indexes an individual country, and where $\tilde{c}^k_t = \Delta c^k_t - \Delta c^{US}_t$ is the difference between the US consumption growth rate and the consumption growth rate of country k over the quarters from $t-4$ to t. In this specification, country k's exposure to $\mathrm{HML}_{\Delta c}$ is given by

$$\beta^k(t) = \gamma_1\tilde{c}^k_t + \gamma_3$$

and therefore varies over time as a function of a country's past consumption growth. Conversely, in this regression, the term $\gamma_3\mathrm{HML}_{\Delta c,t+1} + \gamma_4\overline{\mathrm{rx}}_{t+1}$ captures effects that are common to the cross section of returns.[8]

Table (8) shows the results from the bilateral pricing regression (9). Note first that the interaction of $\mathrm{HML}_{\Delta c}$ with past country-level consumption growth — the coefficient γ_1 — is positive and significant, whereas γ_3 is not significant. Further we cannot reject the null that the country-specific intercepts α^k equal zero jointly, the p-value obtained from an F-Test equals 0.5. These results underpin the interpretation of $\mathrm{HML}_{\Delta c}$ as a global slope factor that explains differences in returns between currencies provided that these countries have different consumption growth rates. As countries change their position in the cross-sectional distribution of past consumption growth rates, their exposure to $\mathrm{HML}_{\Delta c}$ will change as well. Conversely, $\mathrm{HML}_{\Delta c}$ does not significantly impact the average dollar-denominated return on foreign currency. This role of a level factor is, again, mainly played by $\overline{\mathrm{rx}}$, which loads with a coefficient of virtually one on the cross section of currency

[8]We include the first-order term $\gamma_2\tilde{c}^k_t$ to make sure the interaction $\tilde{c}^k_t\mathrm{HML}_{\Delta c,t+1}$ does not become spuriously significant. As we will see, this first-order term will not be significant though and all our results remain unchanged if we drop it.

returns.

To illustrate further that differences in the exposure to $\text{HML}_{\Delta c}$ explain the cross section of currency returns and that $\overline{\text{rx}}$ fully captures level shifts in dollar-denominated returns, we also estimate a version of the panel regression in which we control for time-fixed-effects, τ_t,

$$rx_{t+1}^k = \alpha^k + \gamma_1 \widetilde{C}_t^k \times \text{HML}_{\Delta c,t+1} + \gamma_2 \widetilde{C}_t^k + \tau_t + \varepsilon_{t+1}^k. \quad (10)$$

This panel regression displays a very similar level of fit to the pricing regression above, and the coefficients γ_1 is also very similar and significant; see Table (8). Again, we cannot reject that the α^k are jointly zero (p-value: 0.36). This illustrates that potentially unobserved country characteristics do not affect the results regarding the sensitivity of individual currencies with respect to the common risk factor $\text{HML}_{\Delta c}$. It is also interesting to note that the estimate of the time-fixed effect τ_t in equation (10) is closely linked to the dollar risk factor $\overline{\text{rx}}_t$: the correlation of the two series is literally one. This confirms that the dollar risk factor — the average return an investor gains by borrowing in US dollars and investing in all currencies available in the market — provides a level factor for the cross section of dollar returns.

Regressions (9) and (10) suggest that excess returns from currency investment are related to past consumption growth even at the level of individual currencies: because γ_1 is positive, and because $\text{HML}_{\Delta c}$ is positive on average, currencies of countries with higher than US consumption growth pay positive expected returns, whereas currencies of countries with relatively low consumption growth pay negative expected returns. However, excess returns on high-consumption-growth currencies may turn negative, and expected returns on low-growth currency portfolios may turn positive, when there is a large negative shock to $\text{HML}_{\Delta c}$, which will be the case in bad times when global stock market returns decline and consumption dispersion increases (see Table 2).

To emphasize that it is truly exchange rate risk that drives currency returns, and not forward discounts that are known *ex ante*, the lower panel of Table (8) reports results from estimating regressions (9) and (10) again, but now with nominal exchange rate changes, $-\Delta s^k_{t,t+1}$, instead of currency returns as the left-hand variable.[9] The observation that the estimate of γ_1 remains virtually unchanged corroborates our conclusion that nonzero expected currency excess returns merely compensate an investor for the exchange rate risk to which he exposes himself when holding currencies of countries with high past consumption growth that promise positive expected returns.

5.5 Further comparison between consumption-sorted and the interest-rate sorted portfolios

The analysis so far suggests that $\text{HML}_{\Delta c}$ and HML_{FX} not only behave very similar in the time series (see Figure (1)), but the two risk factors also seem largely equivalent in terms of pricing currency returns. Before we interpret these findings in a theoretical framework, we show that, empirically, sorting currencies on past consumption growth or on forward discounts yields similar cross-sectional results. Figure (5) plots the return of each of the five consumption growth sorted portfolios together with the return of the respective forward discount sorted portfolio, whereby the deviation of each portfolio's return from the average USD currency market return, $rx^j_{t+1} - \overline{\text{rx}}_{t+1}$, is shown.

For all five portfolio pairs, these portfolio-specific returns co-move quite strongly, suggesting that sorting on consumption or interest rates yields very similar returns at the level of the individual portfolio. Discrepancies between the two sorting procedures mainly occur in the period during and after the 2008 financial crisis. In that period, the lowest forward discount (lowest interest rate) currencies performed quite well, manifesting the insurance value of these currencies. In contrast, the lowest consumption growth curren-

[9] As currency excess returns are given by $rx^k_{t,t+1} = f^k_{t,t+1} - s^k_{t+1} - \Delta s^k_{t,t+1}$, for the sake of comparability, we use the negative of the nominal exchange rate change $-\Delta s^k_{t,t+1}$ as the left-hand variable. Recall that $-\Delta s^k_{t,t+1} > 0$ indicates an appreciation of currency k against the US dollar between t and $t+1$.

cies plummeted. As a consequence, the carry trade return $\text{HML}_{\Delta c}$ did not fall to the same extent as HML_{FX} during that crisis, see Figure (1) again. During the crisis, it was rather the portfolio with the second lowest consumption growth currencies that performed best. In Figure (A.2) in the appendix, we trace out the path of individual currencies through portfolios over time, both for the interest-rate sort and for the consumption-growth sort. As is apparent, the discrepancy between the 'low' portfolios during 2008-09 is due to countries such as Iceland or Hungary. These countries have low consumption growth and high interest rates during the crisis, implying that their currencies end up in a 'high' portfolio when sorted on interest rates and in a 'low' portfolio when sorted on consumption growth. On the other hand, typical funding currencies like the Swiss franc or the Japanese yen persistently fall into the low interest rate portfolio, but experienced relatively high consumption growth rates in the aftermath of the global financial crisis and during the European sovereign debt crisis. However, barring these easily interpreted differences, we think that it is striking how similar the two sorts ultimately are. We take this *de facto* equivalence of consumption- and interest-rate based sorts as an important starting point for our interpretation of the data in terms of a simple theoretical model.

6 Interpreting the stylized facts: a consumption habit model

We have shown that currencies of countries that recently experienced consumption booms appreciate on average, whereas currencies of low-past-consumption-growth countries tend to depreciate. This pattern reflects a compensation for global risk: consumption boom currencies depreciate strongly in times of global distress. In this section, we interpret these stylized facts using a version of the consumption habit model proposed by Campbell and Cochrane (1999), based on Verdelhan (2010). As we show, in this model, sorting currencies on their consumption growth over the last several quarters approximates sorting them on their risk aversion. Intuitively, a sequence of high consumption growth rates leads to high surplus consumption relative to habit and, therefore, to low risk aversion. Conversely, a country that experiences low consumption growth over several quarters will have a low surplus consumption ratio and, therefore, high levels of risk aversion.

It has previously been shown by Verdelhan (2010) that the habit model can reproduce the uncovered interest rate parity puzzle and that the resulting nonzero expected carry trade returns compensate investors for consumption growth risk. Unlike Verdelhan (2010), however, our version of the model explicitly allows for a global component in all countries' consumption growth rates. This is important for the interpretation of our results: while country-specific consumption growth shocks disappear at the portfolio level, the average country in any large portfolio will still be affected by global consumption growth risk. Thereby, marginal utility in high-growth, low-risk-aversion countries reacts less sensitively to consumption shocks than marginal utility in low-growth, high-risk-aversion countries. Therefore, the return spread between a portfolio of consumption boom countries and a portfolio of consumption bust countries — our $\text{HML}_{\Delta c}$ factor — reflects international differences in the exposure of marginal utility growth to global consumption growth risk. Hence, the habit formation model suggests that the $\text{HML}_{\Delta c}$ factor captures differences in risk aversion between countries.

We now proceed to present the model and then use simulated data to illustrate that the model can replicate some of the major empirical regularities that we discovered in the OECD data sample.

6.1 The model

Our setup closely follows Campbell and Cochrane (1999) and Verdelhan (2010). There are $k = 1 \dots K$ endowment economies in each of which a representative agent is characterized by external habit preferences

$$E\sum_{t=0}^{\infty}\beta^{t}\frac{(C_t^k-H_t^k)^{1-\gamma}-1}{1-\gamma}$$

where C_t^k denotes the level of country k's consumption of the single good, and H_t^k is the external consumption habit level. The relation between consumption and habits is captured by the surplus consumption ratio $\mathsf{S}_t^k \equiv (C_t^k - H_t^k)/C_t^k$, which depends on past consumption through the following process for the log surplus consumption ratio s_t:

$$\mathsf{s}_{t+1}^k = (1-\phi)\bar{\mathsf{s}}+\phi \mathsf{s}_t^k+\lambda(\mathsf{s}_t^k)(\Delta c_{t+1}^k - g)$$

where $0<\phi<1$ and where g and $\bar{\mathsf{s}}$ are the unconditional means of consumption growth and the log consumption surplus ratio.[10] The function $\lambda(\mathsf{s_t})$ governs how sensitively the surplus consumption ratio reacts to the current realization of consumption growth. It is given by

$$\lambda(\mathsf{s}_t) = \frac{1}{\bar{\mathsf{S}}}\sqrt{1-2(\mathsf{s}_t-\bar{\mathsf{s}})}-1, \text{ when } \mathsf{s}\leq \mathsf{s}_{\max}, 0 \text{ elsewhere}$$

where $\bar{\mathsf{S}}=\sigma\sqrt{\frac{\gamma}{1-\phi-B/\gamma}}$, $\mathsf{s}_{\max}=\bar{\mathsf{s}}+(1-\bar{\mathsf{S}}^2)/2$, and $B=\gamma(1-\phi)-(\gamma^2\sigma^2)/(\bar{\mathsf{S}}^2)$, and σ denotes the standard deviation of consumption growth.

In this model, the coefficient of relative risk aversion of country k is given by $-C_t^k U_{cc}(t)/U_c(t) = \gamma/\mathsf{S}_t^k$. Hence, if country k's consumption is close to the habit level, the surplus consumption ratio of country k is low, which implies that the representative agent of country k is highly risk averse. In this model, the stochastic discount factor is given by

[10] We use sans serif letters (S and s) to denote the surplus consumption ratio and its logarithm, respectively. The spot nominal exchange rate and its logarithm continue to be denoted by the standard typeface S and s. Using different typefaces in this way allows us to stay in keeping with both the international finance literature and the literature on habit formation, which both use the letter 'S'.

$$M_{t+1}^k = \beta \left(\frac{\mathsf{S}^k{}_{t+1} C_{t+1}^k}{\mathsf{S}_t^k C_t^k} \right)^{-\gamma} = \beta exp \left\{ -\gamma [g + (\phi - 1)(\mathsf{s}_t^k - \bar{\mathsf{s}}) + (1 + \lambda(\mathsf{s}_t^k))(\Delta c_{t+1}^k - g)] \right\}$$

where g is the mean growth rate of consumption. The risk-free interest rate is $r_t^k = \bar{r} - B(\mathsf{s}_t^k - \bar{\mathsf{s}})$ with $\bar{r} = -\ln(\beta) + \gamma g - (\gamma^2 \sigma^2)/(2\overline{\mathsf{S}}^2)$.[11] We follow Verdelhan (2010) and impose $B < 0$. This implies that risk-free interest rates are procyclical; that is, higher in countries with higher surplus consumption ratios.

We assume that consumption growth of country k follows an i.i.d. normal process.

$$\Delta c_{t+1}^k = g + \xi_{t+1} + u_{t+1}^k \qquad \xi_{t+1} \sim \text{i.i.d. } N(0, \sigma_{glob}^2),\ u_{t+1}^k \sim \text{i.i.d. } N(0, \sigma_{idio}^2)$$
$$\text{cov}(\xi_{t+1}, u_{t+1}^k) = 0$$

At each point in time, the average growth rate g and the global shock to consumption growth ξ_{t+1} are common to all countries, whereas u_{t+1}^k denotes country-specific shocks to consumption growth. Concerning the variance of the global and the country-specific shocks, we assume that $\sigma_{glob} = \sigma_{idio} = \sigma/\sqrt{2}$. As we will discuss shortly, the presence of a global component in consumption growth is important in explaining our results.

We assume that financial markets are complete, which implies that the change in the real exchange rate between two countries equals the ratio of the two countries' marginal utility growth rates or stochastic discount factors

$$\frac{Q_{t+1}^k}{Q_t^k} = \frac{M_{t+1}}{M_{t+1}^k}$$

where M_{t+1} is again the discount factor of the home country, Q_t^k is the real exchange rate measured in units of country k goods per one unit of the home country good, so that an

[11] For details about the derivation of equation (11), the reader is referred to Campbell and Cochrane (1999) and Verdelhan (2010).

increase in Q^k implies a depreciation of country k's currency vis-à-vis the home country. Taking logarithms and substituting in from above for the logarithmic pricing kernel, we obtain the rate of change of the real exchange rates

$$\Delta q_{t+1}^k = \kappa_t + \gamma(1+\lambda(\mathsf{s}_t^k))(\Delta c_{t+1}^k - g) - \gamma(1+\lambda(\mathsf{s}_t))(\Delta c_{t+1} - g) \qquad (11)$$

where κ_t summarizes all variables known at time t.[12]

It is instructive to compare this condition for optimal risk sharing with the one obtained from a model with constant relative risk aversion preferences without habit formation (see, e.g., Backus and Smith (1993) and Kollmann (1995)), which is given by the following.

$$\Delta q_{t+1}^k = \kappa_t + \gamma(\Delta c_{t+1}^k - \Delta c_{t+1})$$

The model without habit formation predicts that exchange rates move in lockstep with consumption growth differences between countries. It is well known that this condition is grossly violated in the data. By contrast, in the habit model, whether the real exchange rate appreciates or depreciates will not only depend on current differences in consumption growth between countries. Rather, past differences will matter as well, because they are reflected in differences in the surplus consumption ratio between the two countries. Specifically, if countries differ in their consumption histories, the real exchange rate will change even if both countries experience the same consumption shock $\Delta c_{t+1}^k = \Delta c_{t+1} \neq 0$: because the sensitivity function $\lambda(\mathsf{s})$ is low when surplus consumption is high, the country with the higher surplus and, therefore, the higher average consumption over the recent past will experience an appreciation if the common consumption shock is positive, or a depreciation if the shock is negative. The reason for this is that risk aversion in the high-surplus (low-λ) country is low and that marginal utility growth is less exposed to

[12]When used without a superscript, the variables s_t and Δc pertain to the home country.

the common consumption shock. Optimal risk sharing entails that purchasing power is redistributed to the high-risk-aversion country in periods when both countries are hit by the same negative consumption growth shock.

Hence, in the habit model, countries differ in their exposure of marginal utility growth to the same common shock. These differences in exposure to common shocks are also the source of the currency risk premium in this model, which is given by the following.[13]

$$E(rx_{t+1}^k) = r_t^k - r_t - E_t(\Delta q_{t+1}^k) \quad = \quad \frac{\gamma^2\sigma^2}{\bar{\mathsf{S}}^2}(\mathsf{s}_t^k - \mathsf{s}_t) \tag{12}$$

Equation (12) shows that currencies of consumption boom countries generate positive expected excess returns. This risk premium compensates for a likely depreciation of the currency in times of low aggregate consumption growth. As we show in our simulations, sorting currencies on past consumption growth is very similar to sorting them on their surplus consumption ratio.

