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Concealed carry[☆]

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ABSTRACT

The slope carry takes a long (short) position in the long-term bonds of countries with steeper (flatter) yield curves. The traditional carry takes a long (short) position in countries with high (low) short-term rates. We document that: (i) the slope carry return is slightly negative (strongly positive) in the pre (post) 2008 period, whereas it is concealed over longer samples; (ii) the traditional carry return is lower post-2008; and (iii) expected global growth and inflation declined post-2008. We connect these findings through an equilibrium model in which countries feature heterogeneous exposure to news shocks about global output and global inflation.

1. Introduction

The international finance literature has proposed several currency strategies based on sorting the cross section of countries on various criteria. While the performance of these strategies over long periods of time is well-documented, their behavior over different sample periods is not. In this study, we provide novel empirical evidence that shows that after 2008 there are relevant changes in the returns of two popular carry trade strategies based on sorting countries on the level and on the slope of their yield curves. In addition, we document that (i) expected global inflation and output growth have also changed substantially post-2008, and (ii) countries feature relevant heterogenous exposure to news shocks about both expected global growth and expected global inflation. In the context of a news-based asset pricing model, combining these two sources of heterogeneity rationalizes our empirical findings on carry trades.

Specifically, we document that (i) a strategy which consists in taking a short (long) position in low (high) interest rate currencies (henceforth "traditional carry trade") has experienced a marked decline post-2008, and (ii) a strategy that is short (long) the long-term bonds of countries with flatter (steeper) yield curves for one month (henceforth "slope carry") has a slightly negative return before the global financial crisis and a strongly positive one in the more recent part of the sample. While the first finding can be easily explained with the widespread compression of short-term interest rates that has taken place since 2008, the second finding is more puzzling. This is because the standing view in the literature is that a strategy based on investments in the cross section of long-term sovereign bonds should yield a null excess return (see, for example, Lustig et al., 2019b).

Our point of departure is that the lack of profitability of this carry strategy is *concealed* over a sample that goes back about 30 years, due to a combination of a slightly negative excess return during the first half of the sample, followed by a strong positive excess return in the second half of the sample.

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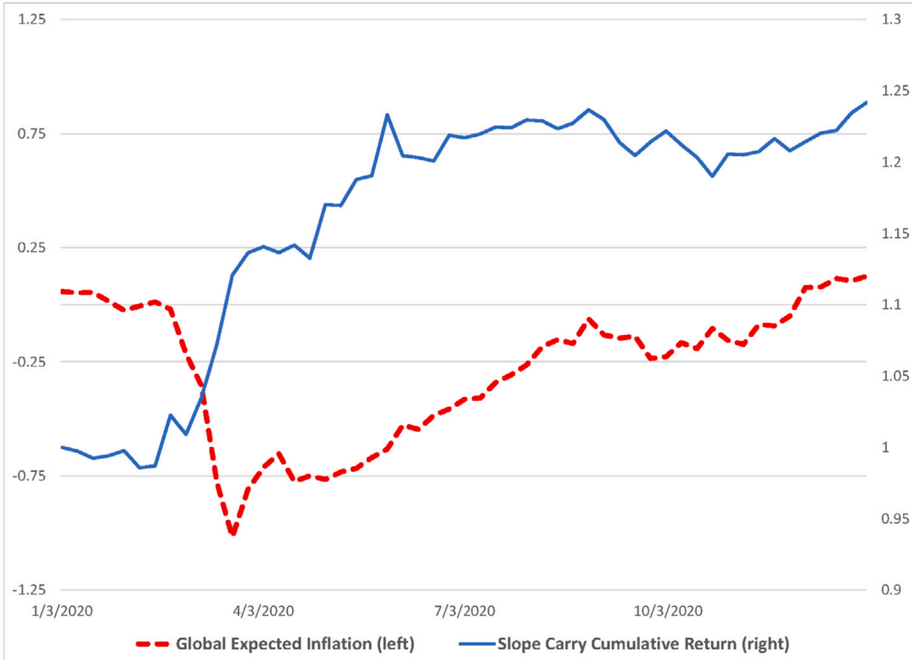


Fig. 1. Global Inflation and Slope Carry Returns. The figure reports (i) the GDP-weighted average of the 5-year break-even inflation for the G10 countries that issue inflation indexed Treasuries (Australia, Canada, Germany, Japan, Sweden, UK, and US); and (ii) the cumulative return from the slope carry strategy applied G10 countries. The slope carry is short (long) the long-term bonds of countries with flatter (steeper) yield curves for one month.

We propose an explanation of these empirical findings in the context of an endowment economy in which: (i) investors have recursive preferences, (ii) financial markets are complete, (iii) the growth rate of consumption in each country features heterogeneous exposure to a global expected growth rate component, and (iv) inflation is characterized by a country-specific exposure to a global expected inflation component. In the interest of parsimony we abstract away from local news shocks.

The first three ingredients are needed to obtain a persistent and profitable traditional carry risk premium as shown in Colacito et al. (2018). The fourth one is the key driver of the slope carry. Indeed, in our model investing in the long-term bonds of high global inflation exposure countries earns a positive excess return. This is because their bonds are exposed to more nominal interest rate risk. Furthermore, in times of lower than average expected inflation, such as in the post-2008 sample period, countries with high exposure to global inflation tend to have lower interest rates and steeper yield curves. In Fig. 1, we provide suggestive evidence implying that similar dynamics took place also in the immediate aftermath of the 2020–21 pandemic crisis. Specifically, the slope carry strategy (i) became very profitable when inflation expectations rapidly declined in 2020; and (ii) it stopped paying high returns as global inflation expectations have been revised upwards.

Equivalently, our model predicts that, post-2008, investing in the long-term bonds of countries with steep yield curves should be profitable, consistent with the empirical findings that we put forward in our empirical investigation. A similar argument can be used to argue that, at times of higher than average expected inflation, such as in the period prior to the global financial crisis, high expected inflation countries should have flatter yield curves, and the slope carry strategy should earn a negative excess return. In Section 5, we show that similar considerations apply to 1975–1985 decade, that is, a period in which expected inflation changed drastically.

Under our benchmark calibration, we are able to produce an average traditional carry annual spread of 2.75%, which declines when expected global growth and inflation are below their historical averages. This currency risk premium originates from a positive correlation between the returns to carry trade and expected global growth news. When, for example, a negative growth news shock hits, the carry trade yields a negative return due to the appreciation of the funding currencies (that is, countries with a high exposure to the growth rate of global GDP). Since our representative investors perceive this state of the world as negative, their marginal utility increases and a positive risk premium must be paid in equilibrium.

Furthermore, we document that our model features an unconditional slope carry excess return close to zero, which turns sharply positive during times of below-average expected global inflation. This result is primarily due to the interaction between the way in which countries are sorted and their inflation risk premium. According to the slope carry, we must take a long position in countries with relatively steeper yield curves. When expected inflation is below average, this sorting results in investing in countries with high exposure to inflation risk. Since investing in countries that load more on global expected inflation commands a larger risk premium, the slope carry must pay positive average returns. In our baseline calibration, the slope carry delivers an average excess return of 7.65% post-2008, in sharp contrast with its nearly zero unconditional average.

By no arbitrage, the risk premium of the slope carry strategy is tightly related to the entropy of the permanent component of the stochastic discount factors of the countries in the extreme slope-sorted portfolios (Lustig et al., 2019b). In our model, this entropy is constant at the country-level, but heterogenous in the cross-section. As a result, the entropy at the portfolio-level is time-varying if the portfolio composition changes over time. We show that this is the case in the pre- and post-2008 samples of our study.

To discipline our calibration, we use OECD data on expected GDP growth rates and inflation for the 10 countries with the most traded currencies in the world. We construct measures of the global expected GDP growth rate and inflation as the cross-sectional average across all 10 countries' expectations. We document that countries display a substantial degree of heterogeneity in terms of their exposures to these global expectations by running regressions of each country's expected GDP growth rate and inflation on their global counterparts.

In particular, countries like Australia and New Zealand, which are commonly featured in the long leg of the traditional carry trade strategy, have very low exposures to the global expected GDP growth rate, whereas countries like Japan, which represent a typical funding currency in the traditional carry trade, feature a substantially higher degree of exposure to this source of risk. This confirms the findings of Colacito et al. (2018), which are obtained using the projection of GDP growth rates onto lagged values of price–dividend ratios.

We also find that countries such as the United Kingdom and Sweden have some of the largest exposures to global expected inflation. According to our model, the long-term bonds of these countries should command a substantial inflation risk premium, and their term structures of interest rates should be steeper (flatter) during times of below (above) average global expected inflation. This helps us rationalize our empirical findings concerning the slope carry excess return.

We complete our analysis by studying an extended version of our model featuring both an intertemporal elasticity greater than one and a global demand shock. In this setting, all of our main results are preserved and the global inflation news shocks explain a moderate share of the variance of the local yields, consistent with Duffee (2018).

Related literature. Our analysis relates currency risk and equilibrium exchange rates to macroeconomic factors and country-level characteristics (see, among others, Lustig et al., 2011, 2014, Bansal and Shaliastovich, 2013, Lustig and Richmond, 2019, Mueller et al., 2017, Sandulescu et al., 2020, and Zviadadze, 2017). Della Corte et al. (2009), Della Corte et al. (2011), Della Corte et al. (2016a) study the empirical behavior of spot and forward exchange rates. Hassan (2013), Hassan et al. (2015, 2016), Heyerdahl-Larsen (2015), Jiang (2019), Stathopoulos (2017), Richmond (2019), and Richmond and Jiang (2020) build equilibrium models of currency risk and relate them to country size, fiscal policy, habit formation, and trade network. Finally, Della Corte et al. (2016b), Koijen and Yogo (2019), Pavlova and Rigobon (2007, 2010, 2013), Lilley et al. (2022) study the equilibrium formation of exchange rates and how it relates to international capital flows.

On the one hand, we differ from prior studies for our attention to heterogenous exposure to global inflation risk and its implication for the concealed slope carry. On the other hand, our benchmark model with heterogeneous exposure to growth and inflation news is consistent with Verdelhan (2018), as it enables global long-run shocks to contribute to bilateral exchange rate variance. Our focus on large infrequent changes in global expected growth rate and inflation is related to work on rare disasters (Barro, 2006, Gabaix, 2012, and Gourio, 2012) and its applications to international finance (see, for example, Gourio et al., 2014b, Farhi et al., 2015, and Chernov et al., 2018).

Borri and Shakhnov (2021) document that the slope carry is different from zero in the cross section of emerging countries. We document variation of the slope carry in the time series even when focusing on developed countries. In addition, in our model we decouple heterogenous exposure to global inflation news from heterogenous exposure to global growth news.

Several articles have documented limitations of the long-run risks model in a one-country setting (see, for example, Le and Singleton, 2010 and Beeler and Campbell, 2012). In our analysis, we document that while our complete-markets framework goes a long way in accounting for the international dynamics of asset prices and quantities, it does not fully replicate the cross section. Furthermore, our model abstracts away from country-specific news shocks, which may be relevant to obtain a more accurate matching of moments pertaining to the distribution of asset prices and quantities in the cross-section of countries.

Our paper also relates to the literature on inflation risk and its link to the real and nominal term structure of interest rates (see, among others, Piazzesi and Schneider, 2005, Wachter, 2006 Bansal and Shaliastovich, 2013, Song, 2017). In our analysis, we document the presence of heterogenous exposure to global inflation risk and study its impact on the dynamics of currency risk premia.

The introduction of frictions (see, for example, Gabaix and Maggiori, 2015, Maggiori, 2017; Maggiori et al., 2020; Schreger and Du, 2016;Froot and Stein, 1991, Ready et al., 2017b,a; Farhi and Werning, 2014; Lustig and Verdelhan, 2018; Zhang, 2020; Du et al., 2020; Caballero et al., 2008; Gopinath et al., 2020; Kalemi-Ozcan et al., 2020; Avdjiev et al., 2020 and Bakshi et al., 2017) may be important to (i) resolve these limitations, and (ii) address the empirical link with international capital flows (Froot and Ramadorai, 2005, Gourinchas and Rey, 2007, Gourio et al., 2014a, Coppola et al., 2020).

Organization of the paper. The paper is organized as follows. Section 2 reports our empirical evidence concerning the heterogeneous exposure to global expected GDP growth and inflation in G10 countries. In Section 3 we present our economic model and its equilibrium conditions. Section 4 presents our main simulation results. Section 5 provides empirical and model-related extensions. Finally, Section 6 concludes.

2. Empirical analysis

In this section, we show our main empirical results and introduce the moments that we replicate in our international macro-finance equilibrium model.

2.1. Preliminaries and notation

Data. We obtain monthly sovereign bond yield data for Australia, Canada, Germany, Japan, New Zealand, Norway, Sweden, Switzerland, United Kingdom and United States. In what follows, we will refer to these countries as G10 countries. When possible, all yields data are collected from Refinitiv Eikon Datastream from January 1995 through December 2020. The set of maturities for each country is reported in Appendix A.1. Exchange rates relative to the US Dollar are also obtained from Refinitiv Eikon for the same sample period (see Internet Appendix).

We also collect data on the forecasts of real GDP growth and inflation for the same set of countries. The source for these data is the website of the Organisation for Economic Co-operation and Development (henceforth OECD). For GDP forecasts, the sample starts in 1961 for all countries, except for Germany (starting year: 1992), New Zealand (starting year: 1971), and Switzerland (starting year: 1966). For inflation forecasts, our sample starts in 1961 for all countries, except for Canada (starting year: 1993), Germany (starting year: 1996), and UK (starting year: 1991). A full description of the dataset is reported in the Internet Appendix.

Notation. Let $P^m_{i,t}$ denote the price of a discount bond of maturity m in country i at date t. Let $R^h_{i,m,t}$ denote the date t gross holding period return associated to holding a bond of country i, maturity m for h periods, that is

$$R^h_{i,m,t} = \frac{P^{m-h}_{i,t}}{P^m_{i,t-h}}.$$

We shall denote as $r^h_{i,m,t}$ the logarithm of $R^h_{i,m,t}$. Let $E_{k,i,t}$ ($\Delta e_{k,i,t}$) denote the value (the natural logarithmic growth rate) of the currency of country i in units of the currency of country k at time t.

We denote as $RFX^n_{i,t}$ the one-month return on a strategy that is short the US 3-month bond and long the n-month bond of country i:

$$\log RFX^n_{i,t} = \left(r^1_{i,n,t} + \Delta e_{us,i,t}\right) - r^1_{us,3,t},$$

where $r^1_{i,n,t}$ is the date t 1-month log-return of investing in the n-month bond of country i, and $\Delta e_{us,i,t}$ is the date t log-growth rate of the exchange rate of currency i relative to the US Dollar.

Table 1
Traditional Carry. The table reports the excess returns associated to borrowing at the 3 months interest rate of the US and investing in 3 months bonds of a GDP-weighted portfolio of countries with low (1), medium (2), and high (3) interest rates. The column label "3-1" reports the average return from being long portfolio 3 and short portfolio 1. Portfolios are rebalanced every month. Returns are in gross units. The analysis is conducted over three samples: 1/1995-12/2020 ("Whole sample"), 1/1995-7/2008 ("Pre-08/2008"), and 8/2008-12/2020 ("Post-08/2008"). Numbers in square brackets denote standard errors. Numbers in parentheses refer to the frequency with which a country belongs to a specific portfolio.

	1 (Low)	2	3 (High)	3-1 (High–Low)
Whole Sample				
Mean	−1.99	0.34	3.22	5.21***
				[1.92]
Sharpe Ratio	−0.24	0.04	0.32	0.53
Pre-08/2008				
Mean	−3.37	2.01	5.59	8.96***
				[2.47]
Sharpe Ratio	−0.37	0.29	0.76	0.99
Recurrent countries:	Jpn (100%)	Can (77%)	NZ (91%)	
	Swi (100%)	Swe (62%)	Aus (90%)	
	Ger (40%)	UK (34%)	UK (66%)	
Post-08/2008				
Mean	−0.48	−1.47	0.64	1.12
				[1.39]
Sharpe Ratio	−0.06	−0.18	0.05	0.11
Recurrent countries:	Swi (95%)	UK (95%)	NZ (100%)	
	Ger (82%)	Can (59%)	Aus (91%)	
	Jpn (55%)	Swe (47%)	Nor (78%)	

Table 2
Slope Carry. The table reports the excess returns associated to borrowing at the 3 months interest rate of the US and investing in the 10 year bonds of a GDP-weighted portfolio of countries with flatter (1), medium (2), and steeper (3) yield curves. The column label "3-1" reports the average return from being long portfolio 3 and short portfolio 1. Portfolios are rebalanced every month. Returns are in gross units. The analysis is conducted over three samples: 1/1995-12/2020 ("Whole sample"), 1/1995-7/2008 ("Pre-08/2008"), and 8/2008-12/2020 ("Post-08/2008"). Numbers in square brackets denote standard errors. Numbers in parentheses refer to the frequency with which a country belongs to a specific portfolio.

	1 (Flatter)	2	3 (Steeper)	3-1 (Steep-flat)
Whole Sample				
Mean	4.69	2.22	6.58	1.89
				[2.20]
Sharpe Ratio	0.46	0.22	0.69	0.20
Pre-08/2008				
Mean	6.55	3.95	5.80	−0.75
				[2.20]
Sharpe Ratio	0.66	0.38	0.53	−0.07
Recurrent countries:	UK (83%)	Ger (55%)	Swe (59%)	
	NZ (76%)	Swi (43%)	Jpn (56%)	
	Aus (71%)	Jpn (42%)	Swi (49%)	
Post-08/2008				
Mean	2.67	0.34	7.42	4.75***
				[2.08]
Sharpe Ratio	0.26	0.03	0.88	0.51
Recurrent countries:	Jpn (75%)	Swi (53%)	UK (62%)	
	Aus (67%)	Ger (40%)	Ger (53%)	
	Nor (41%)	Can (40%)	Swe (50%)	

2.2. Portfolio returns

Portfolios sorted on the yield curve level. At the beginning of each month, we sort countries based on the yield of their 3-month bond. Excluding the US, we group countries into three portfolios, where portfolio 1 (3) contains the three countries with the lowest (highest) level of the interest rate. We then compute the one-month return of a GDP-weighted portfolio that is short the US 3-month bond and long each of the 3-month bonds in each portfolio p:

$$\log RFX^{3}_{p,t} = \sum_{i\in p} w^{p}_{i,t} \cdot \log RFX^{3}_{i,t}, \quad \forall p \in \{P1, P2, P3\}$$

where the weights are defined as $w^{p}_{i,t} = GDP_i / \left(\sum_{i\in p} GDP_i\right)$ and GDP_i is the average GDP of country i.

Portfolios sorted on the yield curve slope. Similarly, at the beginning of each month, we sort countries based on the spread between the 120-month (i.e. 10 year) yield and the 3-month yield (henceforth the slope of the yield curve). We then form portfolios by sorting countries on the slope of their yield curve, where portfolio 1 has flatter yield curves, and portfolio 3 has steeper yield curves. For each portfolio, we compute the one-month GDP-weighted return for the trading strategy that is short the US 3-month bond and is long each of the 120-month bonds in portfolio p for one month:

$$\log RFX^{120}_{p,t} = \sum_{i\in p} w^{p}_{i,t} \cdot \log\left(RFX^{120}_{i,t}\right), \quad \forall p \in \{P1, P2, P3\}.$$

Carry Excess Returns. We report the average returns for portfolios sorted on the level and slope of the yield curve in Tables 1 and 2, respectively. The top panel of Table 1 refers to the currency excess returns over our whole sample and shows that their average increases across interest rate-sorted portfolios as documented, among others, by Lustig et al. (2011). The excess return of a strategy that is long the high interest rate portfolio and short the low interest rate portfolio is around 5% and it is highly statistically significant. In what follows, we shall refer to this strategy as the "traditional carry".

These results stand in sharp contrast with the returns associated to the portfolios sorted on the slope of the yield curve. Indeed, in the top panel of Table 2 we show that the currency excess returns of the two extreme portfolios are very similar. As a result, a strategy that is long the portfolio of currencies with steeper yield curves and short the portfolio of currencies with flatter yield curves earns an excess return that is not statistically different from zero. This confirms the findings of Lustig et al. (2019b). Since the sorting of this portfolio strategy is based on the slope of the term structure of interest rates, in what follows we will refer to this strategy as the "slope carry".

The relevance of subsamples. We further investigate these results by analyzing our pre- and post-August 2008 sub-samples. In Internet Appendix C, we demonstrate that our results are robust to the specific choice of the sub-periods, that is, splitting our sample in August 2008 is not critical for our findings.

The results reported in the mid and bottom panels of Table 1 confirm the presence of a profitable traditional carry trade strategy both before and after our break. However, this excess return is sizeably smaller in the second part of the sample, a finding that is consistent with the sharp decline in interest rates in the aftermath of the global financial crisis. A visual inspection of the most recurrent currencies in each portfolio reveals a strong degree of similarity across the two sub-samples, with Japan and Australia typically appearing in the extreme portfolios for this strategy.

We find very different results when we focus on portfolios of countries sorted according to their yield curve slope. In the first part of the sample, the average currency excess returns in portfolios 1 to 3 are very similar to each other (see mid-panel of Table 2). Hence, a high–low investment strategy results in a excess return which is very close to zero (−75 basis points). The picture changes dramatically in the later part of the sample: in this period, a high–low strategy delivers a positive average excess return of almost 500 basis points (bottom panel of Table 2). Equivalently, the null excess return in the full sample is the compositional outcome of offsetting excess returns in the two sub-samples. In addition, looking at the cumulative return of the slope carry

Fig. 2. Cumulative Return of the Slope Carry. The figure depicts the cumulative return of a slope carry investment strategy; that is, a strategy long in countries with steep yield curve and short in countries with flat yield curve. The initial value of this strategy is normalized to 1.

depicted in Fig. 2, we note that the gains from the slope carry have been obtained throughout the post-2008 subsample, and not just in the immediate aftermath of the financial crisis. In the next section, we note that this strategy has produced strong gains exactly in periods of subdued global inflation.

Focusing on the composition of these portfolios, we note that Australia is typically associated with portfolio 1, as it is consistently one of the countries with a flat yield curve, whereas Japan and UK switch between the two extreme portfolios pre- and post-break. Namely, UK (Japan) used to be a flatter- (steeper-) yield curve country pre-break and then it became a steeper- (flatter-) yield curve country post-break. These changes in the composition of our portfolios are a key driver of the slope carry. If we were to form our slope carry in, for example, January or July 2008 and hold the portfolios composition constant, the resulting average excess returns in the post-2008 sample would be -2.89% and −2.94%, respectively. Since these switches are not present when we form portfolios according to the level of the yield curve, they represent an important phenomenon that we take seriously and that we rationalize in the next section by looking at heterogeneous exposure to expected inflation.

The role of exchange rates. In Table 3, we report the average depreciation rate of the exchange rates comprised in both the traditional and slope carry. This exercise enables us to study the composition of our excess returns, that is, we can distinguish the portion of each carry trade that is due to currency adjustments as opposed to that stemming from bond returns. For the traditional carry, we note that the exchange rate contribution has been very modest and not statistically significant. More specifically, the exchange rate contribution is positive over our full sample, but negative post-2008. For the slope carry, instead, the contribution is always positive and sizeable post-2008. These facts represent novel empirical evidence that (i) can be explained by our equilibrium model, and (ii) should be taken into account also in future research.

Table 3
The Role of Exchange Rates. The table reports the excess returns associated to borrowing at the 3 months interest rate of the US and investing in the 10 year bonds of a GDP-weighted portfolio of countries with flatter (1), medium (2), and steeper (3) yield curves. The column label "3-1" reports the average return from being long portfolio 3 and short portfolio 1. Portfolios are rebalanced every month. Returns are in gross units. The analysis is conducted over three samples: 1/1995-12/2020 ("Whole sample"), 1/1995-7/2008 ("Pre-08/2008"), and 8/2008-12/2020 ("Post-08/2008"). Numbers in square brackets denote standard errors. Numbers in parentheses refer to the frequency with which a country belongs to a specific portfolio.

	Traditional carry		Slope carry	
	Whole	Post-08	Whole	Post-08
$E(\Delta FX)$ P3 - $E(\Delta FX)$ P1	1.39	−1.53	0.92	3.40
	(1.83)	(1.28)	(2.34)	(2.26)

Robustness. In Appendix C we conduct a series of robustness checks for our empirical evidence. Specifically we document that our main results are very similar to what we reported in preceding sub-sections when (i) using log returns as opposed to gross returns, (ii) excluding the most extreme 10% of the distribution of returns, (iii) changing the break-point to coincide with the end of calendar year 2007, (iv) using Bloomberg's zero coupon yields derived by stripping the par coupon curve, and (v) using equal weights (as opposed to GDP weights) for the construction of the three portfolios. We did not include an analysis using inflation indexed sovereign bonds, due to the limited set of countries for which this type of security is available.