To allow this intuition to extend to portfolios — as our empirical results suggest it does — consumption growth must therefore have a common (global) component that does not wash out in sufficiently large portfolios of currencies. To see this, average equation (11) over a subset of $I \subset \{1....K\}$ of our K currencies. If the number of elements in I, denoted here by $\#I$, is sufficiently large, we get the following.

$$\frac{1}{\#I}\sum_{k\in I}\Delta q_{t+1}^k \quad = \quad \tilde{\kappa}_t + \gamma\left(\frac{1}{\#I}\sum_{k\in I}(1+\lambda(\mathsf{s}_t^k))\right)\xi_{t+1} - \gamma(1+\lambda(\mathsf{s}_t))\Delta c_{t+1} \tag{13}$$

Specifically, forming portfolios by sorting currencies on their past consumption growth and assuming that there are many currencies in each of the consumption-growth-sorted portfolios, the stochastic component of the returns described by our consumption carry factor $HML_{\Delta c}$ is determined by changes in the average rate of change in the real exchange

[13] for further details, see Campbell and Cochrane (1999) and Verdelhan (2010)

rate between high- and low-consumption-growth currencies, given by

$$\Delta q^{hl}_{t+1} \quad = \quad \hat{k}_t + \gamma[\lambda^h_t - \lambda^l_t]\xi_{t+1} \tag{14}$$

where λ^h_t and λ^l_t are the average values of the sensitivity function of high h and low l surplus consumption ratio country portfolios. Exchange rate changes between large portfolios of currencies are therefore solely driven by differences in the exposure to global consumption risk: portfolios of currencies from countries with high surplus consumption ratios — which recently have experienced a series of high consumption growth rates — appreciate if positive global consumption growth shocks occur, and depreciate if the global shock turns out to be negative. The reason is that marginal utility in countries with high surplus consumption (low risk aversion) has lower exposure to global consumption risk than countries with high risk aversion. Optimal risk sharing therefore entails that wealth is redistributed to high-risk-aversion countries when there are negative global shocks.

6.2 Calibration and results

We assume that all countries share the same set of parameters. The risk-aversion parameter γ is set equal to 2, which corresponds to the value chosen by Campbell and Cochrane (1999) and Verdelhan (2010). We estimate the average consumption growth rate g and its standard error σ from the OECD data sample used in the main analysis of this study. Taking sample means over all 29 countries, we find that the quarterly consumption growth rate corresponds to $g = 0.65\%$, and its standard deviation is $\sigma = 0.4\%$. This implies a standard deviation of the global shock and the country-specific shock of $\sigma_{glob} = \sigma_{idio} = \sigma/\sqrt{2} = 0.28$. The country-specific endowment shocks u^k_{t+1}, which all have variance σ_{idio}, are uncorrelated across countries, but there is a common consumption growth shock in all countries' consumption growth rate ξ_{t+1} with variance σ_{glob}. The quarterly real risk-free interest rate is set equal to $\bar{r} = 0.74\%$, which corresponds to the average secondary market US T-bill rate measured over the period from the first quarter of 1990 to the fourth quarter of 2015. As in Verdelhan (2010), we set $B = -0.01$. The persistence parameter $\phi = 0.99$ is chosen such that the mean value of the consumption carry factor $\text{HML}_{\Delta c}$ approximately corresponds to its sample counterpart. These parameter values imply that $\beta = 0.95$, $\overline{\mathsf{S}} = 0.04$ and $\overline{\mathsf{S}}_{max} = 0.07$. All parameter values are thus close to the values chosen by Campbell and Cochrane (1999) and Verdelhan (2010), Table (9) presents an overview of the chosen parameter values.

With these parameters and 10 000 endowment shocks, we generate data and build currency portfolio returns, the dollar risk factor $\overline{rx}$ as well as the consumption carry factor $\text{HML}_{\Delta c}$. In analogy to the empirical analysis in this study, we generate data for 33 countries and then sort countries into six portfolios according to their consumption growth rates over the previous four quarters. Table (10) presents the moments for the currency portfolios that this simulation delivers.

Simulated portfolios of countries that have recently experienced higher consumption growth pay an investor who borrows in his home currency and invests in these portfolios higher returns on average. Furthermore, consumption boom countries have high surplus consumption ratios, which translate into low risk aversion, and thus relatively smooth intertemporal marginal rates of substitution in consumption. The more risk averse the investor is compared with the average country in a particular currency portfolio — that is, the lower his surplus consumption ratio is relative to the average portfolio surplus consumption ratio — the more exposed his marginal utility will be to consumption growth shocks. Currencies of countries with high exposure to global consumption growth shocks will therefore appreciate when a negative global consumption shock occurs. This reflects optimal risk sharing: the exchange rate appreciation redistributes purchasing power to the high-risk-aversion, high-marginal- utility country in recessions.

As carry trade returns are procyclical and thus risky, the investor demands a higher risk premium for investment into portfolios with higher surplus consumption ratios. Against the background of this model, we can therefore interpret our sorting of countries into portfolios according to their recent consumption growth rates as sorting countries on their surplus consumption ratios or risk aversion, and portfolios with higher past consumption growth rates expose the investor to more home and global consumption growth risk. This explains why consumption boom currencies pay higher expected returns.

Equation (14) suggests that within the framework of the consumption habit model outlined above, our consumption carry factor $\text{HML}_{\Delta c}$ should mirror global risk only, and it should be high if consumption growth is globally high and low otherwise. In the simulation with 33 countries and 10 000 global and country-specific endowment shocks, the correlation between the global consumption growth shock ξ_{t+1} and $\text{HML}_{\Delta c}$ equals about 0.4. This correlation is not perfect because with 29 countries, portfolios are not sufficiently large such that not all idiosyncratic endowment shocks u^k_{t+1} average out. Increasing the number of countries in the simulation increases this correlation, and for $K = 58$ countries, it equals about 0.7.

The simulated consumption carry factor $\text{HML}_{\Delta c}$ is a globally priced risk factor, whereas the mean currency return factor $\overline{rx}$ is not. Table (11) presents results from estimating the asset pricing model of Section (5) again, but instead of using the data from our sample of 29 OECD countries, test assets and pricing factors are constructed from simulated data. The habit model with the parameter values specified above generates the stylized facts that we described for the OECD data sample: country portfolio returns covary more strongly with the global recession factor $\text{HML}_{\Delta c}$ the higher their consumption growth rate has been recently, and the risk factor $\text{HML}_{\Delta c}$ is globally priced whereas the level factor $\overline{\text{rx}}$ is not.

7 Robustness checks

The Appendix presents several robustness checks that confirm our results. First, similar to Lustig et al. (2011) and Mancini et al. (2013), we regress portfolio foreign exchange rate changes, $-\Delta s^{j}_{t+1}$, rather than portfolio carry trade returns, rx^{j}_{t+1}, on the dollar return factor and on $\text{HML}_{\Delta c}$. All $\text{HML}_{\Delta c}$ betas estimated using exchange rate changes as test assets presented in Table (A.3) are basically the same as those in Table (3) which were based on carry trade returns. Also, risk prices and factor loadings remain largely unchanged when exchange rate changes are used (see Table(A.4)). This implies that low past consumption growth currency portfolios offer insurance against $\text{HML}_{\Delta c}$ risk because they appreciate when the consumption carry factor $\text{HML}_{\Delta c}$ drops, not because the forward discounts on these currencies decline. On the other hand, high past consumption growth currency portfolios expose carry traders to $\text{HML}_{\Delta c}$ risk because they depreciate when $\text{HML}_{\Delta c}$ declines and not because forward discounts increase.

Second, we sort currencies into portfolios according to their β with respect to the consumption carry trade factor $\text{HML}_{\Delta c}$. To do so, we estimate the following regression for each currency k separately over rolling windows of 20 quarters.

$$rx^{k}_{t+1} \quad = \quad a^{k} + \beta^{k}_{1} \cdot \overline{\text{rx}}_{t+1} + \beta^{k}_{2} \cdot \text{HML}_{\Delta c,t+1} + \varepsilon^{k}_{t+1} \qquad (15)$$

Hence, to obtain estimates $\beta^{k}_{2,t}$, we run regression (15) using time series that span the preceding 20 quarters; i.e. the quarters from $t-19$ to t. Because of this rolling window estimation procedure, the first five years of observations are lost, such that the analysis covers the period from 1995(1) to 2015(4). Table (A.5) reveals that portfolios of currencies with a high β^{k}_{2}, i.e. currencies that at a given point in time load heavily on the risk factor $\text{HML}_{\Delta c}$, pay higher returns on average and have experienced higher consumption growth rates over the preceding year. This confirms our result that high-consumption-growth currency portfolios are more exposed to global risk than low-consumption-growth portfolios. Third, in the same spirit as Mancini et al. (2013), we add average portfolio forward discounts, $f_t^j - s_{t+1}^j$, as an explanatory variable when regressing portfolio average currency excess returns, rx_{t+1}^j, on the dollar risk factor and on the consumption carry factor. Table (A.6) reveals that all $\text{HML}_{\Delta c}$ betas remain nearly unchanged. Further, we estimate the model with alternative base currencies. Using the Swiss franc, the Canadian dollar, the British Pound, the Norwegian krone or the Australian dollar as base currencies, we obtain very similar results to those using the US dollar. By way of example, results for the Swiss franc are presented in Tables (A.7, A.8, A.9). Finally, we only use the most traded currencies of our sample to build and price consumption growth sorted portfolios; these currencies are the Australian dollar, Canadian dollar, Swiss franc, Euro (and before its inception the German mark, (and optionally also the Italian lira and the French franc)), British pound, Hong-Kong dollar, Japanese yen, Mexican peso, Norwegian krone, New Zealand dollar, Swedish krone, and the US dollar. We sort these currencies into 4 portfolios. Again, as shown in Tables (A.10, A.11) the time series betas for $\text{HML}_{\Delta c}$ increase monotonically from the low growth portfolio to the high growth portfolio, and $\text{HML}_{\Delta c}$ carries a significantly positive risk price, whereas the dollar risk factor, $\overline{\text{rx}}$, is not priced.

8 Summary and conclusion

In this paper, we have suggested a new, consumption-based factor for pricing currency returns. Our factor, which we refer to as the consumption carry factor or $\text{HML}_{\Delta c}$, is based on sorting currencies into portfolios based on past consumption growth and reflects the excess return of borrowing in countries with the lowest consumption growth in the world over the past year and investing in the currencies of countries that have experienced relative consumption booms over the last year. $\text{HML}_{\Delta c}$ is a global risk factor in the sense that it successfully explains the world cross-section of currencies — for portfolios sorted on either past consumption growth or on forward discounts as well as for individual currency pairs. In fact, we show that currencies with high past consumption growth trade at high forward discounts, so that countries with consumption booms appreciate much more than uncovered interest parity (UIP) would imply, whereas countries with low past consumption growth appreciate by less than is implied by UIP. These excess returns on consumption boom currencies are a compensation for the higher exposure of these currencies with respect to our global factor: high-consumption-growth currencies depreciate more during times of aggregate distress, exposing investors to global risk. The consumption carry factor $\text{HML}_{\Delta c}$ is as effective as other, purely financial factors that have been proposed in the recent literature. In fact, we show that sorting currencies into portfolios on past consumption growth is empirically equivalent to sorting on interest rates. This explains why — in spite of the high level of noise in consumption data as compared to interest rates — our factor $\text{HML}_{\Delta c}$ prices currencies almost as well as the HML_{FX} factor suggested by Lustig et al. (2011).

Our results are built on minimal theoretical restrictions and, in particular, are free of any specific assumptions about preferences. They therefore provide strong independent evidence that risk associated with longer- to medium-term movements in consumption are a key driver of the cross section of currency returns. While our results impose minimal restrictions on preferences, we showed that they can be interpreted in the context of a consumption-based habit formation model. In the habit model, sorting currencies on past consumption growth is akin to sorting countries according to their risk aversion (and equivalent to sorting on interest rates): consumption bust countries have low surplus consumption ratios and high risk aversion. Global consumption shocks therefore load more strongly on marginal utility in consumption bust countries, and optimal risk sharing requires that these currencies should appreciate in worldwide downturns — as we find in the data.

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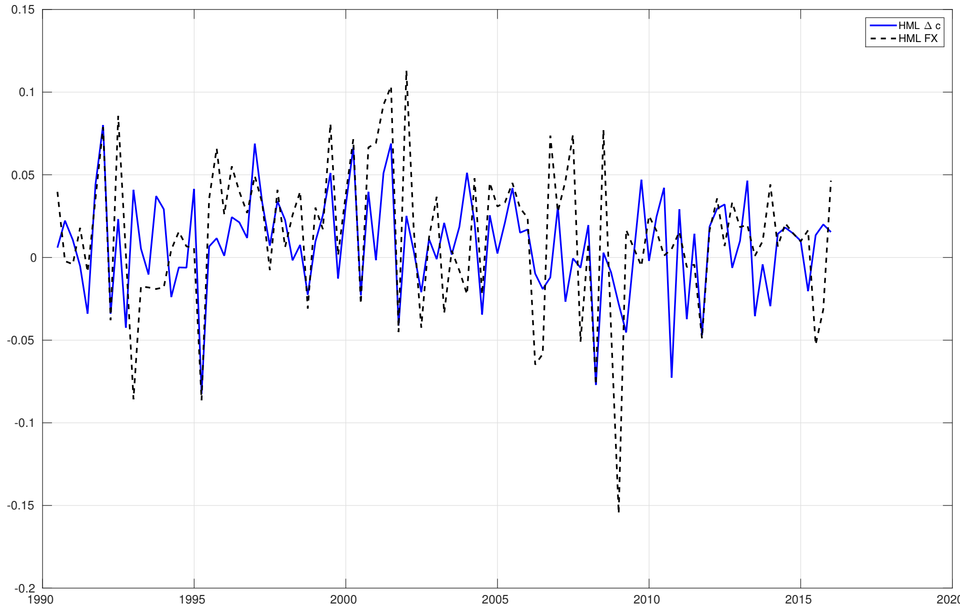
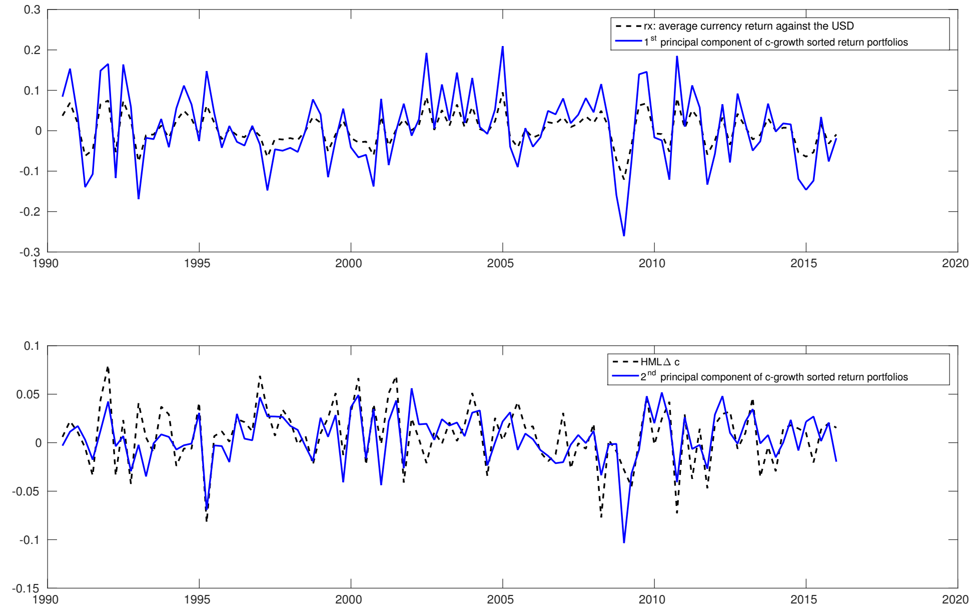
Figure 1: HML_{FX} and $\text{HML}_{\Delta c}$



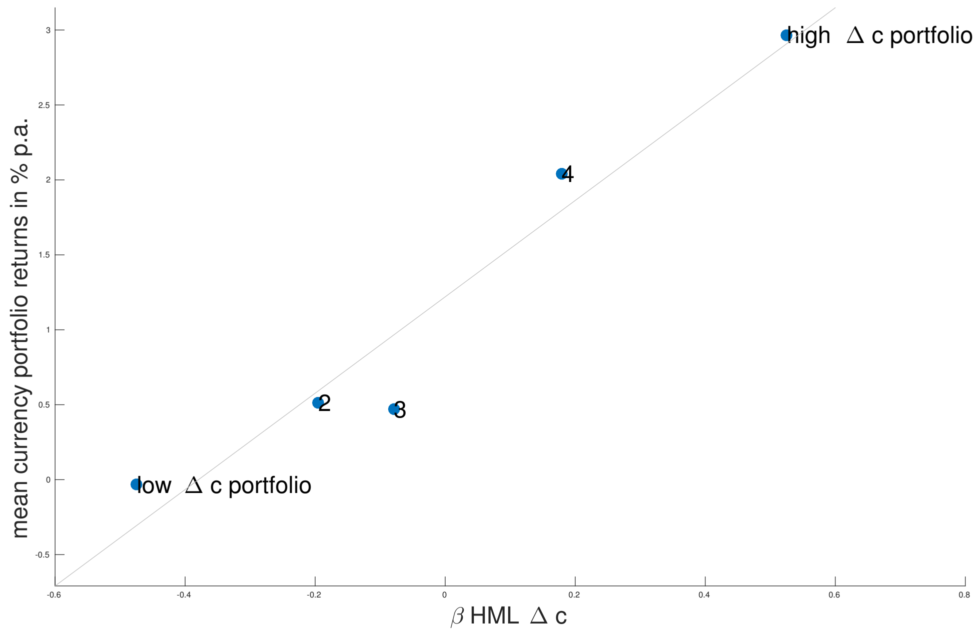
The blue solid line plots the consumption carry trade factor $\text{HML}_{\Delta c}$, and the black, dotted line shows the Lustig et al. (2011) carry trade factor HML_{FX}. The $\text{HML}_{\Delta c}$ factor is the cross-country average return a global investor obtains when she borrows in the currencies of countries which experienced low consumption growth over the last year and invests in currencies of countries with high past consumption growth. The HML_{FX} factor corresponds to the return obtained from borrowing in low interest rate (forward discount) currencies and lending in high interest rate (forward discount) currencies. Both factors are constructed from quarterly data which encompass the OECD sample specified in the main text.