2.3. Local and global expectations

Global expectations over time. We construct annual expectations for global inflation ($E_t\left[\pi_{G10,t+1}\right]$) and global real GDP growth ($E_t\left[\Delta y_{G10,t+1}\right]$) as the GDP-weighted cross-sectional averages across the 10 countries in our sample. When a country has a missing observation, we drop it for that year, and we rescale the GDP weights over the remaining countries.

Fig. 3 reports the time series of global expectations over the same period that we used in our portfolio analysis. We note the following two important results. First, both GDP and inflation forecasts experienced a sizeable decline in 2009 in the aftermath of the global financial crisis. In theory, this fact is consistent with the realization of a negative long-run shock to global demand.

Second, if we split the sample into two parts, as we did in our portfolio analysis, the average inflation and GDP growth rate are lower

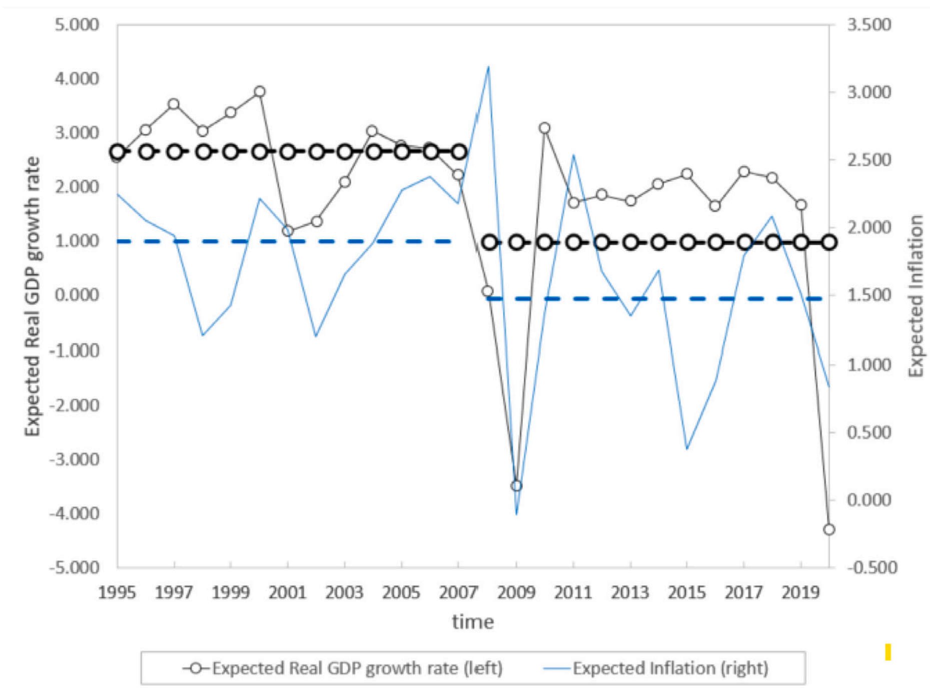


Fig. 3. Expected Global Inflation and GDP growth rate. The figure reports the expected global GDP growth rate ($E_t\left[\Delta y_{G10,t+1}\right]$) and inflation ($E_t\left[\pi_{G10,t+1}\right]$) computed as the cross-sectional GDP-weighted average across our G10 countries. The horizontal dashed line (with circles) represents the average expected inflation (GDP growth rate) before and after 2008..

post-break. Indeed the average inflation and real GDP growth forecasts are 1.89 and 2.67, respectively, in the period going from 1995 to 2007, and sharply decline to 1.48 and 0.98 in the sub-sample starting in 2008. The drop is present even if we remove 2009 and 2020, i.e., the years of the sharpest decline for both forecasts (see Table A.6 in Internet Appendix).

Sensitivity of local expectations to global expectations. For each country in our cross section, we estimate the sensitivity of country-specific expected GDP growth and expected inflation with respect to their global counterparts. Specifically, we estimate the following regressions:

$$E_t\left[\Delta y_{i,t+1}\right] = \mu_{i,y} + \beta_{i,y}\cdot E_t\left[\Delta y_{G10,t+1}\right] + \varepsilon_{i,t} \tag{1}$$

$$E_t\left[\pi_{i,t+1}\right] = \mu_{i,\pi} + \beta_{i,\pi}\cdot E_t\left[\pi_{G10,t+1}\right] + \varepsilon_{i,t}, \tag{2}$$

for $i \in G10$ and where $E_t\left[\Delta y_{i,t+1}\right]$ and $E_t\left[\pi_{i,t+1}\right]$ denote the conditional expectations of GDP growth and inflation for each of the 10 countries, respectively. We conduct the estimations on the longest samples available (1961–2020 for GDP growth rate regressions;1991–2020 for inflation regressions) and report our results in Table 4.

The estimates of the exposures to expected GDP growth document a substantial degree of heterogeneity in the cross section of countries. In particular, we note that countries' exposures to expected growth tend to line up with the typical sorting of countries according to the level of their respective yield curves. Indeed, Japan and Australia are at opposite ends of the spectrum in terms of their exposures to expected real growth. This result confirms the findings of Colacito et al. (2018), but it is obtained in a different way: we use expectations data as opposed to extracting expected global growth from global equity valuations.

In the bottom portion of Table 4, we also show the existence of a substantial degree of cross-sectional heterogeneity with respect to global expected inflation shocks, although the sorting of countries according to $\beta_{i,\pi}$ seems to be imperfectly correlated with the sorting according to $\beta_{i,y}$. Indeed, while Australia, New Zealand, and Norway are featured on the low end of the spectrum for both types of exposures, the sorting of the remaining countries appears to be more inverted.

Table 4
Expectations Exposures. Exposures of each country's expected GDP growth rate and expected inflation to GDP weighted expectations of GDP and inflation. The first panel reports the estimates of $\beta_{i,y}$ in Eq. (1). The second panel reports the estimates of $\beta_{i,\pi}$ in Eq. (2). The numbers in parentheses underneath the estimated coefficients are standard errors.

Exposures to expected GDP growth										
	NZL	NOR	AUS	SWI	SWE	UK	US	CAN	GER	JPN
$\beta_{i,y}$	0.353	0.492	0.532	0.541	0.606	0.908	0.923	0.976	0.997	1.422
	(0.174)	(0.098)	(0.106)	(0.067)	(0.152)	(0.159)	(0.055)	(0.079)	(0.117)	(0.191)

Exposures to Expected Inflation										
	NOR	**NZL**	**AUS**	**CAN**	**JPN**	**GER**	**US**	**UK**	**SWI**	**SWE**
$\beta_{i,\pi}$	0.233	0.568	0.591	0.627	0.670	0.821	1.107	1.240	1.454	1.762
	(0.125)	(0.218)	(0.148)	(0.087)	(0.186)	(0.066)	(0.079)	(0.266)	(0.242)	(0.226)

In particular, we note that Japan (the country with the largest estimated exposure to real growth) has a relatively low inflation exposure, while the UK, Sweden, and Switzerland (which have a moderate real growth exposure) are the three countries with the largest inflation exposure. The imperfect link between exposure to global GDP growth and exposure to global inflation is relevant because it confirms that heterogeneous exposure to inflation news shocks is a distinct and novel dimension that can be relevant in understanding the cross section of currency returns. In Appendix D, we show that this heterogeneity can be interpreted as heterogeneity in Taylor's rules in a simple New-Keynesian model.

We corroborate this point by studying the statistical significance of the differences in exposures of the three most recurrent countries in the extreme portfolios formed for our slope carry strategy. Specifically, we focus on Australia, Japan, and UK. Our results are reported in Table 5. We note that the exposure of expected GDP growth rates is larger for Japan compared to Australia and the United Kingdom (left panel). Indeed, a t-test for the null that $\beta_{Japan,y} = \beta_{Australia,y}$ and that $\beta_{Japan,y} = \beta_{UK,y}$ yields t-statistics equal to 5.81 and 1.69, respectively. When we repeat the same exercise for expected inflation, we note

Table 5
Differences of Expectations Exposures. This table reports differences of exposures of expected GDP growth rate (left) and expected inflation (right) between Australia, Japan, and UK. Each entry represents the difference between the exposures of the country in each column and the country in the row. Numbers in parentheses are standard errors. One, two, and three stars represent statistical significance at the 10%, 5%, and 1% levels, respectively.

	Expected GDP growth				*Expected inflation*		
	AUS	JPN	UK		AUS	JPN	UK
AUS	–	0.889***	0.376**	**AUS**	–	0.079	0.649**
		(0.153)	(0.159)			(0.211)	(0.276)
JPN		–	−0.514*	**JPN**		–	0.570**
			(0.304)				(0.230)
UK			–	**UK**			–

that the ranking of countries' sensitivities is different (right panel). Specifically, the sensitivity of the UK's expected inflation is the largest; a t-test for the null that $\beta_{UK,\pi} = \beta_{Australia,\pi}$ and that $\beta_{UK,\pi} = \beta_{Japan,\pi}$ yields t-statistics equal to 2.35 and 2.48, respectively.

In our theoretical model, we explain the connection between these estimated exposures to expected GDP growth and inflation and the risk-premia on the traditional and slope carries. In particular, we document that the excess return on the traditional carry reflects exposures to expected GDP growth (β_y), while the excess return on the slope carry is primarily determined by exposures to expected inflation (β_π).

Since the composition of the traditional carry portfolios have remained largely unchanged before and after the break, the traditional carry risk premium is a reflection of nearly unchanged portfolio-level exposures to expected growth and inflation news shocks. This explains why the excess returns on the traditional carry have remained positive across the two regimes.

Conversely, the large swing in expected global inflation and growth that we observe post-break is associated with a large redistribution of countries across our slope-sorted portfolios. This compositional change has caused a drastic change in the portfolio-level exposures of the top and bottom portfolios of the slope carry to growth and inflation risk. Specifically, the UK has moved from portfolio 1 to portfolio 3, and Japan has moved in the opposite direction. Through the lens of our model, inflation risk has a positive market price of risk and hence the post-break reallocation of high-β_π (low-β_π) countries to portfolio 3 (1) causes the slope carry to earn a positive risk premium.

Robustness. In Table A.2 of Appendix A.3 we estimate the inflation exposures using alternative models to forecast inflation based on Stock and Watson (2008). The results are highly correlated with those reported in the bottom panel of Table 4. Additionally, we also conduct the analysis using an alternative set of inflation forecasts based on all analysts available in Bloomberg. Due to data limitations (the sample starts in 2008 for most countries), we focus on quarterly forecast horizons. The rankings that we obtain from this exercise confirm that the UK is a high inflation exposure country, while Australia and Japan are on the opposite end of the spectrum. Finally, in Appendix A.5 we show that by augmenting equation (1) and (2) with the inclusion of both the global expectation of GDP growth and the global expectation of inflation, we obtain estimated exposures that are very close to those reported in Table 4.

3. The model

In this section we present an equilibrium model that can explain our empirical findings by taking into account the documented heterogeneous exposure to global real growth and inflation. While our model abstracts away from endogenous trade in the consumption goods market (Colacito et al., 2018), it constitutes a useful benchmark in the international finance literature, and it has been applied to the analysis of exchange rate volatility (Colacito and Croce, 2011a), international term structure of interest rates (Bansal and Shaliastovich, 2013), and gravity in exchange rate fluctuations (Lustig and Richmond, 2019), among others. We follow the literature and focus on this setup due to its ability to deliver closed-form solutions for all the objects of interest, and leave a fully fledged general equilibrium analysis to future research.

3.1. Setting

Preferences. The economy consists of N countries, indexed by $i \in \{1, 2, \dots, N\}$. Each country is populated by a representative agent with recursive preferences:

$$U_{i,t} = (1-\delta)\log C_{i,t} + \delta\theta \log E_t \exp\left\{\frac{U_{i,t+1}}{\theta}\right\},$$

where γ denotes the risk aversion coefficient, δ is the subjective discount factor, and $\theta = 1/(1-\gamma)$. These preferences correspond to Epstein and Zin (1989b) preferences for the case of unit intertemporal elasticity of substitution (henceforth IES). Throughout our analysis, we will assume that $\gamma > 1$, which implies that $\theta < 0$. Under this assumption, news shocks are priced.