Figure 2: principal components of USD returns of past consumption growth sorted currency portfolios and $\text{HML}_{\Delta c}$



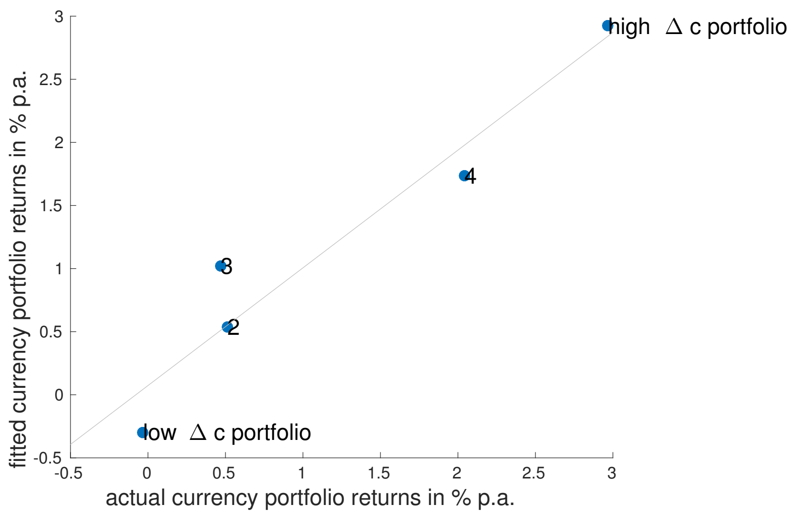
The upper figure plots the first principal component of quarterly USD returns obtained from investing in five past consumption growth sorted currency portfolios against $\overline{\text{rx}}$ which is the USD return from going long in equal weights in all currencies included in the sample at a given point in time. The lower panel plots the second principal component of the returns of the five consumption growth sorted portfolios against our consumption carry factor $\text{HML}_{\Delta c}$. Principal components are constructed using the covariance matrix of portfolio returns. The first principal component explains 82% of the variance present in portfolio returns, the second principal component explains 6.8%.

Figure 3: time series estimates of $\beta^j_{\mathrm{HML}_{\Delta c}}$ against average currency portfolio returns



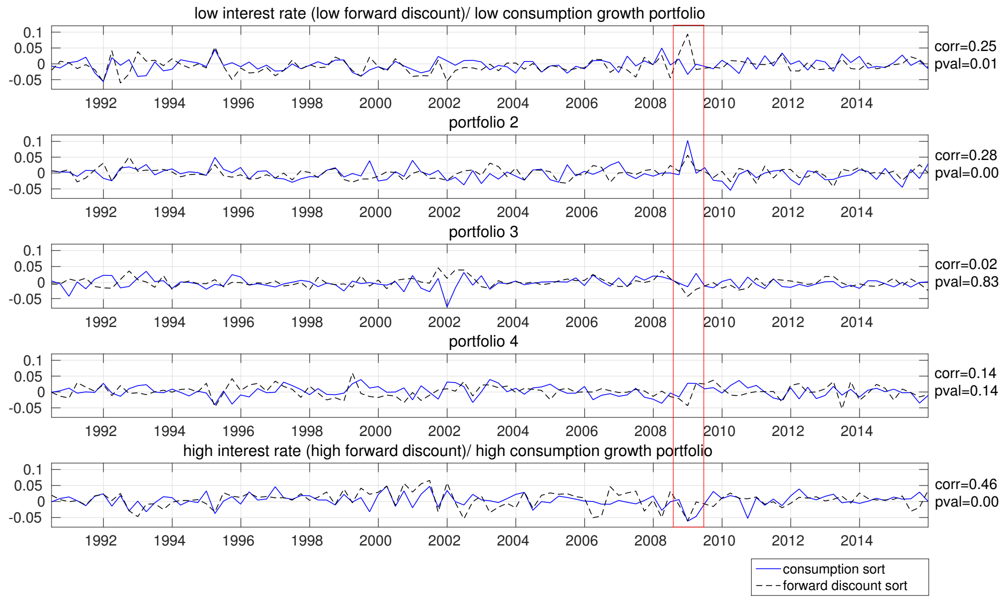
For each currency portfolio j, the figure plots the OLS estimate of $\beta^j_{\mathrm{HML}_{\Delta c}}$ in the regression $rx^j_{t+1} = \alpha^j + \beta^j_{\overline{\mathrm{rx}}} \cdot \overline{\mathrm{rx}}_{t+1} + \beta^j_{\mathrm{HML}_{\Delta c}} \cdot \mathrm{HML}_{\Delta c, t+1} + \varepsilon^j_{t+1}$ on the horizontal axis against mean portfolio returns $(1/T)\sum_{t=1}^{T} rx^j_t$ on the vertical axis.

Figure 4: actual vs fitted mean consumption growth sorted currency portfolio returns



The figure plots actual average consuption growth sorted currency portfolio returns against predicted average returns. The model to predict returns is given by $E(M_{t+1}rx^{j}_{t+1}) = 0$ and $M_t = 1 - b'(f_t - E(f))$. Factors f included in the analysis are $\overline{\text{rx}}$ and $\text{HML}_{\Delta c}$ as described in the text.

Figure 5: difference between returns and $\overline{rx}$ of consumption growth sorted and forward discount sorted currency portfolios



The figures show time series of the deviation of currency portfolio returns from the average dollar return ($rx_t^j - \overline{\mathrm{rx}}_t$) for five portfolios sorted on past consumption growth (blue/solid line) and forward discounts (balck/dashed line) respectively. Currency portfolios are re-balanced each quarter. Returns plotted are quarterly returns. Table (A.2) in the appendix shows the currency composition of each portfolio at each point in time. Generally speaking, the returns of consumption growth sorted and forward discount sorted protfolios are very similar. However, the red rectangle marks the period of the global financial crisis, during which low interest rate currencies performed much better than low consumption growth currencies. Correlation coefficients and p-values quantify the time-series correlation of portfolio returns; small p-values indicate that a particular correlation is likely to be different from zero.

Table 1: currency portfolios sorted on previous year consumption growth

portfolio j	low	2	3	4	high	$\overline{\text{rx}}$	$\text{HML}_{\Delta c}$
	excess return: rx^j						
mean	−0.0328	0.5121	0.4687	2.0416	2.9667	1.2445	2.9995
std	18.5312	17.8247	18.1688	16.6550	17.4474	16.0941	12.2156
Sharpe ratio	−0.0018	0.0287	0.0258	0.1226	0.1700	0.0773	0.2455
skewness	−0.1984	0.0686	−0.0197	0.2231	−0.7316	−0.1221	−0.4379
	spot change: Δs^j						
mean	−1.1478	−0.6573	−1.1337	0.0308	−0.0174		
std	18.5150	17.7673	18.0058	16.5034	17.4211		
	consumption growth: Δc^j						
mean	−0.3145	1.4313	2.3432	3.2124	5.0671		
std	2.4311	1.3452	1.2299	1.2155	1.7042		
	forward discount: $f^j - s^j$						
mean	0.0028	0.0029	−0.0012	0.0022	−0.0063		
std	0.0070	0.0050	0.0547	0.0273	0.1006		

This table presents descriptive statistics of USD returns of five currency portfolios. Portfolios are constructed by sorting currencies according to countries' consumption growth rate over the preceding year; portfolios are rebalanced quarterly. The first portfolio always contains currencies of countries with the lowest fifth of past consumption growth rates, and the last portfolio always contains currencies of countries with the highest fifth of past consumption growth rates. The second last column presents the average return obtained from borrowing in US dollars and investing in equal weights in all currencies of the sample, this return is labelled $\overline{\text{rx}}_{t+1}$. The last column shows descriptive statistics for the carry trade portfolio $\text{HML}_{\Delta c}$ which is given by a short position in all currencies of the low consumption growth portfolio and a long position in the currencies of the high consumption growth portfolio. Portfolio excess returns are calculated as $rx^j_{t+1} = f^j_t - s^j_t - \Delta s^j_{t+1}$, where rx^j_{t+1} is the average return from borrowing in US dollars and investing in equal weights in all currencies of portfolio j. f^j_t is the log 3M forward exchange rate of the currencies in portfolio j against the US dollar, and Δs^j_{t+1} is the log difference of the spot exchange rates between dates t and $t+1$; an increase in s^j corresponds to a depreciation of the currencies in portfolio j against the US dollar. Quarterly returns are calculated using average forward and spot exchange rates over the last ten trading days of each quarter. The statistics are presented in percentages per annum, except for the forward discounts. The sample encompasses data for 29 OECD countries and it spans the period from the first quarter of 1990 to the fourth quarter of 2015. Details on the composition of currency portfolios are given in Table (A.2) in the appendix.

Table 2: descriptive statistics of candidate pricing factors

	$HML_{\Delta c}$	HML_{FX}	$\overline{rx}$	VOL	MSCI	mean(Δc)	var(Δc)
mean	2.9995	5.0657	1.2445	0.0001	2.2819	2.5795	7.4251
standard deviation	12.2156	17.2944	16.0941	0.0012	17.5448	1.5199	5.0880
sharpe ratio	0.2455	0.2929	0.0773	–	0.1301	–	–
skewness	−0.4379	−0.6053	−0.1221	–	−0.8467	−1.7346	–

correlation matrix of pricing factors

	$HML_{\Delta c}$	HML_{FX}	$\overline{rx}$	VOL	MSCI	mean(Δc)	var(Δc)
$HML_{\Delta c}$	1	0.4841	−0.1167	−0.2373	0.1937	0.0821	0.0092
		(0.0000)	(0.2403)	(0.0158)	(0.0499)	(0.4098)	(0.9265)
HML_{FX}		1	0.1156	−0.4900	0.3308	0.1705	0.0044
			(0.2450)	(0.0000)	(0.0006)	(0.0850)	(0.9648)
$\overline{rx}$			1	−0.3507	0.3485	0.0099	0.0549
				(0.0003)	(0.0003)	(0.9206)	(0.5817)
VOL				1	−0.5184	0.1984	−0.1716
					(0.0000)	(0.0446)	(0.0830)
MSCI					1	−0.0556	0.0579
						(0.5769)	(0.5610)
mean(Δc)						1	−0.3927
							(0.0000)
var(Δc)							1

This table presents descriptive statistics as well as the cross-correlation matrix of different pricing factors used in asset pricing models. The factors $HML_{\Delta c}$ and HML_{FX} are the difference in the returns of high and low consumption growth and forward discount sorted currency portfolios. The foreign exchange volatiliy innovation factor VOL is constructed as described in Menkhoff et al. (2012a). The factors mean(Δc) and var(Δc) are the cross-sectional mean and variance of annual consumption growth rates. MSCI corresponds to the growth rate (log difference) of the MSCI world index, of which end of quarter values have been downloaded from http://www.msci.com/products/indices/performance.html. All moments are reported in percentages per annum, only for the volatiliy factor VOL, the mean and the standard deviation are quarterly values. In the lower panel, the numbers reported in parentheses are p-values for the null that the correlation between two risk factors is zero. If the p-value is small, say less than 0.05, then a particular correlation is significantly different from zero.

Table 3: factor betas

	a^j	$\beta^j_{\overline{\text{rx}}}$	$\beta^j_{\text{HML}_{\Delta c}}$	$\overline{R}^2$
low	0.0003	1.0151	−0.4746	
	(0.2295)	(22.4508)	(−10.1541)	0.94
2	−0.0002	0.9608	−0.1952	
	(−0.1094)	(11.2704)	(−2.8803)	0.79
3	−0.0015	1.0516	−0.0790	
	(−1.0759)	(28.5594)	(−1.3500)	0.88
4	0.0008	0.9572	0.1789	
	(0.3871)	(22.3283)	(4.2258)	0.84
high	0.0003	1.0151	0.5254	
	(0.2295)	(22.4508)	(11.2429)	0.93

This table shows estimates and t-statistics obtained from running the following time series regression for each currency portfolio j separately:

$$rx^j_{t+1} \quad = \quad a^j + \beta^j_{\overline{\text{rx}}} \cdot \overline{\text{rx}}_{t+1} + \beta^j_{\text{HML}_{\Delta c}} \cdot \text{HML}_{\Delta c,t+1} + \varepsilon^j_{t+1}$$

Standard errors are corrected for serial correlation using the Newey and West (1987) estimator for the covariance matrix of the error terms ε^j_{t+1}.

Table 4: risk price and factor loadings

	$\lambda_{\overline{\text{rx}}}$	$\lambda_{\text{HML}_{\Delta c}}$	$b_{\overline{\text{rx}}}$	$b_{\text{HML}_{\Delta c}}$
OLS estimate	0.0030	0.0081	2.7004	9.1339
t-stat	(0.7238)	(2.4641)	(0.8870)	(2.1513)
pricing error test		0.71		0.70
R^2		0.93		0.93
GLS estimate	0.0031	0.0078	2.0396	8.1186
t-stat	(0.7261)	(2.4992)	(0.7223)	(2.3936)
pricing error test		0.77		0.79

This first two columns of this table report results from estimating the following cross-sectional regression:

$$E(rx^j) \quad = \quad \beta^j_{\overline{\text{rx}}} \cdot \lambda_{\overline{\text{rx}}} + \beta^j_{\text{HML}_{\Delta c}} \cdot \lambda_{\text{HML}_{\Delta c}} + \alpha^j$$

$\beta^j_{\overline{\text{rx}}}$ and $\beta^j_{\text{HML}_{\Delta c}}$ correspond to the estimates obtained from running time series regressions of portfolio returns on the risk factors as reported in Table (3). Here, the factor βs and the prices of risk $\lambda_{\overline{\text{rx}}}$ and $\lambda_{\text{HML}_{\Delta c}}$ are estimated jointly using GMM. This approach yields standard errors which correct for the fact that the βs are estimates. The third and the fourth column of this table report results from estimating the following cross-sectional regression:

$$E(rx^j) \quad = \quad cov(\overline{\text{rx}}, rx^j) \cdot b_{\overline{\text{rx}}} + cov(\text{HML}_{\Delta c}, rx^j) \cdot b_{\text{HML}_{\Delta c}} + \alpha^j$$

where again, covariances and factor loadings b have been estimated jointly using GMM. Let $\mu^j = \frac{1}{T}\sum_{t=1}^{T} rx^j_t$ denote the (time-) average return on portfolio j and $\mu = \begin{bmatrix} \mu^1, & \mu^2, & \ldots & \mu^J \end{bmatrix}'$ the $J \times 1$ vector stacking these average returns. Furthermore, let $\overline{\mu} = \frac{1}{J}\sum_{j=1}^{J} \mu^j = \mu' 1/J$ where 1 is a $J \times 1$ vector of ones. Then R^2 measures are obtained using $R^2 = 1 - \frac{\hat{\alpha}'\hat{\alpha}}{(\mu - \overline{\mu}1)'(\mu - \overline{\mu}1)}$ where $\hat{\alpha} = \begin{bmatrix} \alpha^1, & \alpha^2, & \ldots & \alpha^J \end{bmatrix}'$ is the vector of average portfolio j pricing errors α^j given by $\alpha^j = \overline{rx}^j - cov(\hat{f}, rx^j)'\hat{b} = \overline{rx}^j - \widehat{\beta}^{j\prime}\widehat{\lambda}$ where $\beta^j = \begin{bmatrix} \beta^j_{\overline{\text{rx}}}, & \beta^j_{\text{HML}_{\Delta c}} \end{bmatrix}'$ and $\lambda^j = \begin{bmatrix} \lambda^j_{\overline{\text{rx}}}, & \lambda^j_{\text{HML}_{\Delta c}} \end{bmatrix}'$. Hats denote estimates. The pricing error test reports the p-value for the null that the pricing errors are jointly zero. If the p-value is small, say less than 0.05, then pricing errors are significantly different from zero.