Real Consumption and Inflation. Let $x_{c,t}$ and $x_{\pi,t}$ denote time-varying components in expected global consumption growth and inflation, respectively. We model these components as follows:

$$\underbrace{\begin{bmatrix} x_{\pi,t} \\ x_{c,t} \end{bmatrix}}_{x_t} = \underbrace{\begin{bmatrix} \rho_\pi & 0 \\ \rho_{c\pi} & \rho_c \end{bmatrix}}_{K} \cdot \begin{bmatrix} x_{\pi,t-1} \\ x_{c,t-1} \end{bmatrix} + \underbrace{\begin{bmatrix} \sigma_{x,\pi} & 0 \\ 0 & \sigma_{x,c} \end{bmatrix}}_{\Sigma} \begin{bmatrix} \varepsilon_{\pi,t} \\ \varepsilon_{c,t} \end{bmatrix}, \tag{3}$$

in which $\varepsilon_{\pi,t}$ and $\varepsilon_{c,t}$ are iid $N(0,1)$ news shocks. Our specification allows expected inflation to be correlated with expected growth according to the coefficient $\rho_{c\pi}$. We can think of $\rho_{c\pi} < 0$ as capturing the relative dominance of global aggregate supply shocks relative to global demand shocks.[1] The parameter ρ_c (ρ_π) determines the half-life of growth (inflation) news shocks.

At the country level, the log-growth rate of consumption is given by

$$\begin{aligned} \Delta c_{i,t+1} &= \mu_c^i + \beta_i^c x_{c,t} + \sigma_c \eta_{i,t+1}^c \\ \pi_{i,t+1} &= \mu_\pi^i + \beta_i^\pi x_{\pi,t} + \sigma_\pi \eta_{i,t+1}^\pi, \end{aligned}$$

where β_i^c and β_i^π capture country-specific heterogeneous exposure to news shocks about global consumption growth and inflation, and the shocks $\eta_{i,t+1}^c$ ($\eta_{i,t+1}^\pi$) are distributed as standard normals. These shocks represent short-run growth (inflation) risk and are independent within and across each country.

We detail our calibration in the next section. Here we note two points. First, we think of the base country in our cross section as having $\beta_i^c = \beta_i^\pi = 1$. Second, we allow for country-specific growth and inflation rates, μ_c^i and μ_π^i, in order to have a properly defined cross section of short-term risk free rates. This is an innocuous assumption that we could relax either by having country-specific discount rates δ^i or by modeling very persistent deviations from a common global stochastic trend (as in Colacito et al., 2018).

Financial markets. We assume that there is a complete set of state and date contingent bonds that each investor has access to in frictionless financial markets at each point in time.

[1] We analyze an endowment economy which features a convolution of both demand and supply shocks. Our economy with exogenous supply and inflation processes can be interpreted as a reduced form representation of a richer structural model of demand and supply, in which the correlation is the endogenous outcome of more fundamental forces that are not present in our model.

3.2. Equilibrium pricing

In what follows, we report the analytical results that are essential to interpret the implications of our model. Detailed derivations are available in Appendices E and F.

Real SDF. Each country i has the following real stochastic discount factor:

$$m^{real}_{i,t+1} = \bar{m}^{real}_i - \beta^i_c x_{c,t} - k^i_{\epsilon c}\sigma_{x,c}\epsilon_{c,t+1} + k^i_{\epsilon\pi}\sigma_{x,\pi}\epsilon_{\pi,t+1} - \gamma\sigma_c\eta^c_{i,t+1},$$

where the unconditional level of the real log-SDF is

$$\bar{m}^{real}_i = \log\delta - \frac{1}{2}(1-\gamma)^2\sigma^2_c - \mu^i_c - \frac{1}{2}\left[(k^i_{\epsilon c}\sigma_{x,c})^2 + (k_{\epsilon\pi}\sigma_{x,\pi})^2\right],$$

and

$$\begin{aligned}
\mu^i_c &= \overline{\mu}_c + \overline{\mu}_c(1-\beta^i_c), \\
k^i_{\epsilon c} &= (\gamma-1)\beta^i_c\left(\frac{\delta}{1-\delta\rho_c}\right) > 0, \\
k^i_{\epsilon\pi} &= -\rho_{c\pi}k^i_{\epsilon c}\left(\frac{\delta}{1-\delta\rho_\pi}\right).
\end{aligned} \tag{4}$$

All of the heterogeneity across countries derives from their heterogeneous exposure to real growth news shocks, β^i_c. Real expected growth can change either because of changes in expected global growth ($\epsilon_{c,t+1}$ shocks) or indirectly because of the effects of expected inflation on expected global growth ($\epsilon_{\pi,t+1}$ shocks).

When $\rho_{c\pi} < 0$, news to global inflation and news to real growth determine movements of the stochastic discount factors in opposite directions. Indeed, the third equation in (4) shows that when $\rho_{c\pi} < 0$ the composite coefficient $k^i_{\epsilon\pi}$ is larger than zero, thus implying that positive shocks to expected global inflation cause the marginal utility to increase. The opposite occurs for global growth news shocks, that is, the representative agent marginal utility decreases when $\epsilon_{c,t+1} > 0$. The market price of short-run growth shocks, $\eta^c_{i,t+1}$, is assumed to be homogeneous across countries.

We model μ^i_c as decreasing in β^i_c so that country-specific unconditional average real risk-free rates,

$$\bar{r}^i = \mu^i_c - \log\delta - \left(\frac{1}{2} - \frac{1}{\theta}\right)\sigma^2_c,$$

are decreasing in β^i_c, holding everything else equal (see first equation in (4)). This is a reduced form way to ensure that low real risk-free rate countries are also high-β^i_c countries, consistent with the analysis of Colacito et al. (2018).

Nominal SDF. In each country the nominal stochastic discount factor, $m_{i,t+1}$, is $m^{real}_{i,t+1} - \pi_{i,t+1}$. As a result, we obtain:

$$m_{i,t+1} = \bar{m}_i - \beta^i_c x_{c,t} - \beta^i_\pi x_{\pi,t} - k^i_{\epsilon c}\sigma_{x,c}\epsilon_{c,t+1} + k^i_{\epsilon\pi}\sigma_{x,\pi}\epsilon_{\pi,t+1} - \gamma\sigma_c\eta^c_{i,t+1} - \sigma_\pi\eta^\pi_{i,t+1}, \tag{5}$$

where $\bar{m}_i = \bar{m}^{real}_i - \mu^i_\pi$ and where we specify

$$\mu^i_\pi = \overline{\mu}_\pi - \overline{\mu}_\pi(1-\beta^i_\pi), \tag{6}$$

in order to make high-average inflation countries also high-β^i_π countries, as in our data. Even though agents in each country are heterogeneous with respect to global inflation news shocks, they are identical when it comes to pricing short-run inflation shocks ($\eta_{\pi,t+1}$). This assumption grants parsimony without loss of generality for our results. Given this log-linear representation of our SDF, our term structure inherits standard properties common to all affine log-normal models.

Exchange rates and decomposition of the nominal SDF. Since financial markets are assumed to be complete, the log-exchange rates between the currencies of any two countries i and j are given by the difference of their respective stochastic discount factors:

$$\Delta e_{ij,t+1} = m_{j,t+1} - m_{i,t+1}.$$

We analyze the properties of our currency strategies by decomposing the SDFs into a permanent and a transitory component, as in Chabi-Yo and Colacito (2019), Lustig et al. (2019b), and Sandulescu et al. (2020). Specifically, we solve the eigenfunction problem of Alvarez and Jermann (2005) and Hansen (2012) to obtain a permanent and transitory component of the log-stochastic discount factor of each country such that:

$$m_{i,t+1} = m^P_{i,t+1} + m^T_{i,t+1}.$$

The permanent and transitory components are

$$\begin{aligned}
m^P_{i,t+1} = \bar{m}^P_i &- \beta^i_c k^{i,P}_{\epsilon c}\sigma_{xc}\epsilon_{c,t+1} - \left(\frac{\beta^i_\pi}{1-\rho_\pi} - \beta^i_c k^{i,P}_{\epsilon\pi}\right)\sigma_{x\pi}\epsilon_{\pi,t+1} \\
&- \gamma\sigma_c\eta^c_{i,t+1} - \sigma_\pi\eta^\pi_{i,t+1},
\end{aligned}$$

and

$$\begin{aligned}
m^T_{i,t+1} = \bar{m}^T_i &- \beta^i_c x_{c,t} - \beta^i_\pi x_{\pi,t} + \frac{\beta^i_c}{1-\rho_c}\sigma_{xc}\epsilon_{c,t+1} \\
&+ \left(\beta^i_\pi + \beta^i_c\cdot\frac{\rho_{c\pi}}{1-\rho_c}\right)\frac{\sigma_{x\pi}}{1-\rho_\pi}\epsilon_{\pi,t+1},
\end{aligned}$$

respectively, and the composite parameters are defined as

$$k^{i,P}_{\epsilon c} = k^i_{\epsilon c} + \frac{1}{1-\rho_c}, \quad k^{i,P}_{\epsilon\pi} = k^i_{\epsilon\pi} + \frac{-\rho_{c\pi}}{(1-\rho_\pi)(1-\rho_c)}.$$

When $\rho_{c\pi} < 0$, both $k^{i,P}_{\epsilon c}$ and $k^{i,P}_{\epsilon\pi}$ are positive. The intercepts $\bar{m}^P_i$ and $\bar{m}^T_i$ are defined in Appendix E.

Let $P^n_{i,t}$ denote the price of a nominal bond with maturity n in country i at time t. We use $hpr^\infty_{i,t+1}$ to denote the log-holding period return of a zero-coupon bond with infinite maturity in country i:

$$hpr^\infty_{i,t+1} := \lim_{n\to\infty}\log\left(\frac{P^{n-1}_{i,t+1}}{P^n_{i,t}}\right).$$

As in Alvarez and Jermann (2005), the transitory component $m^T_{i,t+1}$ is equivalent to the negative of the logarithm of the holding period return on an infinite maturity bond:

$$m^T_{i,t+1} = -hpr^\infty_{i,t+1}.$$

This means that when an investor in country j invests in the infinite maturity bond of country i, the exchange rate acts as a perfect hedge against the risk associated with $hpr^\infty_{i,t+1}$ since

$$\Delta e_{ji,t+1} = m_{i,t+1} - m_{j,t+1} = m^P_{i,t+1} - hpr^\infty_{i,t+1} - m_{j,t+1}. \tag{7}$$

Equivalently, the risk premium associated to this strategy reflects only the exposure to the permanent component of the SDF of country i.

3.3. Traditional carry

Sorting countries into portfolios. In the traditional carry strategy, countries are sorted according to their relative short-term interest rates. In our model, the logarithm of the nominal risk-free rate in each country is

$$r^i_{1,t} = \bar{r}^i + \beta^i_\pi x_{\pi,t} + \beta^i_c x_{c,t}, \tag{8}$$

where

$$\bar{r}^i = \left(\mu^i_c + \mu^i_\pi\right) - \log\delta - \left(\frac{1}{2} - \frac{1}{\theta}\right)\sigma^2_c - \frac{1}{2}\sigma^2_\pi.$$

Hence, the sorting of our countries is driven by both country-specific fixed effects, $\bar{r}^i$, and by the interaction of country-specific exposures with expectations about global real growth and inflation, $\beta^i_\pi x_{\pi,t} + \beta^i_c x_{c,t}$. In the data, the sorting of countries according to their short-term interest rate is very stable over time. In order to replicate this empirical fact, we calibrate our model so that the unconditional averages of the risk-free rates, $\bar{r}^i$, tend to dominate the relative sorting of the risk-free rates.

More specifically, if we consider country i and j, the unconditional interest rate differential depends on

$$\bar{r}^i - \bar{r}^j = \bar{\mu}_\pi \left[(\beta^i_\pi - \beta^j_\pi) - \frac{\bar{\mu}_c}{\bar{\mu}_\pi} (\beta^i_c - \beta^j_c) \right]. \tag{9}$$

Since in the data $\frac{\bar{\mu}_c}{\bar{\mu}_\pi} \approx 2$, heterogeneity across β_c's is quantitatively more important than that in β_π's. Therefore under the ergodic distribution implied by our model, high-β_c countries are typically low-interest rate countries.

Traditional carry excess returns. Let us use the index b to denote the base country, and normalize the base country's exposure to global growth to one, $\beta^b_c = 1$. The expected excess return of a strategy that is short the risk-free rate of the base country and long the short-term rate of country i is:

$$\begin{aligned} \log E_t \left[RFX^1_{i,t+1} \right] &= \log E_t \exp \left\{ -r^b_{1,t} + r^i_{1,t} + \Delta e_{bi,t+1} \right\} \\ &= V_t \left[m^b_{t+1} \right] - cov_t \left[m^b_{t+1}, m^i_{t+1} \right] \\ &= V_t \left[m^b_{t+1} \right] - \beta^i_c (k^2_{\epsilon c} \sigma^2_{xc} + k^2_{\epsilon\pi} \sigma^2_{x\pi}), \end{aligned} \tag{10}$$

where $k_{\epsilon c} = (\gamma - 1) \left(\frac{\delta}{1-\delta\rho_c} \right)$ and $k_{\epsilon\pi} = -\rho_{c\pi} k_{\epsilon c} \left(\frac{\delta}{1-\delta\rho_\pi} \right)$. Eq. (10) implies that all of the cross-sectional heterogeneity in risk premia is driven solely by β^i_c. In this case, β^i_π is irrelevant because news to global inflation are priced only through their disruptive effect on expected long-term growth (see $\beta^i_c k_{\epsilon\pi}$ in the equilibrium nominal SDF in Eq. (5)). Specifically, investing in high-β^i_c countries produces an insurance premium as the currency of the targeted country provides a hedge against adverse growth news shocks (Colacito et al., 2018).