Table 5: forward discount sorted currency portfolios and alternative risk factors

	Factor Prices λ					
	$\overline{\text{rx}}$	$\text{HML}_{\Delta c}$	HML_{FX}	VOL	p-value	R^2
Estimate	0.0032	0.0156				
t-stat	(0.7706)	(2.3521)			0.7186	0.95
Estimate	0.0033		0.0124			
t-stat	(0.7769)		(2.5654)		0.8742	0.97
Estimate	0.0033			−0.0006		
t-stat	(0.7835)			(−2.4059)	0.3027	0.88

This table reports the results obtained from estimating the following asset pricing model using three different sets of pricing factors

$$E(rx^j) \quad = \quad \beta^{j\prime}\lambda$$

Pricing factors are the mean dollar currency return $\overline{rx}$ plus either the consumption-based carry trade factor $\text{HML}_{\Delta c}$, or the forward-discount based carry trade factor HML_{FX}, which has been suggested by Lustig et al. (2011), or the FX volatiliy innovation factor VOL, which has been proposed by Menkhoff et al. (2012a). VOL is the innovation to global FX volatiliy and is constructed as described in their paper (p. 692). As in Lustig et al. (2011) and Menkhoff et al. (2012a), test assets are six forward discount sorted currency portfolios. The data encompasses the OECD sample specified in the main text, and it spans the period from 1990(1) to 2015(4). For each model, the pricing error test reports the p-value for the null that the pricing errors are jointly zero; if the p-value is small, say less than 0.05, then pricing errors are significantly different from zero. The R^2 measure is obtained as described in the notes of table (4).

Table 6: factor betas for forward discount sorted portfolio returns as test assets

	a^j	$\beta^j_{\overline{\text{rx}}}$	$\beta^j_{\text{HML}_{\Delta c}}$	a^j	$\beta^j_{\overline{\text{rx}}}$	$\beta^j_{\text{HML}_{FX}}$	a^j	$\beta^j_{\overline{\text{rx}}}$	β^j_{VOL}
low	−0.0037	0.8261	−0.3627	−0.0008	0.9161	−0.4661	−0.0083	0.9641	10.1782
	(−2.1880)	(10.6243)	(−5.0687)	(−0.7099)	(25.5596)	(−14.8913)	(−3.8052)	(11.9054)	(4.0823)
2	−0.0002	1.0579	−0.1270	0.0008	1.0889	−0.1593	−0.0021	1.1243	5.3040
	(−0.1030)	(14.1074)	(−1.7172)	(0.5116)	(17.8303)	(−3.6423)	(−1.2416)	(22.0614)	(3.6572)
3	0.0007	1.0578	−0.0514	0.0006	1.0651	−0.0217	0.0002	1.0727	0.9988
	(0.3671)	(22.2738)	(−0.9347)	(0.2945)	(23.0108)	(−0.5669)	(0.0947)	(23.9377)	(0.6432)
4	0.0003	1.0799	0.1641	0.0007	1.0557	0.0783	0.0028	0.9942	−6.8409
	(0.2026)	(16.2726)	(2.0524)	(0.3868)	(15.3447)	(1.3348)	(1.5481)	(15.3385)	(−4.2729)
high	0.0031	1.0136	0.3514	−0.0008	0.9161	0.5339	0.0072	0.8952	−8.3859
	(1.2819)	(16.0482)	(3.6676)	(−0.7099)	(25.5596)	(17.0540)	(2.5220)	(12.0744)	(−4.0656)

The table shows time series beta estimates and t-statistics obatined from regressing forward-discount sorted portfolio returns on different risk factors. Standard errors are corrected for serial correlation using the Newey and West (1987) estimator for the covariance matrix of the error terms.

Table 7: horse race

	risk price λ					factor loadings b					
	$\overline{\text{rx}}$	$\text{HML}_{\Delta c}$	HML_{FX}	VOL	p-value	$\overline{\text{rx}}$	$\text{HML}_{\Delta c}$	HML_{FX}	VOL	p-value	R^2
Estimate	0.0032	0.0107				3.0399	12.0027				
t-stat	(0.7559)	(2.6230)			0.4349	(0.9258)	(2.2634)			0.4047	0.86
Estimate	0.0032		0.0136			1.0677		7.2458			
t-stat	(0.7526)		(2.7043)		0.8113	(0.3416)		(1.9583)		0.7786	0.91
Estimate	0.0032			−0.0006		−2.7560			−454.5		
t-stat	(0.7537)			(−2.2393)	0.4212	(−0.6737)			(−1.3442)	0.4322	0.80
Estimate	0.0032	0.0078	0.0123			1.9140	5.6354	4.5191			
t-stat	(0.7557)	(2.3642)	(2.4225)		0.9508	(0.5981)	(1.2444)	(1.2404)		0.9373	0.97
Estimate	0.0032		0.0135	−0.0002		0.6307		6.5522	−50.3977		
t-stat	(0.7527)		(2.7568)	(−0.9198)	0.7609	(0.1836)		(1.5862)	(−0.1865)	0.7218	0.91
Estimate	0.0032	0.0088		−0.0004		0.5315	7.6727		−204.5		
t-stat	(0.7568)	(2.7591)		(−1.5478)	0.5339	(0.1528)	(1.9467		(−0.8124)	0.4759	0.91
Estimate	0.0032	0.0079	0.0124	−0.0001		2.4613	5.9573	5.1554	57.5486		
t-stat	(0.7552)	(2.5642)	(2.4574)	(−0.5648)	0.9316	(0.7441)	(1.4166)	(1.1869)	(0.2529)	0.9155	0.97

The panel on the left reports OLS cross-sectional regression estimation results for the following model: $E(rx^j) = \beta^{j\prime}\lambda$, and the panel on the right reports OLS cross-sectional regression estimation results for the following model: $E(rx^j) = cov(f, rx^j)'b$. Factor βs and the risk prices λ, as well as factor loadings b and the covariances between factors f and test asset returns rx are estimated jointly using GMM (for details see Cochrane (2005), chapter 13). There are 10 test assets, five consumption growth sorted currency portfolios plus five forward discount sorted currency portfolios. Pricing factors are the mean dollar currency return $\overline{\text{rx}}$, our consumption carry trade factor $\text{HML}_{\Delta c}$, the Lustig et al. (2011) forward discount carry trade factor HML_{FX}, and the Menkhoff et al. (2012a) currency market volatility innovation factor VOL (see p. 692 of their paper). Pricing factors and test asset returns are constructed from the OECD data set used in this paper, only the VOL factor is build from a larger data set. Quarterly returns are obtained from average spot- and forward exchange rates over the last ten trading days of each quarter; the data spans the period from 1990(1) to 2015(4). For each model, the pricing error test reports the p-value for the null that the pricing errors are jointly zero. The adjusted R^2 are obtained as described in the notes of Table (4).

Table 8: pricing the cross-section of individual currencies: panel estimation

	γ_1	γ_2	γ_3	γ_4	α^k	R^2
	$rx^k_{t+1} = \alpha^k + \gamma_1 \cdot \left(\widetilde{\text{c}}^k_t \cdot \text{HML}_{\Delta c,t+1}\right) + \gamma_2 \cdot \widetilde{\text{c}}^k_t + \gamma_3 \cdot \text{HML}_{\Delta c,t+1} + \gamma_4 \cdot \overline{\text{rx}}_{t+1} + \varepsilon_{t+1}$					
estimate	0.1104	0.0001	0.0199	0.9776		
t-stat	(7.3359)	(0.3520)	(0.4942)	(27.0108)	p-value for α^k jointly zero: 0.50	0.58
	$rx^k_{t+1} = \alpha^k + \gamma_1 \cdot \left(\widetilde{\text{c}}^k_t \cdot \text{HML}_{\Delta c,t+1}\right) + \gamma_2 \cdot \widetilde{\text{c}}^k_t + \tau_{t+1} + \varepsilon_{t+1}$					
estimate	0.1471	0.0001				
t-stat	(7.9257)	(0.2759)			p-value for α^k jointly zero: 0.36	0.56
	$-\Delta s^k_{t+1} = \alpha^k + \gamma_1 \cdot \left(\widetilde{\text{c}}^k_t \cdot \text{HML}_{\Delta c,t+1}\right) + \gamma_2 \cdot \widetilde{\text{c}}^k_t + \gamma_3 \cdot \text{HML}_{\Delta c,t+1} + \gamma_4 \cdot \overline{\text{rx}}_{t+1} + \varepsilon_{t+1}$					
estimate	0.1069	0.0003	0.0211	0.9691		
t-stat	6.9591	0.7759	0.5346	26.7442		0.58
	$-\Delta s^k_{t+1} = \alpha^k + \gamma_1 \cdot \left(\widetilde{\text{c}}^k_t \cdot \text{HML}_{\Delta c,t+1}\right) + \gamma_2 \cdot \widetilde{\text{c}}^k_t + \tau_{t+1} + \varepsilon_{t+1}$					
estimate	0.1426	0.0001				
t-stat	(7.8686)	(0.2522)				0.57

This table shows panel estimation results with single countries' currency return as the dependent variables and our consumption based carry trade factor $\text{HML}_{\Delta c}$ as the expanatory factor. $rx^k_{t+1} = i^k_t - i^{US}_t - \Delta s^k_{t+1}$ is the return an investor obtains by borrowing in US dollars and investing into the currency of country k over the quarter form t to $t+1$. $\widetilde{\text{c}}^k_t = \Delta c^k_t - \Delta c^{US}_t$ is the difference between the US consumption growth rate and the consumption growth rate of country k over the quarters from $t-4$ to t. α^k are country-specific intercepts (country-fixed-effects), and τ_t is a time fixed effect. Δs^k_{t+1} is the quarterly change (log difference) of the bilateral exchange rate between the currency of country k and the US dollar. An increase in s^k indicates a depreciation of the currency of country k towards the US dollar. The data spans the period 1990(1) - 2015(4), and countries are included in the panel whenever data is available — see the data section in the appendix. Standard errors are autocorrelation and heteroscedasticity consistent following (Newey and West (1987)).

Table 9: habit model, parameter values

	this paper	Campbell and Cochrane (1999)	Verdelhan (2010)
	calibrated parameters		
$g(\%)$	0.65	0.74	0.53
$\sigma(\%)$	0.38	0.75	0.51
$\sigma_{idio}(\%)$	0.27	-	-
$\sigma_{glob}(\%)$	0.27	-	-
$\bar{r}(\%)$	0.74	0.23	0.34
γ	2.00	2.00	2.00
ϕ	0.99	0.97	0.99
B	-0.01	-	-0.01
ρ		-	0.15
	implied parameters		
β	0.995	0.97	1.00
$\overline{S}$	0.04	0.06	0.07
S_{max}	0.07	0.09	0.12

This table presents the parameters of the habit formation model outlined in section (6) and their chosen values in this paper, in Campbell and Cochrane (1999) and in Verdelhan (2010). The data is at quarterly frequency. For this paper, the reference period is 1990(1)-2015(4) (1947-1995 in Campbell and Cochrane (1999), and 1947(2)-2004(4) in Verdelhan (2010)). The average consumption growth rate g and its standard error σ are estimated from the OECD data sample used in the main analysis of this study. The standard error of consumption growth σ is decomposed into a global and an idiosyncratic component such that $\sigma_{glob} = \sigma_{idio} = \sigma/\sqrt{2}$, whereby we assume that country-specific and global consumption growth shocks are uncorrelated. The quarterly risk-free rate corresponds to the US average 3-Month Treasury Bill secondary market rate (source: FRED database), it amounts to 0.74 percent. The persistence parameter ϕ is chosen such that the mean value of the consumption carry factor $HML_{\Delta c}$ approximately corresponds to its sample counterpart. In Verdelhan (2010), ρ corresponds to the correlation of each simulated countries consumption growth shocks.

Table 10: habit model, simulation results: currency portfolios

portfolio j	low	2	3	4	high	$\overline{\text{rx}}$	$\text{HML}_{\Delta c}$
	excess return: rx^j						
mean	-1.3256	-0.3523	0.3158	0.8791	1.4014	0.1954	2.7270
std	64.3859	64.4582	63.7416	63.1764	63.3794	59.8827	35.9967
Sharpe ratio	-0.0206	-0.0055	0.0050	0.0139	0.0221	0.0033	0.0758
	spot change: Δq^j						
mean	1.0069	0.4118	-0.0187	-0.3942	-0.59251		
std	64.2002	64.2697	63.5460	63.0002	63.2079		
	consumption growth: $\Delta c^j_{t-4,t}$						
mean	1.8418	2.2714	2.5245	2.7992	3.2555		
std	0.5556	0.5516	0.5494	0.5491	0.5557		
	surplus consumption ratio: s_t						
mean	0.0423	0.0453	0.0473	0.0490	0.0521		
std	0.0150	0.0151	0.0149	0.0146	0.0142		
	interest rate differential: $r^j - r$						
mean	-2.3052	-0.2450	0.6118	1.2928	1.9790		
std	2.3521	1.8582	1.8280	1.9202	2.1617		

This table presents descriptive statistics for five currency portfolios obtained from simulated data. With the parameters presented in Table (9) and $10'000$ endowment shocks, we use the habit model outlined in section (6) to generate data for 29 hypothetical countries which then are sorted into portfolios according to their consumption growth rate over the previous four periods. This procedure is analogous to the approach taken in the empirical asset pricing analysis of this paper. The first portfolio always contains countries with the lowest fifth of consumption growth rates, and the last portfolio always contains countries with the highest fifth of consumption growth rates. Currency excess returns rx^j_{t+1}, which an investor obtains when borrowing at home and investing into particular currency portfolios, average interest rate differentials between portfolio j and the home country $r^j_{t+1} - r_{t+1}$, consumption growth rates Δc^j_t and exchange rate changes Δq^j_{t+1} are expressed in percentage per annum. The exchange rate is measured in units of foreign goods per home good, such that $\Delta q^j < 0$ implies an appreciation of the foreign good. The portfolio average surplus consumption ratios s_t refer to quarterly values. The second last column presents descriptive statistics for the simulated return the home investor gains when borrowing at home and investing each period in all the other countries of the sample, and the last column presents the returns the average (global) investor obtains when borrowing in low growth countries and investing in high growth countries: as in the main analysis of this paper, $\text{HML}_{\Delta c}$ is given by the difference in returns of the high and the low growth portfolio.