Since a traditional carry strategy is long the currency of high-interest rate (**H**) countries (low-β_c countries, henceforth β^L_c) and short the currency of the low-interest rate (**L**) countries (high-β_c countries, henceforth β^H_c), the resulting traditional carry risk premium, $E[carry^T]$, is:

$$\begin{aligned} E[carry^T] &:= \log E_t \left[RFX^1_{\mathbf{H},t+1} \right] - \log E_t \left[RFX^1_{\mathbf{L},t+1} \right] \\ &= \left(\beta^H_c - \beta^L_c \right) \left[k^2_{\epsilon c} \sigma^2_{xc} + k^2_{\epsilon\pi} \sigma^2_{x\pi} \right]. \end{aligned} \tag{11}$$

The expression for the traditional carry risk premium in (11) specializes the findings of Lustig et al. (2011) to the economy that we analyze in this paper. It confirms that the currency premium reflects heterogeneous exposure to a global risk factor in the cross section of countries. In the context of our economy, the relevant source of heterogeneity is associated to the exposure to global real growth news shocks. In the next section, we document how the heterogeneous exposure to expected inflation shocks enables our model to explain the cross section of slope carry excess returns.

3.4. Slope carry

Sorting countries into portfolios. Based on the slope carry strategy, we sort countries according to the slope of their term structure of yields. Our model is affine and it features two state variables comprised in the vector x_t (see Eq. (3)). As a result, the yield on an n-period maturity bond is:

$$r^n_{i,t} = A^n_i + B^{n\prime}_i \cdot x_t,$$

where the coefficients A^n_i and $B^{n\prime}_i$ are consistent with no-arbitrage and are detailed in Appendix G.5.

We follow (Lustig et al., 2019b) and focus on the slope of the yield curve determined by the difference between the yields on the infinite maturity and on the one-period bonds in each country. By letting $n \to \infty$, it is possible to show that:

$$\lim_{n\to\infty} B^n_i = [0 \quad 0]$$

$$\lim_{n\to\infty} A^n_i = \bar{r}^i - \beta'_i (I-K)^{-1} \Sigma \left[\frac{\Sigma'}{2} \left[(I-K)^{-1} \right]' \beta_i + \Lambda_i \right],$$

that is, the yield on the infinite maturity bond is constant and equal to $r^\infty_i = \lim_{n\to\infty} A^n_i$. Combining this result with the equilibrium risk-free rate in Eq. (8), we obtain the slope of the yield curve in each country:

$$slope^\infty_{i,t} = \overline{slope}^\infty_i - \beta^i_c x_{c,t} - \beta^i_\pi x_{\pi,t},$$

where $\overline{slope}^\infty_i = -\beta'_i (I-K)^{-1} \Sigma \left[\Sigma' \left[(I-K)^{-1} \right]' \beta_i / 2 + \Lambda_i \right]$. The sorting of countries is again driven by both country-specific fixed effects, $\overline{slope}^\infty_i$, and by the interaction of country-specific exposures with transitory fluctuations in the expectations about global real growth and inflation, $\beta^i_\pi x_{\pi,t} + \beta^i_c x_{c,t}$. The negative sign in front of the transitory components refers to the fact that when expected growth (inflation) increases, the nominal short-term rate rises as well and the yield curve spread shrinks.

In contrast to the traditional carry strategy, sorting countries according to their relative yield curve's slope produces relevant reallocations across portfolios over time. In order to replicate this empirical fact, we calibrate our model so that the country-specific fixed effects are nearly irrelevant, that is, we have $\overline{slope}^\infty_i \approx \overline{slope}^\infty_j \quad \forall i, j$. Since the unconditional level of the yield curve slope is increasing in both β_π and β_c, countries featuring high (low) β_π and high (low) β_c tend to have similar unconditional slopes. We anticipate that this combination of sensitivity coefficients applies to both the data and our calibration.

Hence in our model the placement of countries in different slope-sorted portfolios depends mainly on $\beta^i_\pi x_{\pi,t} + \beta^i_c x_{c,t}$ for $i = 1, \ldots, 10$. We analyze the time behavior of this processes by means of simulations in Section 4.

Slope carry excess returns. The expected excess return of a strategy that is short the risk-free rate of base country b and long the infinite horizon bond of country i for one period is

$$\begin{aligned} \log E_t \left[RFX^\infty_{i,t+1} \right] &= \log E_t \exp \left\{ -r_{b,t} + hpr^\infty_{i,t+1} + \Delta e_{bi,t+1} \right\} \\ &= V_t \left[m_{b,t+1} \right] - cov_t \left(m^P_{i,t+1}, m_{b,t+1} \right). \end{aligned} \tag{12}$$

where the last equality follows from Eq. (7), that is, from the observation that the exchange rate perfectly hedges $hpr^\infty_{i,t+1}$ in our complete markets economy. After normalizing the coefficients of the base country so that $\beta^b_c = \beta^b_\pi = 1$, we get:

$$\begin{aligned} \log E_t \left[RFX^\infty_{i,t+1} \right] = \log E_t \left[RFX^1_{i,t+1} \right] - \beta^c_i \left[\frac{k_{\epsilon c} \sigma^2_{xc}}{1-\rho_c} - \frac{\rho_{c\pi} k_{\epsilon\pi} \sigma^2_{x\pi}}{(1-\rho_c)(1-\rho_\pi)} \right] \\ + \beta^\pi_i \frac{k_{\epsilon\pi} \sigma^2_{x\pi}}{1-\rho_\pi}. \end{aligned} \tag{13}$$

Eq. (13) shows three important results. First, this strategy exposes the investor to the same extent of currency risk that we have seen for the traditional carry ($\log E_t \left[RFX^1_{i,t+1} \right]$). Second, the investor is also exposed to the risk associated with the holding period return of the long-maturity bond. Specifically, when good news for long-run growth materialize, either directly ($\varepsilon_{c,t+1} > 0$) or indirectly ($\varepsilon_{\pi,t+1} < 0$ and assuming $\rho_{c\pi} < 0$), yields increase and the infinite-maturity bond produces a loss in states of world with low marginal utility. As a result, this strategy provides a hedge against global growth news shocks, thus commanding a negative risk premium (see middle term in Eq. (13)).

Third, this strategy commands a positive risk premium with respect to expected global inflation news (last term in Eq. (13)). Nominal yields increase when positive news to expected inflation materialize, thus resulting in a negative holding period return in high-marginal utility states. This inflation risk premium is increasing in β^i_π. Furthermore, we anticipate that under our benchmark calibration, the last term in Eq. (13) accounts for a large share of the excess return $\log E_t \left[RFX^\infty_{i,t+1} \right]$. Equivalently, the inflation risk premium is the key driver of the excess return on foreign long-term bonds investments, and investing in the long-term bonds of high β^π_i countries should command a premium over investing in the long-term bonds of low β^π_i countries.

In the next section, we calibrate the model and assess its quantitative performance. When doing so, we consider a cross section of β^i_c and

Table 6

Calibration. This table reports the value of our parameters under our baseline calibration. Some parameters are calibrated to be within the confidence intervals of their counterpart estimated in the data. HAC-corrected standard errors are reported in the parentheses. Other parameters are calibrated to match cross sectional averages (Avg.$_i$) in the data. Empirical estimates are from the specification detailed in Eq. (3). Our data set is detailed in Section 2.

Description	Parameter	Value	Estimate/ moment
Subjective discount factor	δ	0.997	Avg.$_i$ $\left[E(r^f)\right]$
Risk Aversion	γ	10	$E(carry^S)$
Cross-country average consumption growth	$\bar{\mu}_c$	0.49%	Avg.$_i$ $[\Delta c]$
Volatility of cons growth short-run shock	σ_c	0.46%	Avg.$_i$ $[\sigma(\Delta c)]$
Volatility of cons growth long-run shock	σ_{xc}	0.11%	Avg.$_i$ $\left[ACF_1(\Delta c)\right]$
Autocorr. cons growth long-run risk	ρ_c	0.810	0.601 (0.145)
Cross-country average inflation growth	$\bar{\mu}_\pi$	0.25%	Avg.$_i$ $[\pi]$
Volatility of inflation short-run shock	σ_π	0.55%	Avg.$_i$ $[\sigma(\pi)]$
Volatility of inflation long-run shock	$\sigma_{x\pi}$	0.11%	Avg.$_i$ $\left[ACF_1(\pi)\right]$
Autocorr. inflation long-run risk	ρ_π	0.988	0.916 (0.040)
Cons growth/inflation long-run feedback	$\rho_{c\pi}$	−0.050	−0.019 (0.039)

Table 7

Heterogeneous Exposure and Cross-sectional Moments. The table reports cross sectional averages (Avg.$_i$) and cross sectional coefficients of variation (StDev$_i$/Avg.$_i$) for several moments of interest. The column 'Value' reports our point estimates computed using the data set described in Section 2. We report the associated HAC-adjusted standard errors under the column 'Std Err'. The entries for the column 'Model' are obtained by simulating 1000 short samples comprising 100 quarterly observations. Simulated data are time aggregated at the annual frequency. All parameters are set to their benchmark values reported in Table 6. For $ACF_1(\Delta c)$, $ACF_1(\pi)$ and $Corr(\Delta c, \pi)$, we report StDev$_i$ rather than StDev$_i$/Avg.$_i$.

	Avg.$_i$			StDev$_i$/Avg.$_i$		
	Value	(Std err)	Model	Value	(Std err)	Model
β_c	0.91	(0.08)	0.65	0.39	(0.11)	0.36
$E(\Delta c)$	2.21	(0.18)	2.60	0.35	(0.04)	0.19
$\sigma(\Delta c)$	1.08	(0.18)	1.02	0.27	(0.06)	0.16
$ACF_1(\Delta c)$	0.35	(0.12)	0.08	0.19	(0.04)	0.21
β_π	0.96	(0.11)	0.96	0.47	(0.17)	0.40
$E(\pi)$	1.66	(0.13)	1.20	0.43	(0.05)	0.59
$\sigma(\pi)$	0.94	(0.12)	1.75	0.21	(0.04)	0.25
$ACF_1(\pi)$	0.20	(0.12)	0.40	0.18	(0.04)	0.22
$Corr(\Delta c, \pi)$	−0.23	(0.10)	−0.12	0.34	(0.05)	0.19

β_π^i consistent with our empirical estimates, and analyze the currency returns through simulations that reflect the estimated dynamics of expected growth and inflation.

4. Calibration and simulations

We detail our baseline quarterly calibration in Table 6. The subjective discount factor δ is set to reflect an average annualized nominal risk free rate of 4.7%, consistent with the data. The risk aversion parameter is equal to 10. This value enables us to match the conditional expected value of the returns from the slope carry strategy. The parameters $\overline{\mu}_\pi$ and $\overline{\mu}_c$ are chosen to reflect the average annual inflation and consumption growth in the data.

Global expected consumption growth (x_c) and inflation (x_π) are modeled according to Eq. (3). We calibrate the autocorrelation parameters ρ_c and ρ_π to be consistent with the confidence internals of our estimates of Eq. (3). The consumption–inflation feedback parameter $\rho_{c\pi}$ is set equal to −0.05, again consistent with our estimation. The volatility of our short-run consumption shocks, σ_c, and that of our long-run news shocks about global consumption growth, σ_{xc}, are chosen to target the average volatility and autocorrelation of consumption growth in our data set, respectively. We apply a similar strategy for the volatility parameters in the inflation process.

We generate cross-sectional differences across countries by setting heterogeneous exposure to both global consumption, β_c^i, and inflation, β_π^i, for ten different countries. Our calibration of these parameters is reported in the appendix (Table F.1) and informed by our estimates described in Section 2.[2] Given our cross section of exposure parameters, we generate country-level mean growth and inflation by spreading around the mean values μ_c and μ_π according to the parsimonious formula in Eqs. (4) and (6). Given these parameters, we simulate the model for 100 quarters and show average results across 1000 simulations.

In Table 7, we focus on key moments of both consumption and inflation for our cross section of countries. For the sake of parsimony, we report global averages and cross-sectional dispersion. Specifically, we report cross-sectional averages, label as "Avg.$_i$", of moments simulated in the time-series at the country level. In order to measure heterogeneity across countries we also report the cross-sectional coefficient of variation, labeled as "StDev$_i$/Avg.$_i$", of these moments across our ten countries.

Our model fits well the data as our simulated moments are in line with our empirical confidence intervals. We point out three minor limitations. First, our inflation processes are on average slightly more volatile than in the data. Second, we produce a cross-sectional variation in the average of consumption growth that is slightly smaller than in the data. Third, the cross sectional variation in $corr(\Delta c^i, \pi^i)$ in our simulation is smaller than its empirical counterpart. These issues could be easily resolved by (i) introducing country-specific volatility for short-run consumption growth shocks; (ii) enriching the link between average consumption growth and exposure to growth news shocks stated in Eq. (4); and (iii) adding a country-specific inflation component. Since these variations would improve our results at the cost of tractability, we decided to abstract away from them and focus on our constrained (and hence more conservative) calibration.

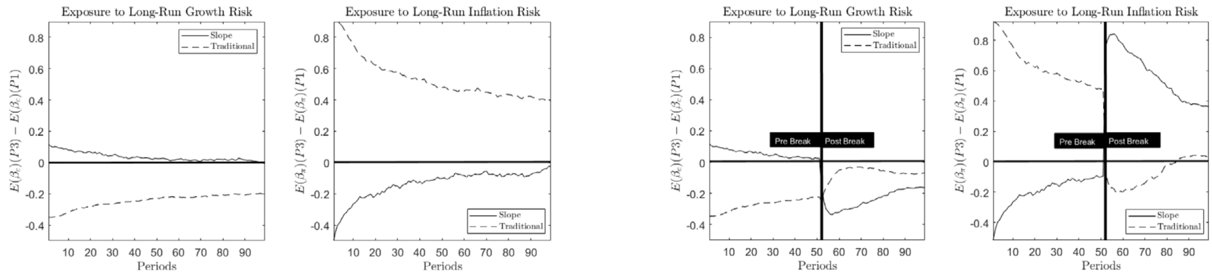
4.1. Simulating expectations

To preserve tractability, we focus on a setting with log-normally distributed shocks. Within this setting, we model variations in expected inflation and economic growth as the realization of a large joint negative news shock.

Specifically, we think of the *pre-break* period as a sub-sample in which both of our state variables, $x_{c,t}$ and $x_{\pi,t}$, start from positive values. Consistent with our empirical evidence, we set the initial point of expected global growth and inflation so that $x_{c,0} = x_{\pi,0} = 0.13\%$, i.e., both processes capture above-average expectations. At the time of the break, $t = t^*$, our agents receive negative news shocks about both expected growth and inflation, so that in the *post-break* sample expectations decline below average: $x_{c,t^*} = x_{\pi,t^*} = -0.54\%$. We simulate 1000 different samples with 100 quarterly observations, and introduce this low-probability event at $t^* = 51$, consistent with our empirical pre-break sample.

Within each sub-sample, we are interested in sorting countries according to either their short-term rate or the slope of their yield curve, at each point in time. The first characteristic is key in forming portfolios used in the traditional carry strategy. The yield curve slope, on the other hand, is important in forming portfolios for the slope carry. This simulation exercise is relevant for at least two reasons. First, it accounts for the endogenous probability of a country to be reallocated across portfolios depending on the chosen sorting variable; that is,

[2] In the Internet Appendix, we detail both our calibration strategy and the model-implied constraints that we face. Throughout our analysis, we assume that consumption and GDP exposures coincide. Our conclusions regarding FX risk premia are similar to those obtained by Colacito et al. (2018), who measure GDP as consumption plus net exports.



(a) Without Break (b) With Break

Fig. 4. Simulated Portfolio-Level Exposures. This figure shows differences in simulated portfolio-level exposures to long-run growth risk (β_c, left panels) and expected global inflation news shocks (β_π, right panels). In panel (a), there is no break in expected growth and inflation. In panel (b), a break suddenly reduce both expected growth and inflation. For the traditional carry, portfolio P1 (P3) comprises low-interest rate (high-interest rate) countries. For the slope carry, portfolio P1 (P3) comprises flatter-yield curve (steeper-yield curve) countries. Our quarterly calibration is detailed in Table 6. At the break point, both expected global growth and expected global inflation decline as in the data (see Fig. 3). We depict averages across repetitions of small sample in which both expected inflation and growth are initialized above their unconditional average.

either the level or the slope of the yield curve. Second, it enables us to compute time-varying properties at the portfolio level.

To illustrate the extent of this time variation, in Fig. 4, we report the GDP-weighted exposure coefficients across portfolios both with respect to growth and inflation news shocks (i.e., the weighted averages of β_c and β_π for each portfolio). In the top panels, we depict the case in which there is no extreme variation, whereas the bottom panels include a sizeable negative shock. In both cases, expectations are initialized to be above their unconditional levels. In the next subsections, we describe in detail how this time variation is relevant for the traditional and slope carries.

Traditional and slope carry without a break. In Fig. 4(a), we depict the behavior of the exposure coefficients of our carry strategies in the scenario in which there is no break. In our model, the traditional carry strategy features a negative exposure to global growth news shocks, as the investor in the base country borrows in high-β_c currencies and invests in low-β_c currencies. When we initialize our pre-break sub-sample, the top-three (bottom-three) β_c countries end up in the low (high) risk-free rate portfolio, henceforth “P1” (“P3”). Because of (i) mean reversion, and (ii) the fact that our country fixed effects in the nominal risk-free rates are moderate (see Eq. (9) and Table F.1 in the Internet Appendix), the exposure of the traditional carry tends to decrease in absolute value as some of the countries with intermediate levels of β_c enter more frequently in portfolios P1 and P3 due to fluctuations in $\beta_c^i x_{c,t} + \beta_\pi^i x_{\pi,t}$. A similar logic applies to the exposure of the traditional carry to inflation risk, meaning that it is very positive at the beginning of our simulation and it decreases in magnitude over time.

Turning to the slope carry, we point out that in the middle of our sample it has a nearly null exposure to global growth risk and a slightly negative exposure to inflation risk. As a result, this strategy should bear an unconditional risk premium close to zero.

Traditional and slope carry with a break. In Fig. 4(b), we depict the behavior of the exposure coefficients of our carry strategies in the scenario in which there is a break , i.e., a substantial downward revision in expectations. The traditional carry depends only on the exposure to growth news shocks, β_c (Eq. (11)). Qualitatively, the behavior of the this exposure remains the same. In the post-break sample, its magnitude is reduced compared to the no-break scenario, but its sign is unchanged.

In contrast, the break changes substantially the exposures of the slope carry both in terms of magnitude and in terms of sign. In the aftermath of a joint negative shock to the growth and inflation expectations, steeper-slope countries feature higher β_π and lower β_c. In order to understand this dramatic change of sign, we note that the unconditional slopes are very similar across countries (see Table F.1 in the Internet Appendix), implying that the slope-based ranking of our countries is almost entirely driven by the transitory components $\beta_c^i x_{c,t} + \beta_\pi^i x_{\pi,t}$.

More specifically, in our model dispersion in β_π's is more pronounced than that in β_c's. As a result, the relative slopes of the yield curves are mainly driven by exposure to inflation, consistently with our empirical findings reported in Table B.1. Hence, in the context of our simulations, we can note that $slope_{i,t}^\infty - slope_{j,t}^\infty \approx -(\beta_\pi^i - \beta_\pi^j)x_{\pi,t}$. If we consider the situation in which country i has higher inflation exposure than country j, then $\mathbf{sign}(\beta_\pi^i - \beta_\pi^j) = 1$, and

$$\mathbf{sign}\left(slope_{i,t}^\infty - slope_{j,t}^\infty\right) = -\mathbf{sign}\left(x_{\pi,t}\right). \tag{14}$$

Equivalently, when expected global inflation is below average, the yield curves of high-β_π countries tend to be steeper, whereas the opposite is true when expected inflation is above average. Given the decline in both expected global inflation and long-run growth that we have estimated in the data post-break, we can think of the slope carry as going long (short) in high-β_π countries post-break (pre-break). Since in our data-driven calibration there is a mild negative correlation between β_c's and β_π's, the slope carry also features a negative exposure to growth news shocks post-break.

In the next section, we analyze how these endogenous time-varying exposures of our portfolios affect currency risk premia in equilibrium.

4.2. Impulse response functions and risk premia

Impulse responses. In Fig. 5, we show the response of our portfolios to adverse shocks to expected global growth and inflation. In both cases, the marginal utility of the investor in the base country increases, meaning that we are looking at high marginal utility states.

Consistent with our analysis of the portfolio exposures, we see that the traditional carry has a negative exposure to growth news shocks both before and after the break. As a result, this strategy must pay a positive risk premium against long-run global growth risk. We note also that given our calibration, this strategy has a negative exposure to global inflation shocks, that is, its holding period return is negative in high-marginal utility states and hence it must pay a positive risk premium also with respect to inflation shocks.

The behavior of the slope carry returns deserves more attention. Pre-break, this strategy produces positive excess returns with respect to both negative growth news shocks and positive inflation news shocks. Hence this strategy provides insurance against both sources of global risk. In the post-break period, however, the opposite holds. Furthermore, we note that the responses to inflation shocks are much more pronounced compared to those relative to growth news shocks. Equivalently, the contribution of the risk premium of inflation risk appears to dominate in our simulations.

Given these observations, let us focus solely on the role of inflation risk in what follows. Recall from Eq. (14) that when $x_{\pi,t} > 0$ ($x_{\pi,t} < 0$), a steeper-slope (henceforth **S**) country features low-β_π (high-β_π). The opposite is true for the flatter-slope (henceforth **F**) country. Under these conditions, the conditional risk premium of the slope carry can be computed as:

$$E[carry^S|x_{\pi,t}] := \log E_t\left[RFX_{\mathbf{S},t+1}^\infty\right] - \log E_t\left[RFX_{\mathbf{F},t+1}^\infty\right] \tag{15}$$

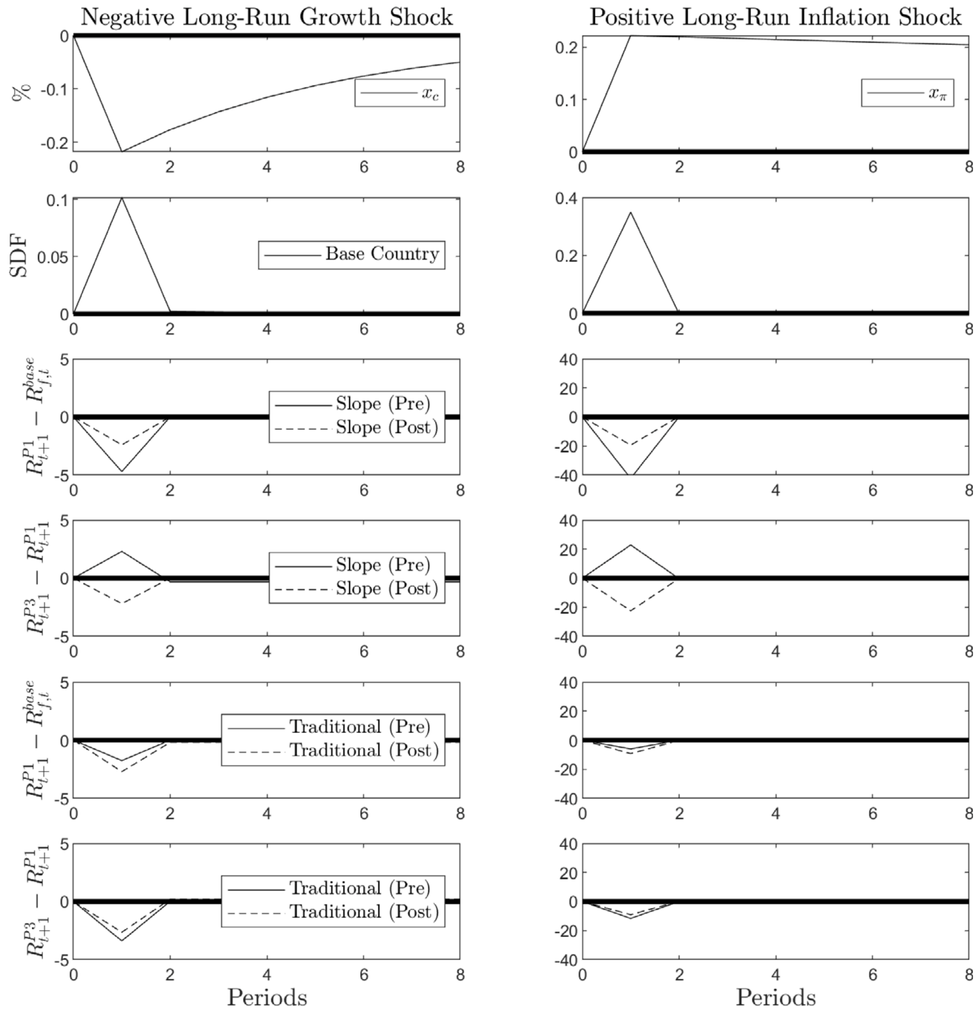


Fig. 5. Portfolios Response to Global News Shocks. This figure shows portfolio-level impulse response functions for the Pre-Break (solid line) and Post-Break (dashed line) period. The left (right) panels report the response to adverse global consumption growth (inflation) news shocks. SDF refers to the stochastic discount factor in the base country. $R^{P1}_{t+1} - R^{base}_{f,t}$ ($R^{P3}_{t+1} - R^{base}_{f,t}$) is the excess return that an investor in the base country obtains by investing in the "low" ("high") portfolio, RFX^n_{P1} (RFX^n_{P3}), $n \in \{1, \infty\}$. $R^{P3}_{t+1} - R^{P1}_{t+1}$ refers to the excess returns of the carry strategy. For the traditional (slope) carry, P1 comprises low-interest rate (flat-yield curve) countries. Our quarterly calibration is detailed in Table 6.

$$\approx -\text{sign}(x_{\pi,t}) \underbrace{(\beta^H_\pi - \beta^L_\pi)}_{>0} \underbrace{\frac{k_{\epsilon\pi}\sigma^2_{x\pi}}{1-\rho_\pi}}_{>0},$$

where the second row of (15) is an approximation about $\beta^H_c = \beta^L_c$ or, equivalently, the risk premium obtained by abstracting away from the role of growth news shocks.