Table 11: habit model, asset pricing results using simulated data

Panel A: risk prices and factor loadings				
	$\lambda_{\overline{\text{rx}}}$	$\lambda_{\text{HML}_{\Delta c}}$	$b_{\overline{\text{rx}}}$	$b_{\text{HML}_{\Delta c}}$
OLS estimate	0.0005	0.0070	0.0204	0.8615
t-stat	(0.2894)	(7.4505)	(0.2966)	(7.4237)
pricing error test		0.03		0.026
R^2		0.87		0.87

Panel B: time series regression				
	a^j	$\beta^j_{\overline{\text{rx}}}$	$\beta^j_{\text{HML}_{\Delta c}}$	R^2
low	-0.0001	1.0027	-0.5488	
	(-0.2167)	(371.3243)	(-113.1387)	0.96
2	-0.0014	0.9994	0.0085	
	(-2.3564)	(182.3644)	(0.9103)	0.86
3	0.0001	0.9934	0.0288	
	(0.1661)	(201.4177)	(3.2815)	0.87
4	0.0012	1.0007	0.0665	
	(2.4701)	(211.5931)	(8.6029)	0.90
high	-0.0001	1.0027	0.4512	
	(-0.2167)	(371.3243)	(93.0060)	0.96

This table shows estimates and standard errors obtained from running the same asset pricing exercise as in the empirical analysis of this paper, but instead of the OECD data set, simulated data are used. From the habit model outlined in section (6) and 10000 endowment shocks, data for 29 hypothetical countries are constructed, and at each point in time, countriesare sorted into five portfolios according to their consumption growth rates realized over the preceding four periods. Test asset returns are the returns a home investor obtains each period by borrowing at home and investing in the different portfolios.

In **panel A**, the first two columns report results from estimating the following cross-sectional regression using GMM:

$$E(rx^j) \quad = \quad \beta^j_{\overline{\text{rx}}} \cdot \lambda_{\overline{\text{rx}}} + \beta^j_{\text{HML}_{\Delta c}} \cdot \lambda_{\text{HML}_{\Delta c}} + \alpha^j$$

The third and the fourth columns show results from estimating the following cross-sectional regression:

$$E(rx^j) \quad = \quad cov(\overline{\text{rx}}, rx^j) \cdot b_{\overline{\text{rx}}} + cov(\text{HML}_{\Delta c}, rx^j) \cdot b_{\text{HML}_{\Delta c}} + \alpha^j$$

where covariances and factor loadings b have been estimated jointly using GMM. R^2 measures are obtained as described in the notes below Table (4). The pricing error test reports the p-value for the null that the pricing errors jointly are zero. If the p-value is small, say less than 0.05, then pricing errors are significantly different from zero.

Panel B shows estimates and t-statistics obtained from running the following time series regression for each currency portfolio j separately:

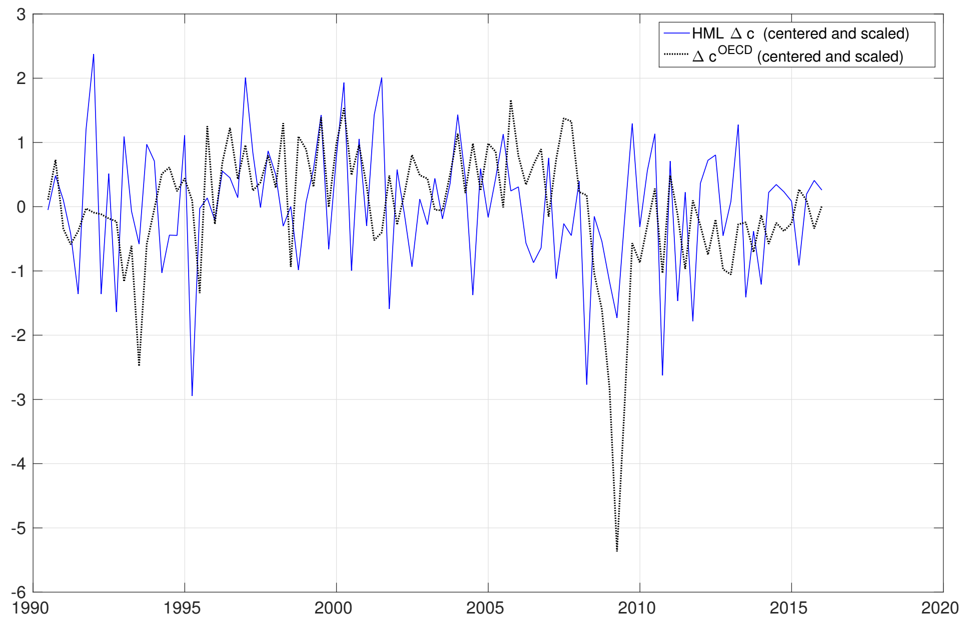
$$rx^j_{t+1} \quad = \quad a^j + \beta^j_{\overline{\text{rx}}} \cdot \overline{\text{rx}}_{t+1} + \beta^j_{\text{HML}_{\Delta c}} \cdot \text{HML}_{\Delta c, t+1} + \varepsilon^j_{t+1}$$

Appendix: for publication as additional web material only.

Data

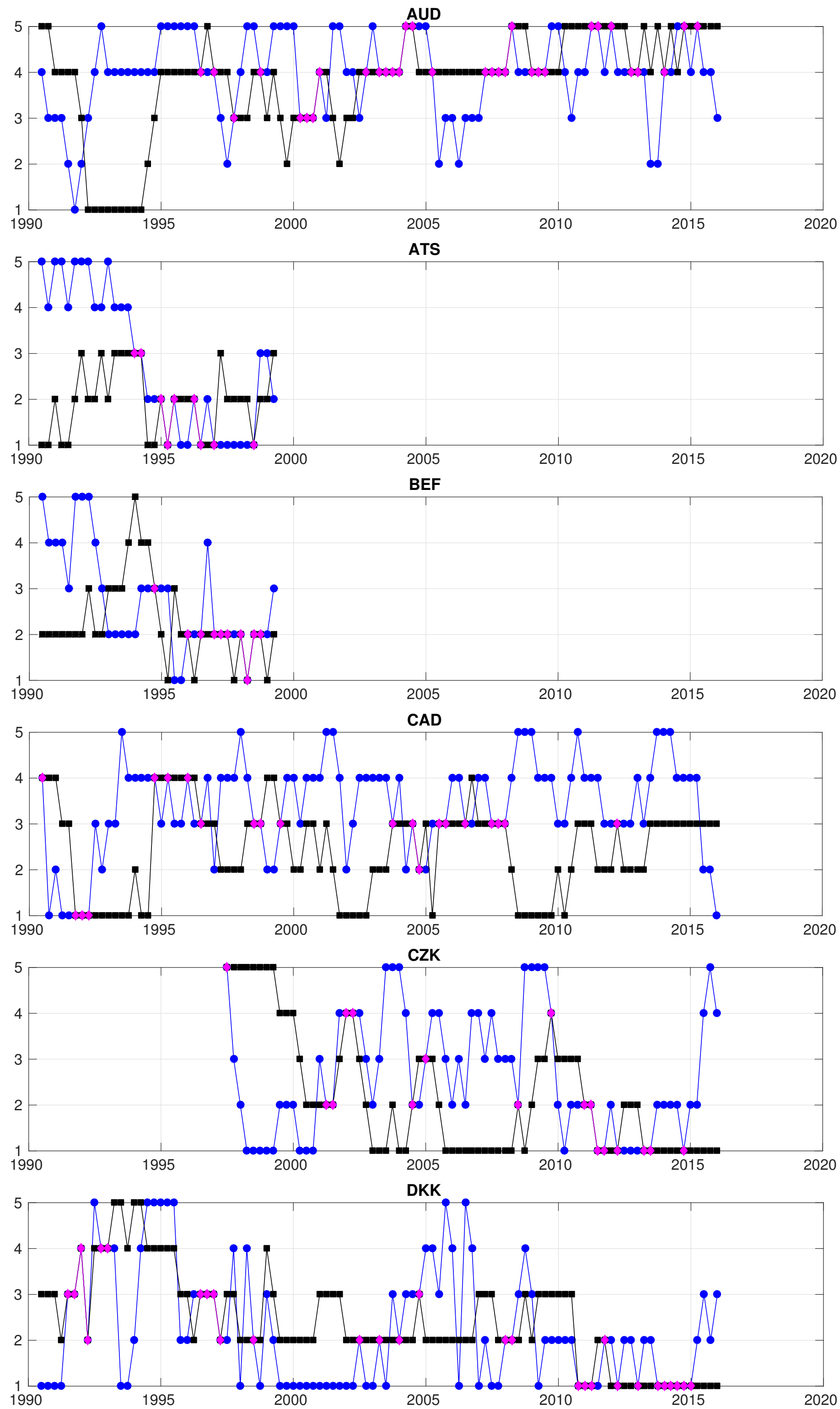
Quarterly consumption data is sourced from the OECD national accounts database. Consumption corresponds to "private final consumption expenditures", whereof seasonally adjusted quarterly growth rates compared to the same quarter of the previous year have been downloaded. Only figure () in the appendix shows percentage changes in consumption growth over the previous quarter (P31S14_S15 GYSA). Forward exchange rates correspond to 3 month forward rates provided by WM/Reuters and accessed via Datastream. Spot rates are downloaded via Datastream as well, but originate from various sources (WM/Reuters, MSCI, BOE). Quarterly values are constructed as averages over the last ten trading days of each quarter. For each country or currency respectively, data is included only if all, forward exchange rates, spot exchange rates, and consumption growth rates are available. Euro area countries are no longer included separately in the sample once they introduced the euro, but summarized in the "Euro area 17 countries" variable. The Menkhoff et al (??) currency market volatility index is constructed from a broader currency data set. Otherwise, the data includes the following countries/currencies: Australia (AUD,1990Q1-2015Q4), Austria (ATS, 1990Q1-1999Q1), Belgium (BEF, 1990Q1-1999Q1), Canada (CAD, 1990Q1-2015Q4), Czech Republik (CRK, 1997Q1-2015Q4), Denmark (DKK, 1990Q1-2015Q4), Estonia (EEK, 2004Q2-2011Q1), France (FRF, 1990Q1-1999Q1), Germany (DEM, 1990Q1-1999Q1), Greece (GRD, 1997Q1-2001Q1), Hungary (HUF, 1998Q1-2015Q4), Iceland (ISK, 2004Q2-2015Q4), Ireland (IEP, 1990Q1-1999Q1), Italy (ITL, 1990Q1-1999Q1), Israel (ILS, 2004Q2-2015Q4), Japan (JPY, 1990Q1-2015Q4), Mexico (MXN, 1997Q1-2015Q4), Netherlands (NLG, 1990Q1-1999Q1), New Zealand (NZD, 1990Q1-2015Q4), Norway (NOK, 1990Q1-2015Q4), Poland (PLN, 1996Q4-2015Q4), Portugal (PTE, 1990Q1-1999Q1), South Korea (KRW, 2002Q2-2015Q4), Sweden (SEK, 1990Q1-2015Q4), Switzerland (CHF, 1990Q1-2015Q4), Spain (ESP, 1990Q1-1999Q1), United Kingdom (GBP, 1990Q1-2015Q4), United States (USD, 1990Q1-2015Q4), Euro area 17 countries (EUR, 1999Q1-2015Q4).

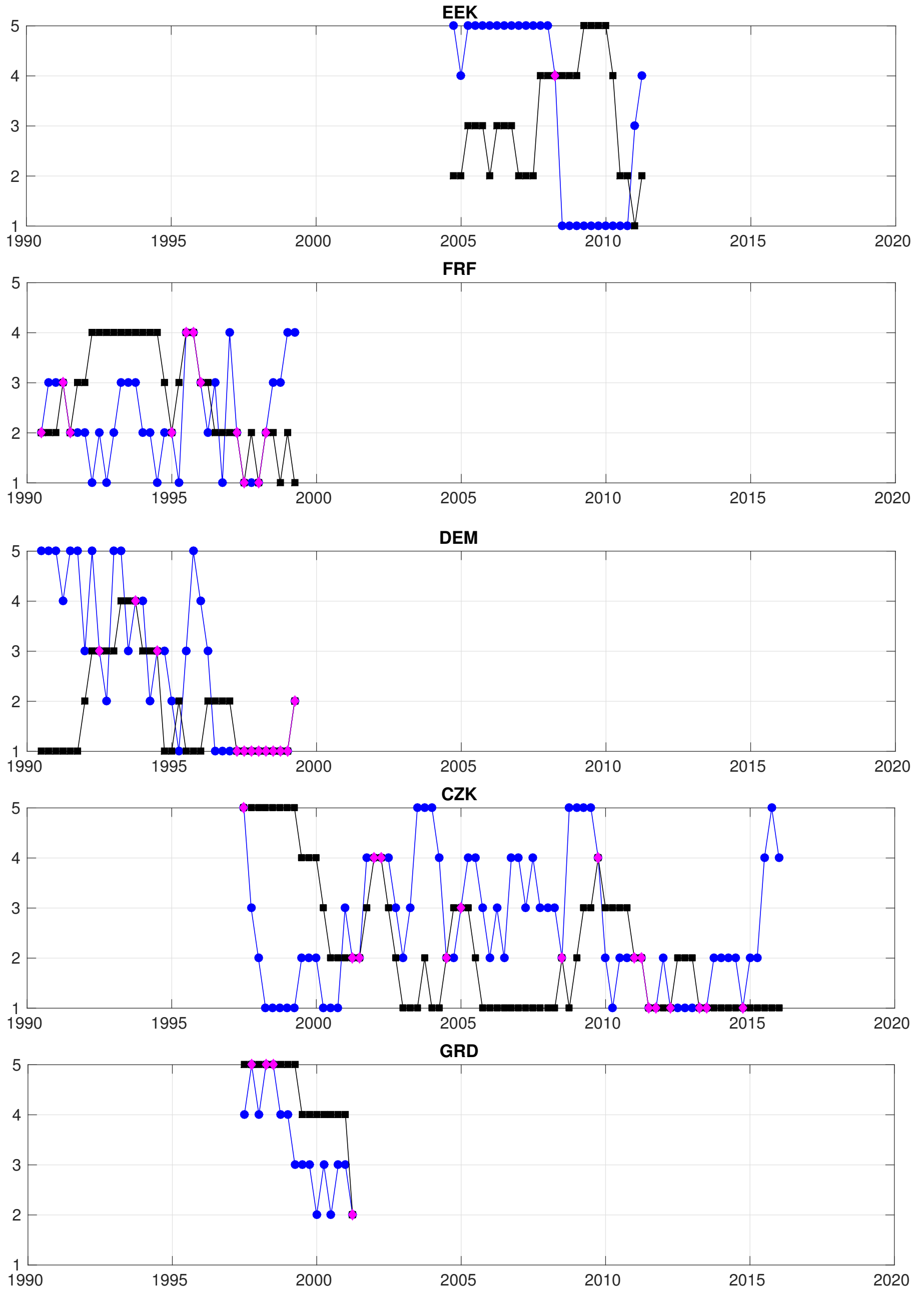
Figure A.1: $\text{HML}_{\Delta c}$and sample average consumption growth