Eq. (15) confirms three relevant points. First, the slope carry strategy features endogenously time-varying exposure to news shocks because the countries that end up in the two legs of the strategy change with the expectations (i.e., $x_{\pi,t}$). Second, the slope carry should produce a positive risk premium in periods in which expected global inflation is below average, consistent with our empirical evidence. Third, its unconditional risk premium should be zero since $E[\mathbf{sign}(x_{\pi,t})] = 0$.

Simulated moments. One key advantage of the tractability of our model is that it features an exact solution and hence it can be simulated without approximation errors. We report key equilibrium moments in Table 8.

Our model captures the key results that we have highlighted in our empirical investigation. Specifically, it produces a nearly null slope carry risk premium in our full sample while simultaneously matching the magnitude of its positive risk premium post-break. Turning our attention to the mid- and bottom-part of the table, we see that these quantitative results have been obtained with a dispersion of the slope across our simulated portfolios that is consistent with that observed in the data. The same is true for our simulated exposures both in the full sample and in the post-break sample. These observations are relevant because our model replicates almost entirely the observed slope carry while simultaneously reproducing plausible cross-sectional spreads for both yield curve slopes and exposure coefficients. In the Internet Appendix, we report the volatility and persistence of both the nominal risk-free rate and slope across countries (Tables F.2 and F.3). Our simulated values are in line with their empirical counterparts.

In addition, our model captures the increasing contribution of the exchange rate to the slope carry. In the post-break sample, the contribution of the exchange rate to the slope carry has been 3.40% in the data. The model produces a similar value, in the order of 4.03%. Hence our model captures an interesting dimension of the composition of the slope carry and it does not rely solely on the bonds' holding period return.

Finally, we note that similar considerations apply to the traditional carry. Hence our model matches (i) key conditional properties of the slope carry through heterogeneous exposure to global inflation news shocks, and (ii) key unconditional properties of the traditional carry through both the inflation and the growth news shock channel.

Expected currency depreciation. By no arbitrage, the expected depreciation rate of the currencies involved in a carry trade must satisfy

Table 8
Simulated Moments. This table reports both empirical and simulated moments for both the traditional and the slope carry strategies. All moments are (i) computed as GDP-weighted averages within each portfolio, (ii) annualized, and (iii) multiplied by 100 (except for β_c and β_π). For the traditional (slope) carry, the "high" portfolio, P3, comprises countries with high short-term interest rates (steeper yield curve slopes). The opposite is true for the "low" portfolio, P1. The entries for the moments are based on 1000 simulations of 100 quarters. All parameters are set to their benchmark values reported in Table 6. $E(\Delta FX)$ refers to the average exchange rate depreciation and $E(\pi)$ refers to the average inflation rate. $E(\beta_c)$ ($E(\beta_\pi)$)) measures the portfolio-level exposure to global expected consumption growth (inflation). The numbers in parentheses denote standard errors.

	Traditional carry		Slope carry	
	Data	Model	Data	Model
$E(carry)$ (Full Sample)	5.21	2.75	1.89	2.36
	(1.92)		(2.20)	
$E(carry)$ (Post-08/08)	1.12	1.48	4.75	7.65
	(1.39)		(2.08)	
$E(sortingvar)$ P3 - $E(sortingvar)$ P1	3.83	1.91	1.44	1.75
	(0.96)		(0.30)	
$E(sortingvar)$ P3 - $E(sortingvar)$ P1 (Post-08/08)	2.65	1.52	1.08	1.98
	(1.64)		(0.25)	
$E(\Delta FX)$ P3 - $E(\Delta FX)$ P1	1.39	0.85	0.92	2.32
	(1.83)		(2.34)	
$E(\Delta FX)$ P3 - $E(\Delta FX)$ P1 (Post-08/08)	−1.53	−0.02	3.40	4.03
	(1.28)		(2.26)	
$E(\beta_c)$ P3 - $E(\beta_c)$ P1	−0.63	−0.17	0.11	−0.06
$E(\beta_c)$ P3 - $E(\beta_c)$ P1 (Post-08/08)	−0.56	−0.06	−0.27	−0.20
$E(\beta_\pi)$ P3 - $E(\beta_\pi)$ P1	−0.11	0.29	0.00	0.16
$E(\beta_\pi)$ P3 - $E(\beta_\pi)$ P1 (Post-08/08)	−0.35	−0.07	0.19	0.55
$E(\pi)$ P3 - $E(\pi)$ P1	2.13	1.42	−0.33	−1.41
	(0.65)		(0.96)	
$E(\pi)$ P3 - $E(\pi)$ P1 (Post-08/08)	1.06	1.23	1.23	−1.33
	(0.51)		(0.56)	

the following condition:

$$E_t[\Delta FX_{t+1}^{P3|P1}] = CRP_t^{P3|P1} - (r^1_{P3,t} - r^1_{P1,t}),$$

where $P3$ ($P1$) refers to the long (short) leg of the carry, $CRP_t^{P3|P1}$ refers to the associated currency risk premium, and $r^1_{P3,t} - r^1_{P1,t}$ refers to the average one-period interest rate of the long (short) portfolio at time t.

As documented in Sections 3.3 and 3.4, in our model the currency risk premium is fully determined by heterogeneous exposure to growth shocks, i.e., by the cross section of β_c's. Even though at the country-level the β_c's are constant, the portfolio-level exposure to growth news shocks is time-varying because the composition of the portfolio can change significantly (see Fig. 4). As a result, at the portfolio-level the contribution of currency risk to the carry risk premia, CRP, is time-varying.

In addition, recall that in our model high-β_c countries feature safe currencies, implying that a carry trade loads significantly on currency risk when its exposure ($E(\beta_c)$ P3 - $E(\beta_c)$ P1) is negative and sizable.

According to our model, the exposure of the traditional carry to growth news shocks goes from −0.17 to −0.06 when comparing the full and the post-08 samples, respectively. Hence the traditional carry expected returns (CRP_t) decline as well by about 125 basis points. In our model, however, the compression of the interest rate differential ($r^{P3}_{1,t} - r^{P1}_{1,t}$) is about 40 basis points. As a result, the expected average depreciation of the currency must decline by about 85 basis points ($E(\Delta FX)$ P3 - $E(\Delta FX)$ P1 goes from 0.85 to −0.02 percent).

In the case of the slope carry, the expected depreciation of the exchange rate behaves differently. Specifically, there is always a net positive contribution of the average exchange rate depreciation to the slope carry. In the full sample, this contribution is 2.32% and it increases to 4.03% post-2008. This increase is necessary in order to pay a currency risk premium of around 3.00% post-2008, given a short term interest rate differential of roughly minus one percent. This higher level of risk is explained by the fact that the slope carry strategy loads more on global growth risk in the post-2008 sample ($E(\beta_c)$ P3 - $E(\beta_c)$ P1 takes a value of −0.2).

Average Portfolio Inflation. Table 8 reports the annualized average inflation of both carry strategies. For the traditional carry, both in the model and in the data, we observe a reduction in the contribution of inflation in our post-2008 sample. For the slope carry, inflation does not appear to play a significant role in the data. In our model, inflation contributes slightly negatively to the slope carry return, both in the full and in the post-08 samples.

Entropy analysis. Lustig et al. (2019b) show that the log currency risk premium of investing in the long-term bond of country i while borrowing short-term in the currency of the base country, b, can be expressed as

$$E_t\left[\log RFX^{\infty}_{i,t+1}\right] = TP_b + L_b - L_i,$$

where TP_b is the expected term premium in the base currency and L_b and L_i are the conditional entropies of the permanent components of the SDFs in the base country and country i, respectively. In the context of our model the conditional entropy of country i is equal to

$$L_i = \frac{1}{2}\left[\frac{\left(\beta^i_c\right)^2\gamma^2}{(1-\rho_c)^2}\sigma^2_{xc} + \left(\beta^i_\pi + \frac{\rho_{c\pi}\gamma}{1-\rho_c}\beta^i_c\right)^2\frac{\sigma^2_{x\pi}}{(1-\rho_\pi)^2} + \gamma^2\sigma^2_c + \sigma^2_\pi\right], \quad (16)$$

when letting $\delta \to 1$. We report the general expression in the Internet Appendix, equation (E.5). At the country level, these entropies are constant and they depend on both the heterogeneous exposures to global expected growth (β^i_c) and global expected inflation (β^i_π). Considering heterogeneity across countries in these two dimensions has two important implications.

First, in our model the slope carry risk premium is decoupled from the traditional carry risk premium, as the latter only depends on growth exposures. Second, our model is able to overcome the shortcoming of the long-run risk model analyzed by Lustig et al. (2019b). Specifically, their long-run risk model abstracts away from heterogeneous exposure to inflation risk. Hence in their setting heterogeneous exposure to growth risk can only be offset by introducing a very specific kind of heterogeneity in the preference parameters across countries. They conclude that the unconditional slope carry risk premia can be equalized in the cross-section of countries only in knife-edge cases. Thanks to heterogeneous exposure to inflation risk, this outcome does not apply in our specific context.[3]

We now turn our attention to the extreme slope carry portfolios. In Fig. 6, we compare the slope carry exposure to expectations about global growth and inflation in both data and model. Our model captures the decline in the exposure of the slope carry strategy to growth news shocks. Even though this phenomenon is less pronounced than in the data, this is mostly inconsequential for the performance of our model, since growth news shocks have a limited quantitative contribution to the conditional average slope carry premium both in the data and in the model. In terms of portfolio exposures to global inflation news shocks, in contrast, we see that the model conforms well with the dynamics of our empirical measure.

While constant at the country level, conditional entropies are time-varying at the portfolio level as countries transition across portfolios. Specifically, in our model the following holds:

$$E_t[\log RFX^{(\infty)}_{p,t+1}] = -\sum_{i\in p_t}\omega^p_{i,t}L_i + L_b + TP_b, \quad p \in \{P1, P2, P3\}, \quad (17)$$

where $P1_t$, $P2_t$ and $P3_t$ represent the possibly time-varying composition sets of P1, P2, and P3 and the ω_ts represent time-varying portfolio weights.

[3] In the model that we consider, we have that $\partial\Lambda_i/\partial\beta^i_c > 0$ and $\partial\Lambda_i/\partial\beta^i_\pi < 0$, as long as $\rho_{c\pi} < -(1-\rho_c)/\gamma$, which is satisfied in our calibration. In this context, the risk premium induced by heterogenous β^i_c can be offset by heterogeneous β^i_π.