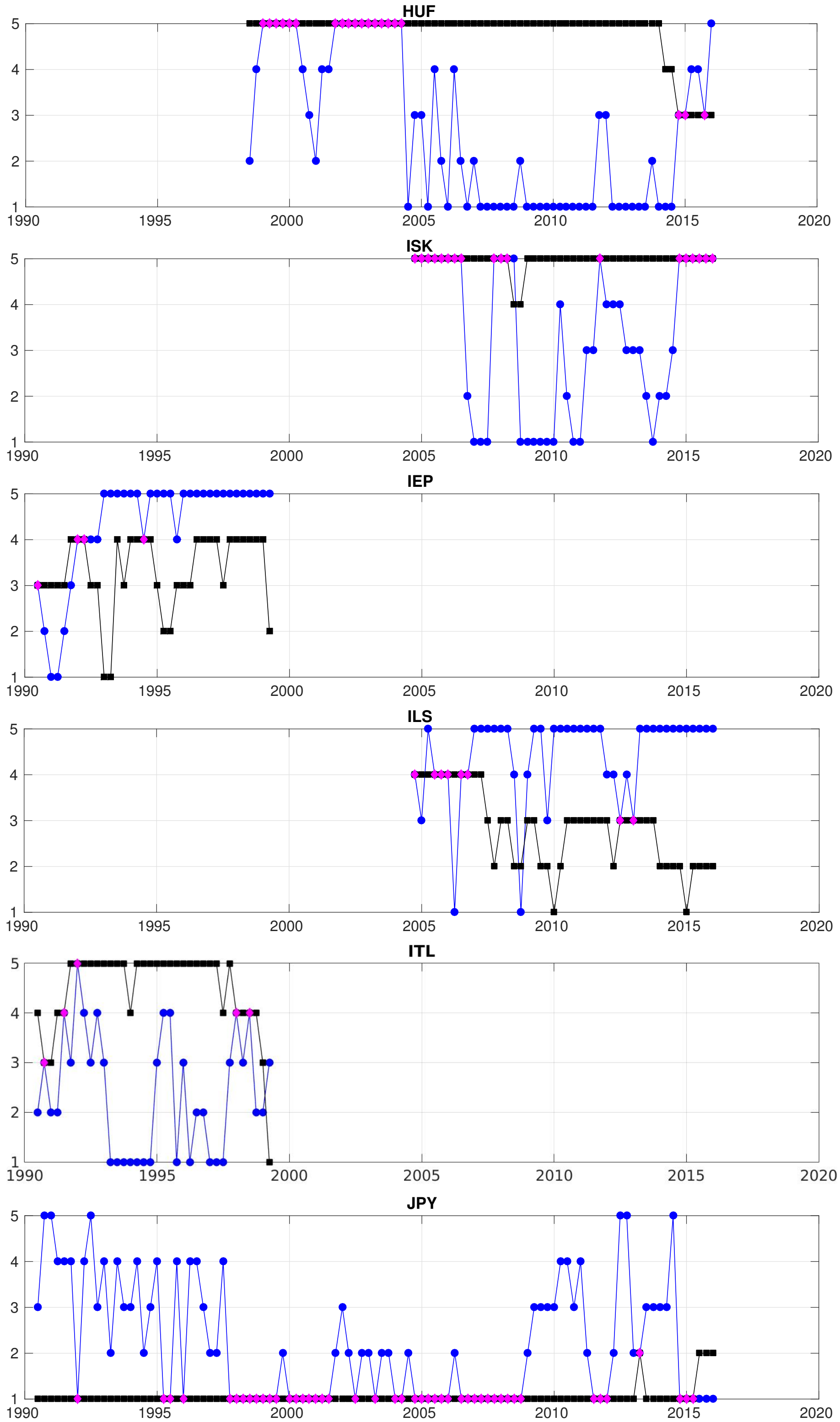


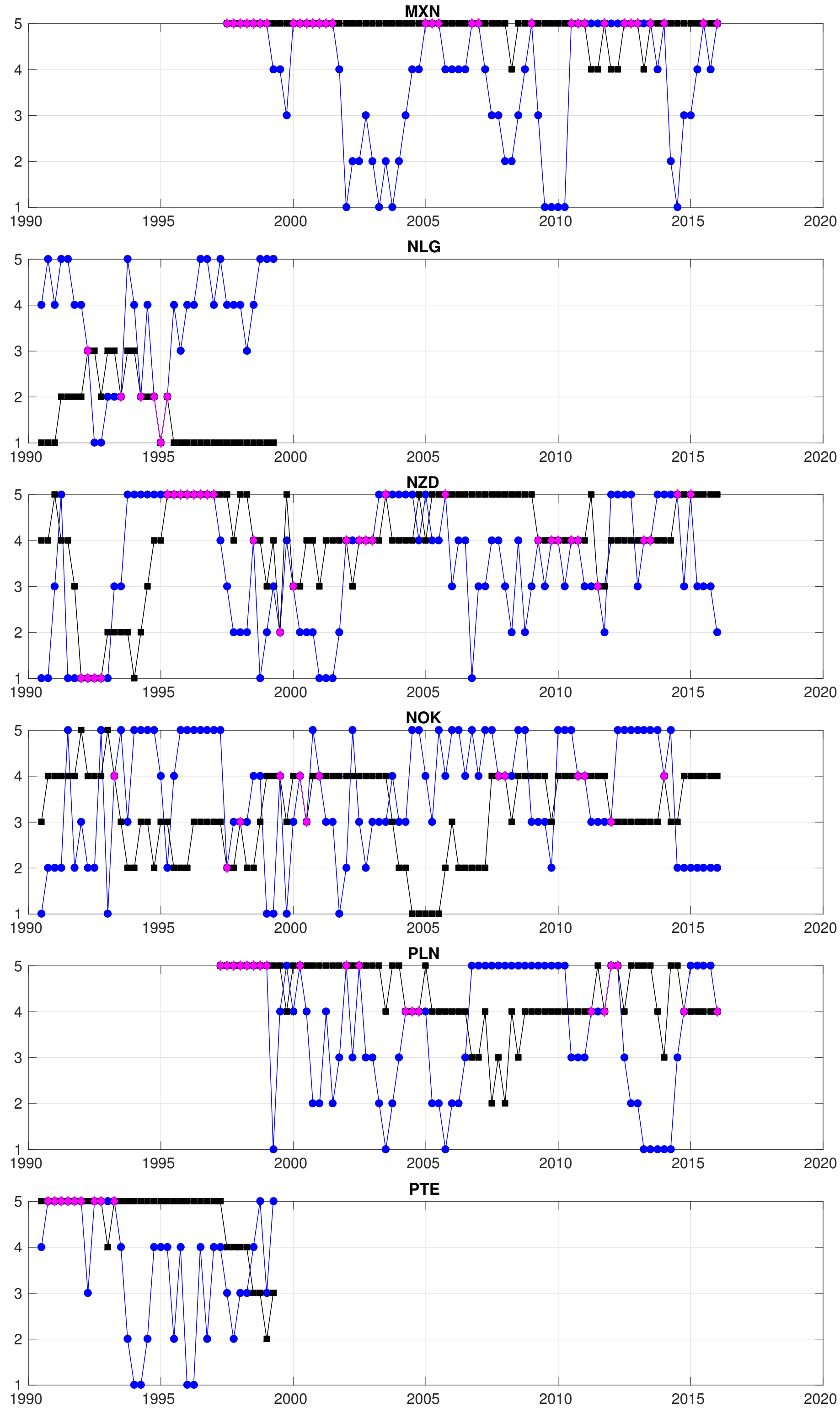
The blue solid line plots the consumption carry trade factor $\text{HML}_{\Delta c}$, and the black, dotted line plots the sample average consumption growth rate Δc^{OECD}. $\text{HML}_{\Delta c}$ corresponds to the cross-country average return a global investor obtains when she borrows in the currencies of countries which experienced low consumption growth over the last year and invests in currencies of countries that experienced a year of relatively high consumption growth. Δc^{OECD} corresponds to the equally weighted sample average of quarterly consumption growth rates. Both variables are centered to have mean zero and standardized to a variance of one. Both variables are constructed from quarterly data which encompasses the OECD sample specified in the main text.

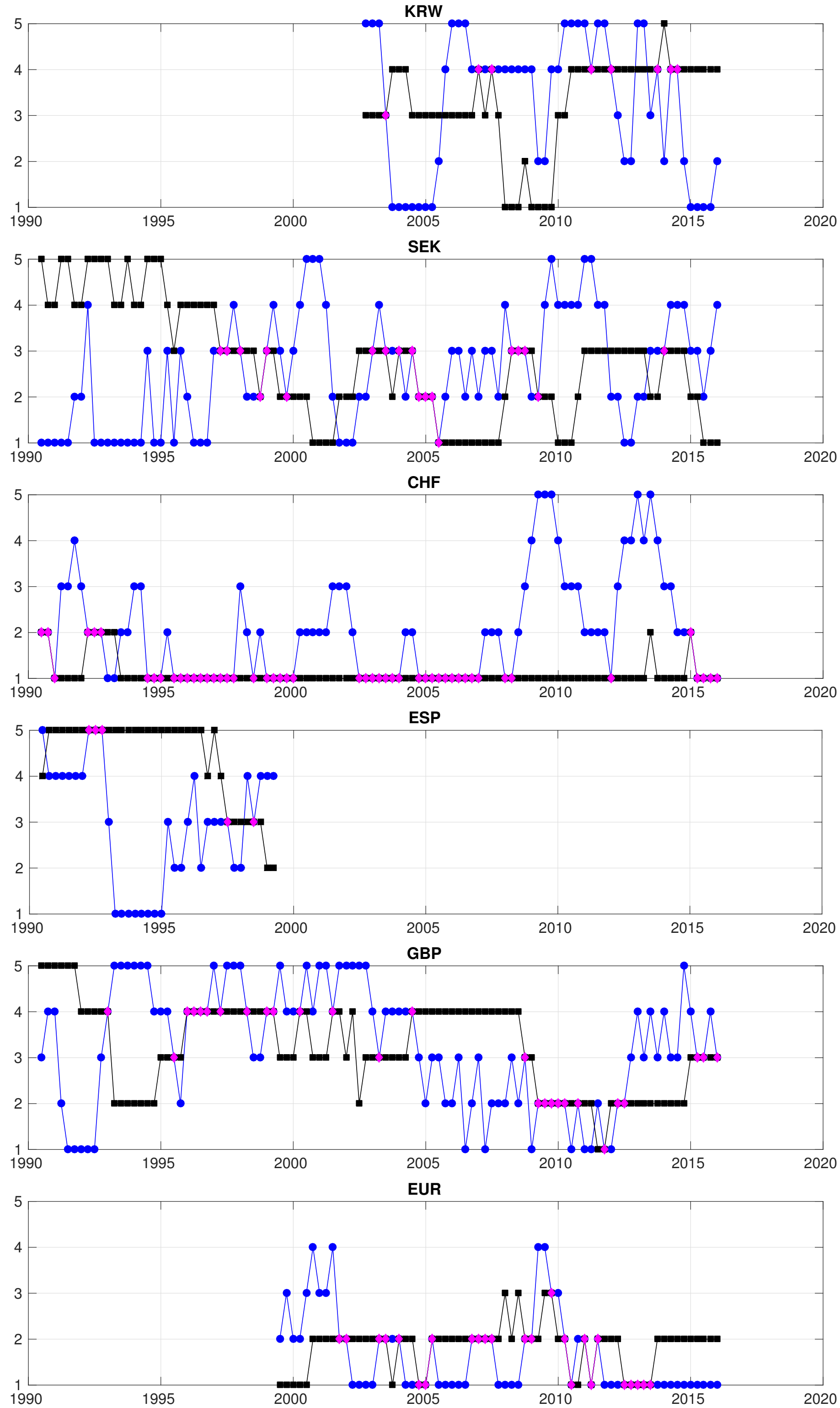
Figure A.2: comparision of consumption sorted and forward discount sorted portfolios




EEK
FRF
DEM
CZK
GRD
1990
1995
2000
2005
2010
2015
2020


HUF
ISK
IEP
ILS
ITL
JPY


MXN
NLG
NZD
NOK
PLN
PTE
1
2
3
4
5
1990
1995
2000
2005
2010
2015
2020



On the horizontal axis, the figures shows the quarters from 1990(1) to 2015(4). The vertical axis indicates the five currency portfolio, where the first portfolio is the "low" portfolio and the fifth portfolio is the "high" portfolio. The black squares indicate in which portfolio a particular currency is placed when currencies are sorted on forward discounts towards the USD. The blue dots indicate in which portfolio the currency falls if currencies are sorted on consumption growth rates. The mangenta colored diamonds indicate when the two sorts are identical.

Table A.1: forward discount sorted currency portfolios

portfolio j	low	2	3	4	high	HML$_{FX}$
	excess return rx^j					
mean portfolio return	−1.5280	0.8594	1.4528	1.9717	3.5378	5.0657
std portfolio return	16.4668	18.5279	18.0586	18.8025	18.7177	17.2944
Sharpe ratio	−0.0928	0.0464	0.0804	0.1049	0.1890	0.2929
skewness	0.3760	0.1597	−0.3056	−0.3887	−0.7232	−0.6053
	spot change Δs^k					
mean	−0.2878	0.7009	0.4610	−0.3855	−2.7980	
std	16.2655	18.2173	17.9384	18.7193	18.8307	
	consumption growth Δc^j					
mean	1.8327	2.2189	2.8245	2.7964	2.4266	
std	1.1539	1.6288	1.7372	1.5447	3.1348	
	forward discount: $f^j - s^j$					
mean	−0.0031	0.0004	0.0025	0.0059	0.0158	
std	0.0044	0.0045	0.0044	0.0043	0.0081	

This table presents descriptive statistics of USD returns of five currency portfolios. Portfolios are constructed by sorting currencies according to their forward discounts against the US dollar; portfolios are rebalanced quarterly. The first portfolio always contains currencies of countries with the lowest fifth of forward discounts (interest rate differentals towards the USD), and the last portfolio always contains currencies of countries with the highest fifth of forward discounts. The last column shows descriptive statistics for the carry trade portfolio HML$_{FX}$ which is given by a short position in all currencies of the low forward discount (interest rate) portfolio and a long position in the currencies of the high forward discount (interest rate) portfolio. Portfolio excess returns are calculated as $rx^j_{t+1} = f^j_{t,} - s^j_t - \Delta s^j_{t+1}$, where rx^j_{t+1} is the average return from borrowing in US dollars and investing in equal weights in all currencies of portfolio j. f^j_t is the log 3M forward exchange rate of the currencies in portfolio j against the US dollar, and Δs^j_{t+1} is the log difference of the spot exchange rates between dates t and $t+1$; an increase in s^j corresponds to a depreciation of the currencies in portfolio j against the US dollar. Quarterly returns are calculated using average forward and spot exchange rates over the last ten trading days of each quarter. The statistics are presented in percentages per annum, except for the forward discounts. The sample encompasses data for 29 OECD countries and it spans the period from the first quarter of 1990 to the fourth quarter of 2015.

Table A.2: composition of consumption growth sorted portfolios

Quarter	low Δc_t portfolio					portfolio 2				portfolio 3				portfolio 4					high Δc_t portfolio				
1990_2	NZD	NOK	DKK	SEK		CHF	ITL	FRF		JPY	GBP	IEP		PTE	CAD	AUD	NLG		BEF	ATS	DEM	ESP	
1990_3	NZD	DKK	SEK	CAD		NOK	IEP	CHF		ITL	FRF	AUD		ESP	BEF	GBP	ATS		NLG	DEM	PTE	JPY	
1990_4	SEK	DKK	IEP	CHF		CAD	ITL	NOK		NZD	AUD	FRF		GBP	ESP	BEF	NLG		ATS	DEM	PTE	JPY	
1991_1	SEK	DKK	CAD	IEP		NOK	GBP	ITL		CHF	AUD	FRF		BEF	JPY	ESP	DEM		ATS	NZD	NLG	PTE	
1991_2	CAD	GBP	NZD	SEK		AUD	IEP	FRF		DKK	BEF	CHF		ESP	ITL	ATS	JPY		NOK	NLG	PTE	DEM	
1991_3	GBP	NZD	CAD	AUD		NOK	SEK	FRF		DKK	IEP	ITL		JPY	CHF	NLG	ESP		BEF	ATS	PTE	DEM	
1991_4	GBP	NZD	CAD	JPY		FRF	SEK	AUD		CHF	NOK	DEM		DKK	NLG	IEP	ESP		ATS	ITL	BEF	PTE	
1992_1	NZD	GBP	CAD	FRF		CHF	DKK	NOK		AUD	NLG	PTE		SEK	IEP	JPY	ITL		ATS	ESP	DEM	BEF	
1992_2	GBP	NZD	SEK	NLG		FRF	NOK	CHF		ITL	CAD	DEM		AUD	IEP	BEF	ATS		DKK	JPY	ESP	PTE	
1992_3	SEK	NLG	NZD	FRF		CHF	CAD	DEM		GBP	JPY	BEF		DKK	IEP	ATS	ITL		AUD	ESP	PTE	NOK	
1992_4	NZD	SEK	NOK	CHF		NLG	BEF	FRF		ESP	ITL	CAD		DKK	AUD	JPY	GBP		ATS	PTE	IEP	DEM	
1993_1	SEK	CHF	ESP	ITL		BEF	JPY	NLG		CAD	NZD	FRF		ATS	NOK	DKK	AUD		PTE	IEP	GBP	DEM	
1993_2	SEK	ITL	ESP	DKK		CHF	NLG	BEF		FRF	NZD	DEM		PTE	JPY	ATS	AUD		CAD	NOK	IEP	GBP	
1993_3	SEK	ITL	ESP	DKK		PTE	BEF	CHF		JPY	FRF	NOK		DEM	ATS	AUD	CAD		NLG	IEP	NZD	GBP	
1993_4	ITL	SEK	ESP	PTE		BEF	FRF	DKK		JPY	CHF	ATS		AUD	DEM	NLG	CAD		IEP	NZD	NOK	GBP	
1994_1	ITL	ESP	SEK	PTE		DEM	NLG	FRF		CHF	BEF	ATS		CAD	DKK	AUD	JPY		NZD	IEP	NOK	GBP	
1994_2	ESP	ITL	CHF	FRF		PTE	ATS	JPY		BEF	DEM	SEK		CAD	NLG	AUD	IEP		NOK	GBP	DKK	NZD	
1994_3	CHF	ESP	ITL	SEK		NLG	FRF	ATS		DEM	JPY	BEF		CAD	AUD	PTE	GBP		NOK	IEP	NZD	DKK	
1994_4	CHF	ESP	SEK	NLG		ATS	FRF	DEM		ITL	BEF	CAD		PTE	GBP	NOK	JPY		IEP	AUD	NZD	DKK	
1995_1	JPY	DEM	FRF	ATS		NLG	CHF	NOK		ESP	SEK	BEF		GBP	ITL	PTE	CAD		AUD	IEP	DKK	NZD	
1995_2	BEF	JPY	SEK	CHF		PTE	ESP	ATS		DEM	GBP	CAD		FRF	ITL	NOK	NLG		DKK	IEP	AUD	NZD	
1995_3	BEF	CHF	ATS	ITL		DKK	ESP	GBP		NLG	SEK	CAD		JPY	PTE	FRF	IEP		DEM	NOK	NZD	AUD	
1995_4	JPY	CHF	PTE	ATS		DKK	BEF	SEK		FRF	ESP	ITL		GBP	DEM	CAD	NLG		AUD	IEP	NZD	NOK	
1996_1	CHF	SEK	ITL	PTE		BEF	ATS	FRF		DKK	DEM	CAD		ESP	GBP	JPY	NLG		AUD	NZD	IEP	NOK	
1996_2	ATS	CHF	SEK	DEM		ITL	ESP	BEF		FRF	CAD	DKK		JPY	AUD	GBP	PTE		NLG	NZD	IEP	NOK	
1996_3	FRF	DEM	SEK	CHF		ATS	ITL	PTE		JPY	DKK	ESP		BEF	CAD	AUD	GBP		NLG	NOK	NZD	IEP	
1996_4	ITL	CHF	DEM	ATS		JPY	CAD	BEF		DKK	SEK	ESP		AUD	FRF	NLG	PTE		GBP	NZD	NOK	IEP	
1997_1	DEM	ITL	ATS	CHF		FRF	BEF	DKK	JPY	ESP	SEK	AUD		CAD	PTE	GBP	NZD		NLG	NOK	PLN	IEP	
1997_2	FRF	ATS	CHF	ITL	DEM	BEF	DKK	NOK	AUD	SEK	NZD	PTE	ESP	JPY	GRD	NLG	CAD		IEP	CZK	GBP	MXN	PLN
1997_3	JPY	ATS	FRF	CHF	DEM	ESP	BEF	PTE	NZD	CZK	ITL	AUD	NOK	DKK	SEK	NLG	CAD		GRD	GBP	IEP	MXN	PLN
1997_4	FRF	DEM	ATS	JPY	DKK	ESP	BEF	CZK	NZD	CHF	SEK	NOK	PTE	GRD	NLG	ITL	AUD		GBP	CAD	IEP	MXN	PLN
1998_1	JPY	DEM	CZK	ATS	BEF	CHF	NZD	FRF	SEK	NOK	PTE	NLG	ITL	ESP	CAD	DKK	GBP		GRD	AUD	MXN	PLN	IEP
1998_2	JPY	CZK	DEM	CHF	ATS	DKK	HUF	BEF	SEK	CAD	FRF	GBP	ESP	PTE	NZD	NOK	NLG	ITL	AUD	GRD	PLN	MXN	IEP
1998_3	CZK	JPY	DEM	DKK	NZD	SEK	CHF	BEF	ITL	ATS	CAD	GBP	FRF	NOK	AUD	GRD	HUF	ESP	PLN	PTE	NLG	MXN	IEP
1998_4	CZK	JPY	DEM	CHF	NOK	CAD	ITL	BEF	NZD	ATS	SEK	DKK	PTE	GRD	FRF	AUD	ESP	GBP	HUF	MXN	PLN	NLG	IEP

Quarter	low Δc_t portfolio					portfolio 2				portfolio 3				portfolio 4					high Δc_t portfolio				
1999_1	JPY	NOK	CZK	PLN	CHF	DEM	DKK	CAD	ATS	BEF	ITL	GRD	NZD	MXN	FRF	ESP	SEK	GBP	AUD	IEP	PTE	NLG	HUF
1999_2	JPY	DKK	CHF			NZD	EUR	CZK		GRD	CAD	SEK		MXN	NOK	PLN			GBP	HUF	AUD		
1999_3	DKK	NOK	CHF			JPY	CZK	SEK		MXN	EUR	GRD		CAD	NZD	GBP			PLN	AUD	HUF		
1999_4	DKK	JPY	CHF			EUR	GRD	CZK		SEK	NOK	NZD		CAD	GBP	PLN			AUD	MXN	HUF		
2000_1	DKK	JPY	CZK			CHF	NZD	EUR		GRD	CAD	AUD		SEK	GBP	NOK			MXN	HUF	PLN		
2000_2	DKK	JPY	CZK			NZD	CHF	GRD		NOK	EUR	AUD		PLN	HUF	CAD			MXN	SEK	GBP		
2000_3	JPY	DKK	CZK			NZD	CHF	PLN		GRD	HUF	AUD		EUR	CAD	GBP			NOK	MXN	SEK		
2000_4	JPY	DKK	NZD			CHF	PLN	HUF		CZK	GRD	EUR		AUD	CAD	NOK			GBP	MXN	SEK		
2001_1	DKK	JPY	NZD			GRD	CHF	CZK		EUR	NOK	AUD		HUF	PLN	SEK			CAD	GBP	MXN		
2001_2	DKK	JPY	NZD			PLN	SEK	CZK		CHF	NOK			EUR	GBP	HUF			CAD	AUD	MXN		
2001_3	DKK	SEK	NOK			NZD	EUR	JPY		PLN	CHF			MXN	CAD	CZK			AUD	GBP	HUF		
2001_4	SEK	DKK	MXN			CAD	NOK	EUR		CHF	JPY			NZD	AUD	CZK			PLN	GBP	HUF		
2002_1	DKK	SEK	EUR			MXN	JPY	CHF		PLN	CAD			AUD	CZK	NZD			NOK	GBP	HUF		
2002_2	JPY	EUR	CHF			MXN	DKK	SEK		AUD	NOK			NZD	CAD	CZK			PLN	GBP	HUF		
2002_3	DKK	CHF	EUR			JPY	NOK	SEK		MXN	CZK	PLN		AUD	NZD	CAD			GBP	HUF	KRW		
2002_4	CHF	EUR	DKK			MXN	JPY	CZK		SEK	PLN	NOK		GBP	NZD	CAD			AUD	KRW	HUF		
2003_1	CHF	MXN	JPY			EUR	PLN	DKK		CZK	GBP	NOK		CAD	SEK	AUD			NZD	KRW	HUF		
2003_2	CHF	DKK	PLN			JPY	MXN	EUR		KRW	NOK	SEK		GBP	CAD	AUD			CZK	NZD	HUF		
2003_3	KRW	MXN	CHF			JPY	EUR	PLN		DKK	SEK	CAD		AUD	NOK	GBP			CZK	NZD	HUF		
2003_4	KRW	JPY	CHF			MXN	EUR	DKK		PLN	SEK	NOK		CAD	AUD	GBP			CZK	NZD	HUF		
2004_1	KRW	EUR	JPY			CHF	SEK	CAD		MXN	DKK	NOK		PLN	GBP	CZK			AUD	HUF	NZD		
2004_2	KRW	HUF	EUR			CHF	JPY	CZK		CAD	SEK	DKK		MXN	GBP	PLN			NOK	AUD	NZD		
2004_3	KRW	JPY	EUR	CHF		SEK	CAD	CZK		GBP	HUF	DKK		PLN	ILS	MXN	NZD		AUD	NOK	EEK	ISK	
2004_4	KRW	EUR	JPY	CHF		SEK	CAD	GBP		ILS	HUF	CZK		PLN	EEK	DKK	NOK		AUD	MXN	NZD	ISK	
2005_1	JPY	HUF	CHF	KRW		EUR	SEK	PLN		CAD	GBP	NOK		CZK	AUD	NZD	DKK		ILS	MXN	ISK	EEK	
2005_2	JPY	CHF	EUR	SEK		KRW	PLN	AUD		DKK	CAD	GBP		NZD	CZK	ILS	HUF		NOK	MXN	EEK	ISK	
2005_3	JPY	CHF	EUR	PLN		HUF	GBP	SEK		CZK	AUD	CAD		KRW	ILS	NOK	MXN		DKK	NZD	EEK	ISK	
2005_4	HUF	CHF	JPY	EUR		PLN	CZK	GBP		AUD	SEK	NZD		CAD	MXN	ILS	DKK		KRW	NOK	EEK	ISK	
2006_1	DKK	ILS	EUR	CHF		AUD	JPY	PLN		GBP	SEK	CZK		MXN	CAD	HUF	NZD		NOK	KRW	ISK	EEK	
2006_2	CHF	GBP	JPY	EUR		HUF	SEK	CZK		PLN	AUD	CAD		ILS	NZD	NOK	MXN		DKK	KRW	ISK	EEK	
2006_3	HUF	CHF	JPY	NZD		EUR	GBP	ISK		AUD	SEK	CAD		CZK	ILS	DKK	KRW		PLN	NOK	MXN	EEK	
2006_4	ISK	JPY	DKK	CHF		EUR	HUF	SEK		GBP	NZD	AUD		KRW	CZK	NOK	CAD		ILS	PLN	MXN	EEK	
2007_1	ISK	HUF	JPY	GBP		CHF	DKK	EUR		SEK	NZD	CZK		CAD	AUD	KRW	MXN		PLN	NOK	ILS	EEK	
2007_2	ISK	JPY	DKK	HUF		EUR	CHF	GBP		SEK	MXN	CAD		NZD	KRW	CZK	AUD		NOK	PLN	ILS	EEK	
2007_3	DKK	HUF	JPY	EUR		GBP	CHF	SEK		MXN	CZK	CAD		NZD	NOK	KRW	AUD		PLN	ISK	EEK	ILS	
2007_4	HUF	JPY	EUR	CHF		MXN	DKK	GBP		CZK	CAD	NZD		SEK	NOK	KRW	AUD		PLN	EEK	ILS	ISK	

Quarter	low Δc_t portfolio				portfolio 2			portfolio 3			portfolio 4				high Δc_t portfolio			
2008_1	JPY	HUF	EUR	CHF	MXN	NZD	DKK	CZK	GBP	SEK	KRW	CAD	NOK	EEK	AUD	PLN	ILS	ISK
2008_2	EEK	HUF	JPY	EUR	CHF	CZK	GBP	SEK	DKK	MXN	NZD	ILS	AUD	KRW	NOK	CAD	PLN	ISK
2008_3	ISK	EEK	JPY	ILS	HUF	EUR	NZD	GBP	CHF	SEK	KRW	MXN	AUD	DKK	CZK	NOK	CAD	PLN
2008_4	ISK	EEK	GBP	HUF	JPY	SEK	EUR	NZD	NOK	DKK	AUD	ILS	KRW	CHF	MXN	CZK	CAD	PLN
2009_1	ISK	EEK	DKK	HUF	GBP	KRW	SEK	JPY	MXN	NOK	EUR	AUD	NZD	CAD	ILS	CHF	CZK	PLN
2009_2	ISK	EEK	MXN	HUF	DKK	KRW	GBP	NZD	JPY	NOK	EUR	SEK	CAD	AUD	ILS	CHF	CZK	PLN
2009_3	EEK	ISK	MXN	HUF	DKK	GBP	NOK	EUR	ILS	JPY	CAD	KRW	CZK	NZD	SEK	AUD	CHF	PLN
2009_4	EEK	ISK	HUF	MXN	DKK	GBP	CZK	EUR	JPY	CAD	NZD	KRW	SEK	CHF	AUD	NOK	ILS	PLN
2010_1	EEK	HUF	CZK	MXN	GBP	EUR	DKK	NZD	CHF	CAD	JPY	SEK	AUD	ISK	PLN	NOK	ILS	KRW
2010_2	EEK	HUF	GBP	EUR	ISK	CZK	DKK	CHF	PLN	AUD	CAD	JPY	SEK	NZD	ILS	MXN	NOK	KRW
2010_3	HUF	EEK	ISK	DKK	CZK	EUR	GBP	CHF	JPY	PLN	SEK	AUD	NZD	NOK	CAD	KRW	ILS	MXN
2010_4	ISK	HUF	DKK	GBP	CZK	EUR	CHF	EEK	NZD	PLN	NOK	CAD	JPY	AUD	SEK	KRW	ILS	MXN
2011_1	HUF	GBP	EUR	DKK	CZK	CHF	JPY	NZD	ISK	NOK	PLN	EEK	KRW	CAD	AUD	SEK	ILS	MXN
2011_2	DKK	JPY	HUF	CZK	CHF	GBP	EUR	ISK	NZD	NOK	SEK	CAD	PLN		KRW	MXN	AUD	ILS
2011_3	GBP	EUR	JPY	CZK	DKK	CHF	NZD	HUF	CAD	NOK	SEK	PLN	AUD		KRW	ISK	ILS	MXN
2011_4	GBP	EUR	JPY	CHF	DKK	CZK	SEK	HUF	NOK	CAD	KRW	ISK	ILS		AUD	PLN	NZD	MXN
2012_1	EUR	HUF	CZK	DKK	GBP	SEK	JPY	CHF	KRW	CAD	ILS	ISK	AUD		NOK	PLN	NZD	MXN
2012_2	EUR	CZK	HUF	SEK	DKK	KRW	GBP	PLN	CAD	ILS	CHF	AUD	ISK		NOK	JPY	NZD	MXN
2012_3	HUF	CZK	EUR	SEK	DKK	KRW	PLN	CAD	GBP	ISK	ILS	AUD	CHF		NZD	JPY	NOK	MXN
2012_4	HUF	EUR	CZK	DKK	PLN	SEK	JPY	ISK	ILS	NZD	CAD	GBP	AUD		KRW	CHF	MXN	NOK
2013_1	CZK	EUR	HUF	PLN	DKK	JPY	SEK	ISK	CAD	GBP	AUD	NZD	CHF		KRW	NOK	ILS	MXN
2013_2	EUR	HUF	PLN	CZK	ISK	AUD	DKK	JPY	KRW	SEK	GBP	CAD	NZD		CHF	ILS	NOK	MXN
2013_3	EUR	DKK	PLN	ISK	HUF	CZK	AUD	JPY	GBP	SEK	KRW	MXN	CHF		CAD	NOK	NZD	ILS
2013_4	EUR	DKK	PLN	HUF	CZK	ISK	KRW	JPY	CHF	SEK	AUD	GBP	NOK		MXN	CAD	NZD	ILS
2014_1	DKK	EUR	HUF	PLN	ISK	MXN	CZK	JPY	CHF	GBP	KRW	SEK	AUD		NOK	CAD	NZD	ILS
2014_2	DKK	MXN	EUR	HUF	CZK	NOK	CHF	PLN	ISK	GBP	SEK	CAD	KRW		NZD	AUD	ILS	JPY
2014_3	JPY	DKK	EUR	CZK	CHF	KRW	NOK	HUF	NZD	MXN	PLN	CAD	SEK		ILS	GBP	AUD	ISK
2014_4	JPY	EUR	DKK	KRW	CHF	CZK	NOK	SEK	HUF	MXN	GBP	CAD	AUD		ISK	PLN	NZD	ILS
2015_1	JPY	KRW	CHF	EUR	DKK	NOK	CZK	GBP	SEK	NZD	MXN	HUF	CAD		AUD	PLN	ISK	ILS
2015_2	JPY	CHF	KRW	EUR	NOK	SEK	CAD	NZD	DKK	GBP	CZK	AUD	HUF		MXN	PLN	ISK	ILS
2015_3	JPY	CHF	KRW	EUR	DKK	CAD	NOK	SEK	HUF	NZD	AUD	MXN	GBP		CZK	PLN	ISK	ILS
2015_4	JPY	CHF	CAD	EUR	NOK	NZD	KRW	DKK	GBP	AUD	SEK	PLN	CZK		MXN	HUF	ILS	ISK

Table A.3: exchange rate returns – factor betas

	a^j	$\beta^j_{\overline{\text{rx}}}$	$\beta^j_{\text{HML}_{\Delta c}}$	$\overline{R}^2$
low	−0.0026	1.0010	−0.4455	
	(−1.1479)	(18.8339)	(−7.9354)	0.90
2	−0.0031	0.9515	−0.2032	
	(−1.2982)	(11.0993)	(−2.9578)	0.79
3	−0.0055	1.0420	−0.0730	
	(−3.3591)	(32.5539)	(−1.4484)	0.88
4	−0.0043	0.9527	0.1905	
	(−2.3211)	(22.1449)	(5.0132)	0.85
high	−0.0069	1.0139	0.4969	
	(−3.8492)	(22.2416)	(10.7819)	0.92

This table shows estimates and t-statistics obtained from running the following time series regression for each currency portfolio j separately:

$$\Delta s^j_{t+1} = a^j + \beta^j_{\overline{\text{rx}}} \cdot \overline{\text{rx}}_{t+1} + \beta^j_{\text{HML}_{\Delta c}} \cdot \text{HML}_{\Delta c,t+1} + \varepsilon^j_{t+1}$$

Standard errors are corrected for serial correlation using the Newey and West (1987) estimator for the covariance matrix of the error terms ε^j_{t+1}.

Table A.4: exchange rate returns – risk price and factor loadings

	$\lambda_{\overline{\text{rx}}}$	$\lambda_{\text{HML}_{\Delta c}}$	$b_{\overline{\text{rx}}}$	$b_{\text{HML}_{\Delta c}}$
OLS estimate	−0.0015	0.0033	−0.6060	3.5303
t-stat	(−0.3557)	(1.0759)	(−0.2308)	(1.0032)
pricing error test		0.81		0.78
R^2		0.75		0.75
GLS estimate	−0.0015	0.0032	−1.0256	2.9347
t-stat	(−0.3488)	(1.0080)	(−0.4067)	(0.9854)
pricing error test		0.86		0.85

This first two columns of this table report results from estimating the following cross-sectional regression:

$$E(rx^j) \quad = \quad \beta^j_{\overline{\text{rx}}} \cdot \lambda_{\overline{\text{rx}}} + \beta^j_{\text{HML}_{\Delta c}} \cdot \lambda_{\text{HML}_{\Delta c}} + \alpha^j$$

$\beta^j_{\overline{\text{rx}}}$ and $\beta^j_{\text{HML}_{\Delta c}}$ correspond to the estimates obtained from running time series regressions of portfolio returns on the risk factors as reported in Table (A.3). Here, the factor βs and the prices of risk $\lambda_{\overline{\text{rx}}}$ and $\lambda_{\text{HML}_{\Delta c}}$ are estimated jointly using GMM. This approach yields standard errors which correct for the fact that the βs are estimates. The third and the fourth column of this table report results from estimating the following cross-sectional regression:

$$E(rx^j) \quad = \quad cov(\overline{\text{rx}}, rx^j) \cdot b_{\overline{\text{rx}}} + cov(\text{HML}_{\Delta c}, rx^j) \cdot b_{\text{HML}_{\Delta c}} + \alpha^j$$

where again, covariances and factor loadings b have been estimated jointly using GMM.R^2 statistics are calculated as described in the notes of table (4). The pricing error test reports the p-value for the null that the pricing errors are jointly zero.

Table A.5: currency portfolios sorted on $\beta_{\text{HML}_{\Delta c,t}}$

portfolio j	low	2	3	4	high
	excess return rx^k				
mean	−0.8730	−1.1905	0.3053	1.5036	0.2951
std	18.4731	18.6700	19.6908	18.3606	16.5088
Sharpe ratio	−0.0473	−0.0638	0.0155	0.0819	0.0179
skewness	0.4305	0.2910	−0.4671	−0.6389	−0.9038
	spot change Δs^k				
mean	0.4710	−1.0155	−0.3250	−0.0818	−2.3259
std	18.2550	18.4025	19.4906	18.1561	16.0220
	consumption growth Δc^j				
mean	1.2903	2.3022	2.3087	2.9328	3.0393
std	1.8209	1.2261	1.3307	1.6721	1.8443
	forward discount: $f^j - s^j$				
mean	−0.0034	−0.0004	0.0016	0.0040	0.0066
std	0.0042	0.0040	0.0044	0.0047	0.0064

This table presents descriptive statistics of USD returns of five currency portfolios. Currencies are sorted into portfolios according to their β_t with respect to the consumption carry trade factor $\text{HML}_{\Delta c}$. For each currency k we estimate the following regression over rolling windows

$$rx^k_{t+1} \quad = \quad a^k + \beta^k_1 \cdot \overline{\text{rx}}_{t+1} + \beta^k_2 \cdot \text{HML}_{\Delta c,t+1} + \varepsilon^k_{t+1}$$

At time t, we run the regression using data for the quarters from $t-19$ to t (20 quarters). Due to the rolling window estimation, five years are lost, such that the data sample reaches from 1995(1) to 2015(4). The consumption carry trade factor $\text{HML}_{\Delta c}$ is constructed as described in the main text, based on five previous years consumption growth sorted currency portfolios. $\overline{\text{rx}}_{t+1}$ is the average return obtained from borrowing in US dollars and investing in equal weights in all currencies of the sample at a given point in time. Portfolio excess returns are calculated as $rx^j_{t+1} = f^j_{t+1} - s^j_t - \Delta s^j_{t+1}$, where rx^j_{t+1} is the average quarterly return from borrowing in US dollars and investing in equal weights in all currencies of portfolio j. f^j_{t+1} is the log 3M forward exchange rate of the currencies in portfolio j against the US dollar, and Δs^j_{t+1} is the log difference of the spot exchange rate between dates t and $t+1$; an increase in s^j corresponds to a depreciation of the currencies in portfolio j against the US dollar. Quarterly returns are calculated using average forward and spot exchange rates over the last ten trading days of each quarter. The statistics are presented in percentages per annum, except for the forward discounts. The sample encompasses data for 29 OECD countries and it spans the period from the first quarter of 1990 to the fourth quarter of 2015.

Table A.6: forward discount factor betas

	a^j	$\beta^j_{\overline{\mathrm{rx}}}$	$\beta^j_{\mathrm{HML}_{\Delta c}}$	$\beta^j_{(\mathrm{f-s})}$	$\overline{R}^2$
low	0.0012	1.0193	−0.4824	−0.2930	
	(0.9520)	(22.5736)	(−10.7603)	(−1.6266)	0.94
2	−0.0010	0.9585	−0.1968	0.2631	
	(−0.3534)	(11.4556)	(−2.9484)	(0.6648)	0.79
3	−0.0015	1.0518	−0.0791	−0.0010	
	(−1.0740)	(27.4906)	(−1.3426)	(−0.1030)	0.88
4	0.0008	0.9582	0.1826	−0.0344	
	(0.4130)	(21.9233)	(4.2897)	(−0.9747)	0.84
high	0.0004	1.0111	0.5244	0.0104	
	(0.2848)	(21.4641)	(11.1407)	(1.9538)	0.93

This table shows estimates and t-statistics obtained from running the following time series regression for each currency portfolio j separately:

$$rx^j_{t+1} = a^j + \beta^j_{\overline{\mathrm{rx}}} \cdot \overline{\mathrm{rx}}_{t+1} + \beta^j_{\mathrm{HML}_{\Delta c}} \cdot \mathrm{HML}_{\Delta c,t+1} + \beta^j_{(f-s)}(f^j_t - s^j_t) + \varepsilon^j_{t+1}$$

Standard errors are corrected for serial correlation using the Newey and West (1987) estimator for the covariance matrix of the error terms ε^j_{t+1}.

Table A.7: Swiss investor – currency portfolios sorted on previous year consumption growth

portfolio j	low	2	3	4	high	$\overline{\text{rx}}$	$\text{HML}_{\Delta c}$
	excess return: rx^j						
mean	−0.5936	−0.6993	0.1818	1.6957	2.8262	0.7563	3.4198
std	14.3048	13.8867	15.0047	16.0968	17.7585	13.5409	12.5767
Sharpe ratio	−0.0415	−0.0504	0.0121	0.1053	0.1591	0.0559	0.2719
	spot change: Δs^j						
mean	3.1690	3.3488	2.7368	1.3018	1.2293		
std	14.3329	13.4734	14.9755	15.9044	17.3590		
	consumption growth: Δc^j						
mean	−0.2535	1.5810	2.4433	3.2817	5.0861		
std	2.4648	1.4247	1.3032	1.2679	1.7091		
	forward discount: $f^j - s^j$						
mean	0.0064	0.0067	0.0018	0.0049	−0.0036		
std	0.0043	0.0046	0.0540	0.0276	0.1003		

This table presents descriptive statistics of CHF returns of five currency portfolios. Portfolios are constructed by sorting currencies according to countries' consumption growth rate over the preceding year; portfolios are rebalanced quarterly. The first portfolio always contains currencies of countries with the lowest fifth of past consumption growth rates, and the last portfolio always contains currencies of countries with the highest fifth of past consumption growth rates. The second last column presents the average return obtained from borrowing in Swiss francs and investing in equal weights in all currencies of the sample, this return is labelled $\overline{\text{rx}}_{t+1}$. The last column shows descriptive statistics for the carry trade portfolio $\text{HML}_{\Delta c}$ which is given by a short position in all currencies of the low consumption growth portfolio and a long position in the currencies of the high consumption growth portfolio. Portfolio excess returns are calculated as $rx^j_{t+1} = f^j_t - s^j_t - \Delta s^j_{t+1}$, where rx^j_{t+1} is the average return from borrowing in Swiss francs and investing in equal weights in all currencies of portfolio j. f^j_t is the log 3M forward exchange rate of the currencies in portfolio j against the Swiss franc, and Δs^j_{t+1} is the log difference of the spot exchange rates between dates t and $t+1$; an increase in s^j corresponds to a depreciation of the currencies in portfolio j against the Swiss franc. Quarterly returns are calculated using average forward and spot exchange rates over the last ten trading days of each quarter. The statistics are presented in percentages per annum, except for the forward discounts. The sample encompasses data for 29 OECD countries and it spans the period from the first quarter of 1990 to the fourth quarter of 2015.

Table A.8: Swiss investor – factor betas

	a^j	$\beta^j_{\overline{\text{rx}}}$	$\beta^j_{\text{HML}_{\Delta c}}$	$\overline{R}^2$
low	0.0009	1.0543	−0.5177	
	(0.9036)	(23.0482)	(−15.0162)	0.99
2	−0.0024	0.8411	−0.1067	
	(−1.0964)	(7.1930)	(−1.7361)	0.62
3	−0.0016	0.9719	0.0200	
	(−0.8098)	(21.3685)	(0.3481)	0.77
4	0.0013	1.0482	0.1137	
	(0.6875)	(27.3443)	(2.0466)	0.83
high	0.0009	1.0543	0.4823	
	(0.9036)	(23.0482)	(13.9892)	0.94

This table shows estimates and t-statistics obtained from running the following time series regression for each currency portfolio j separately:

$$rx^j_{t+1} = a^j + \beta^j_{\overline{\text{rx}}} \cdot \overline{\text{rx}}_{t+1} + \beta^j_{\text{HML}_{\Delta c}} \cdot \text{HML}_{\Delta c,t+1} + \varepsilon^j_{t+1}$$

Standard errors are corrected for serial correlation using the Newey and West (1987) estimator for the covariance matrix of the error terms ε^j_{t+1}.

Table A.9: Swiss investor – risk price and factor loadings

	$\lambda_{\overline{rx}}$	$\lambda_{\text{HML}_{\Delta c}}$	$b_{\overline{rx}}$	$b_{\text{HML}_{\Delta c}}$
OLS estimate	0.0018	0.0092	−1.3392	9.8628
t-stat	(0.5847)	(3.1378)	(−0.4267)	(2.7941)
pricing error test		0.52		0.53
R^2		0.80		0.80
GLS estimate	0.0019	0.0088	−0.7423	7.9662
t-stat	(0.5923)	(2.8758)	(−0.2461)	(2.7504)
pricing error test		0.47		0.63

This first two columns of this table report results from estimating the following cross-sectional regression:

$$E(rx^j) \quad = \quad \beta^j_{\overline{rx}} \cdot \lambda_{\overline{rx}} + \beta^j_{\text{HML}_{\Delta c}} \cdot \lambda_{\text{HML}_{\Delta c}} + \alpha^j$$

$\beta^j_{\overline{rx}}$ and $\beta^j_{\text{HML}_{\Delta c}}$ correspond to the estimates obtained from running time series regressions of portfolio returns on the risk factors as reported in Table (A.8). Here, the factor βs and the prices of risk $\lambda_{\overline{rx}}$ and $\lambda_{\text{HML}_{\Delta c}}$ are estimated jointly using GMM. This approach yields standard errors which correct for the fact that the βs are estimates. The third and the fourth column of this table report results from estimating the following cross-sectional regression:

$$E(rx^j) \quad = \quad cov(\overline{rx}, rx^j) \cdot b_{\overline{rx}} + cov(\text{HML}_{\Delta c}, rx^j) \cdot b_{\text{HML}_{\Delta c}} + \alpha^j$$

where again, covariances and factor loadings b have been estimated jointly using GMM.R^2 statistics are calculated as described in the notes of table (4). The pricing error test reports the p-value for the null that the pricing errors are jointly zero. If the p-value is small, say less than 0.05, then pricing errors are significantly different from zero.

Table A.10: most traded currencies – factor betas

	a^j	$\beta^j_{\overline{\text{rx}}}$	$\beta^j_{\text{HML}_{\Delta c}}$	$\bar{R}^2$
low	0.0014	0.9705	−0.5072	
	(1.6220)	(45.9095)	(−17.9742)	0.95
2	−0.0010	1.0530	−0.1227	
	(−0.4841)	(12.3630)	(−1.7062)	0.77
3	−0.0022	1.0463	0.1273	
	(−0.9865)	(15.4703)	(2.1535)	0.78
high	0.0014	0.9705	0.4928	
	(1.6220)	(45.9095)	(17.4652)	0.94

This table shows estimates and t-statistics obtained from running the following time series regression for each currency portfolio j separately:

$$rx^j_{t+1} = a^j + \beta^j_{\overline{\text{rx}}} \cdot \overline{\text{rx}}_{t+1} + \beta^j_{\text{HML}_{\Delta c}} \cdot \text{HML}_{\Delta c,t+1} + \varepsilon^j_{t+1}$$

Standard errors are corrected for serial correlation using the Newey and West (1987) estimator for the covariance matrix of the error terms ε^j_{t+1}.

Table A.11: most traded currencies – risk price and factor loadings

	$\lambda_{\overline{rx}}$	$\lambda_{HML_{\Delta c}}$	$b_{\overline{rx}}$	$b_{HML_{\Delta c}}$
OLS estimate	0.0021	0.0104	2.2282	2.2282
t-stat	(0.5159)	(2.7266)	(0.6927)	(2.2519)
pricing error test		0.34		0.35
R^2		0.85		0.85
GLS estimate	0.0021	0.0106	3.3987	8.6529
t-stat	(0.5333)	(2.8289)	(1.0730)	(2.7149)
pricing error test		0.27		0.40

This first two columns of this table report results from estimating the following cross-sectional regression:

$$E(rx^j) \quad = \quad \beta^j_{\overline{rx}} \cdot \lambda_{\overline{rx}} + \beta^j_{HML_{\Delta c}} \cdot \lambda_{HML_{\Delta c}} + \alpha^j$$

$\beta^j_{\overline{rx}}$ and $\beta^j_{HML_{\Delta c}}$ correspond to the estimates obtained from running time series regressions of portfolio returns on the risk factors as reported in Table (A.11). Here, the factor βs and the prices of risk $\lambda_{\overline{rx}}$ and $\lambda_{HML_{\Delta c}}$ are estimated jointly using GMM. This approach yields standard errors which correct for the fact that the βs are estimates. The third and the fourth column of this table report results from estimating the following cross-sectional regression:

$$E(rx^j) \quad = \quad cov(\overline{rx}, rx^j) \cdot b_{\overline{rx}} + cov(HML_{\Delta c}, rx^j) \cdot b_{HML_{\Delta c}} + \alpha^j$$

where again, covariances and factor loadings b have been estimated jointly using GMM.R^2 statistics are calculated as described in the notes of table (4). The pricing error test reports the p-value for the null that the pricing errors are jointly zero. If the p-value is small, say less than 0.05, then pricing errors are significantly different from zero.