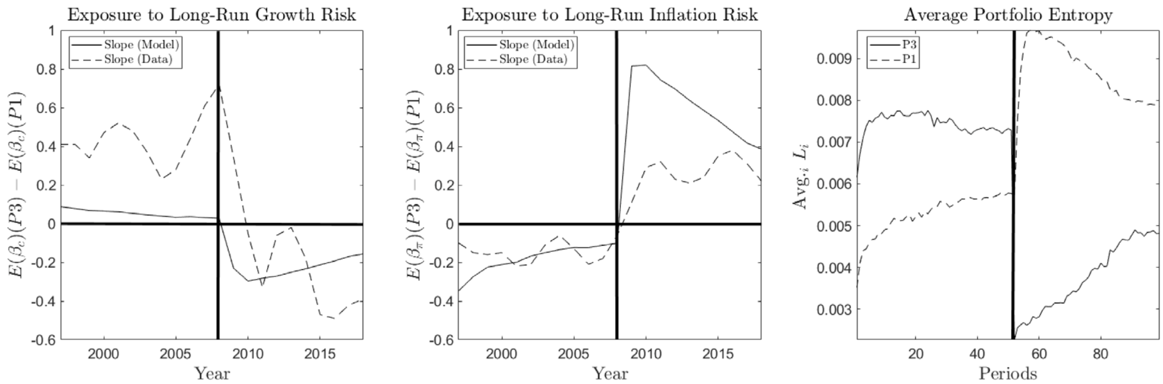


Fig. 6. Slope Carry: Portfolio-Level Exposures for Model and Data. The first two panels of this figure show differences in portfolio-level exposures to long-run growth risk (β_c, left panel) and expected global inflation news shocks (β_π, right panel) for the slope carry. The solid lines are obtained using simulated data. Our quarterly calibration is detailed in Table 6. The dashed lines show the empirical estimates obtained using the data set of Section 2. Portfolio P1 (P3) comprises flatter-yield curve (steeper-yield curve) countries. In the right panel, we show the portfolio-level entropy of the permanent component of the SDF of our extreme slope portfolios, P1 and P3 (Eq. (17)). At the break point (August 2008) both expected global growth and expected global inflation decline as in the data (see Fig. 3). For the simulated data, we depict averages across repetitions of small sample in which both expected inflation and growth are initialized above their unconditional average.

Table 9
Simulated Entropy and Predictability. This table reports average simulated moments based on 1000 simulations of 100 quarters. For the slope carry, the "high" portfolio, P3, comprises countries with high steeper yield curve slopes. The opposite is true for the "low" portfolio, P1. We run the following regression: $\log RFX^{P3}_{t+1} - \log RFX^{P1}_{t+1} = c_0 + \beta F_t + resid_{t+1}$, where F_t is a forecasting variable. As in Lustig et al. (2019b), F_t refers to the difference across portfolios of either (i) the level of the yield curves ($r^1_{P3,t} - r^1_{P1,t}$, column 'YC Level') or (ii) the slope of the yield curves ($slope^\infty_{P3,t} - slope^\infty_{P1,t}$). We report both the average point estimate of β and its average standard error across repetitions. 'Entropy' refers to the annualized percentage of the average difference of entropies of the permanent components of the pricing kernels in the two extreme portfolios ($L^{P1} - L^{P3}$). These figures are annualized and multiplied by 100. All parameters are set to their benchmark values reported in Table 6.

	YC level	YC slope	Entropy
Full Sample			
Point Est.	−5.14	6.15	0.80
St. Err.	(4.66)	(6.82)	–
Post-08/08			
Point Est.	−12.11	14.84	2.38
St. Err.	(10.14)	(12.22)	–

The rightmost panel of Fig. 6 shows the average of the entropies of the countries in the extreme portfolios of the slope strategy. First, we note that the ranking of the entropies changes pre- and post-2008, implying that the expected slope carry return changes sign accordingly. Second, most of the variation in the average entropy happens across sub-samples.

In Table 9, we quantify our claims through simulations. The difference in the entropies of the two extreme portfolios of the slope strategy is time-varying, which results in the slope carry earning a time-varying premium. Simultaneously, our simulations show that an econometrician would not be able to detect predictability by running forecasting regressions that use as forecasting variable either the difference in the level of the risk-free rate across portfolios or the difference of their yield curve slopes. This is because most of the variation in the portfolios unfolds across subsamples, and not within subsamples.

5. Extensions

This section considers two extensions of our model. First, we study the behavior of the slope carry in the 70 s and 80 s. Second, we look at broader specifications of our model.

5.1. Slope carry during the 1970s and 1980s

The period 1975–1985 was characterized by rapidly changing inflation regimes and it is therefore uniquely suited to analyze the model's mechanism. We use the historical data in the replication codes by Lustig et al. 2019a to analyze the performance of the slope carry strategy over this period.

In Table 10, we report our results over various sub-samples between 1975 and 1985. In each panel of the table, we focus on a specific subsample and we report average portfolio excess returns, Sharpe ratios, the three countries that are most frequently present in each portfolio, as well as the portfolios' exposures to inflation and growth (i.e. β_π and β_c for P1, P2, P3 and P3-P1). The exposures are based on the estimates obtained over the extended sample period to allow for a more direct comparison between currency excess returns and economic fundamentals.[4]

There is a sizeable annual cross-sectional premium of almost 8% over the decade going from the mid-1970s to the mid-1980s. This excess return is positive, and so is the average inflation exposure of the slope carry strategy, consistent with our economic explanation.

Furthermore, a large portion of the excess return that the strategy earns in this decade accrues during the first 4 years of the sample. As shown in the second panel of Table 10, the 1975–1979 sample is characterized by a return in excess of 11% per year and by a positive inflation exposure of the slope carry strategy, consistent with our model.

In 1980, however, global inflation peaked and GDP growth collapsed (see right panel of Fig. 7). During the same year, both the slope carry excess return and its inflation exposure declined ($\beta_\pi = -0.59$). The decade concludes with a positive slope carry excess return (see the last panel of Table 10). Inflation (both realized and expected) starts to subside during this period and the slope carry strategy earns a positive excess return while also loading positively on inflation, consistent with the predictions of our model.

In Fig. 7, we offer a graphical representation of the evolution of the slope carry excess return in these years. In both panels, the shaded area is the cumulative excess return on the slope carry. This cumulative excess return is close to 90% during the 1975–1985 decade. The right panel of Fig. 7 highlights three distinct phases of the time-variation of global inflation: (i) slowing inflation in the late 70 s (relative to the mid-1970s peak), (ii) the spike of inflation in 1980, and (iii) the subsequent slowdown in inflation. In addition, in this panel we can see that the evolution of the slope carry excess return matches the evolution of expected inflation: the profitability of the strategy grows when inflation is relatively low and it declines when inflation is high.

[4] We report the details of the historical forecast data used for this part of the analysis in Appendix A.6.

Table 10
Slope Carry: 1975–1985. This table reports the excess returns associated to borrowing at the 3 months interest rate of the US and investing in the 10 year bonds of a GDP-weighted portfolio of countries with flatter (1), medium (2), and steeper (3) yield curves. The column label "3-1" reports the average return from being long portfolio 3 and short portfolio 1. Portfolios are rebalanced every month. Returns are in log-units. The rows labeled "$E[\beta_\pi](P3) - E[\beta_\pi](P1)$" and "$E[\beta_c](P3) - E[\beta_c](P1)$" denote the spread of the inflation and growth exposures between portfolios 3 and 1. The inflation and growth exposures β_π and β_c are estimated on the sample 1975–1990. The numbers in square brackets are t-statistics.

	1 (Flatter)	2	3 (Steeper)	3-1 (Steep-flat)
Sample: 12/1974–12/1985				
Mean	−12.06%	−9.23%	−4.32%	7.74% [2.00]
Sharpe Ratio	−0.79	−0.63	−0.25	0.49
Recurrent countries:	NZ (95%)	Ger (57%)	Jpn (71%)	
	Swe (56%)	Aus (50%)	Nor (61%)	
	Can (52%)	Swi (41%)	UK (41%)	
$E[\beta_\pi](P3) - E[\beta_\pi](P1)$	1.13	1.03	1.21	0.08
$E[\beta_c](P3) - E[\beta_c](P1)$	0.42	0.59	0.56	0.14
Sample: 12/1974–12/1979				
Mean	−8.2%	−5.89%	3.08%	11.28% [2.28]
Sharpe Ratio	−0.86	−0.49	0.2	0.69
Recurrent countries:	NZ (100%)	Nor (67%)	UK (66%)	
	Can (79%)	Aus (66%)	Swi (56%)	
	Swe (43%)	Ger (56%)	Jpn (54%)	
$E[\beta_\pi](P3) - E[\beta_\pi](P1)$	1.14	0.96	1.28	0.14
$E[\beta_c](P3) - E[\beta_c](P1)$	0.48	0.59	0.54	0.06
Sample: 12/1979–12/1980				
Mean	−5.91%	−34.96%	−11.78%	−5.88% [-0.73]
Sharpe Ratio	−0.41	−1.9	−0.46	−0.3
Recurrent countries:	UK (92%)	Aus (69%)	Jpn (100%)	
	NZ (69%)	Swi (69%)	Nor (100%)	
	Can (46%)	Ger (62%)	Can (38%)	
$E[\beta_\pi](P3) - E[\beta_\pi](P1)$	1.74	0.73	1.15	−0.59
$E[\beta_c](P3) - E[\beta_c](P1)$	0.46	0.54	0.57	0.1
Sample: 12/1980–12/1985				
Mean	−18.07%	−7.55%	−9.66%	8.41% [2.27]
Sharpe Ratio	−0.93	−0.49	−0.62	0.59
Recurrent countries:	NZ (97%)	Ger (57%)	Nor (84%)	
	Swe (70%)	UK (57%)	Jpn (84%)	
	Swi (52%)	Can (51%)	Aus (41%)	
$E[\beta_\pi](P3) - E[\beta_\pi](P1)$	1.02	1.15	1.15	0.14
$E[\beta_c](P3) - E[\beta_c](P1)$	0.35	0.59	0.57	0.23

In the left panel of Fig. 7, we document the dynamics of inflation exposure, β_π, during this period. Specifically, we report the cumulative exposure of the slope carry excess return, which is obtained by adding up $\beta^{P3}_{\pi,t} - \beta^{P1}_{\pi,t}$ over time. This panel clearly shows that slope carry exposure to inflation grew during periods of slowing inflation and it declined during the middle period of high inflation, thus confirming that our economic explanation is broadly consistent with the dynamics of the slope carry return in the 1975–1985 period.

5.2. Extended model

In this section, we extend our model in two dimensions. First, we explore the role of the intertemporal elasticity of substitution (IES) by considering Epstein and Zin (1989a) preferences. Next, we introduce a demand shock and explore the relevance of global inflation shocks for the volatility of domestic yields. All of our derivations are reported in Appendix G and follow the same steps of those reported for the special case with IES=1.

5.2.1. The role of the IES

We replicate our analysis by adopting the following preferences,

$$U_{i,t} = \left\{ (1-\delta) C_{i,t}^{1-\frac{1}{\psi}} + \delta E_t \left[U_{i,t+1}^{1-\gamma} \right]^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}},$$

where ψ and γ determine the IES and the relative risk aversion, respectively. These preferences imply the following real stochastic discount factor,

$$m^{\text{real}}_{i,t+1} = \theta \log \delta - \frac{\theta}{\psi} \Delta c_{i,t+1} + (\theta - 1) r^c_{i,t+1},$$

where $r^c_{i,t}$ is the return on the consumption claim and $\theta := \frac{1-\gamma}{1-\frac{1}{\psi}}$. In each country, the nominal discount rate is still determined as $m_{i,t+1} = m^{real}_{i,t+1} - \pi_{i,t+1}$.

Up to a log-linearization, our extended model (i) preserves the affine structure of our benchmark setting, and (ii) differs from our baseline case because the IES is no longer forced to be equal to one.

In Table 11, we compare our simulated results when we set $IES = 2$, a typical number in the international macro-finance literature (see, for example, Colacito and Croce 2011b). Keeping everything else constant, a higher IES reduces the spread in the interest rates and hence it reduces the profitability of the traditional carry both over the full sample and in the post-2008 period.

In contrast, the slope carry increases (decreases) post-2008 (pre-2008). This is because the SDF features loadings with respect to both growth and inflation news that are larger than before, as they depend on $\gamma - 1/\psi > \gamma - 1$ when $\psi > 1$. Equivalently, going back to Eq. (11), the coefficients $k_{\epsilon c}$ and $k_{\epsilon \pi}$ are more sizable.

Looking at all of the other moments, we find only marginal variations in our simulated models when we increase our IES from one to two.

5.2.2. Determinants of treasury yields: the role of demand shocks

Duffee (2018) documented that inflation expectation shocks explain a relatively small fraction of the variability of Treasury yields in the US. We show that introducing demand shocks can easily preserve our main results and enable our setting to be consistent with this empirical finding.

Specifically, we assess the role of global inflation shocks in an extended version of our model with (i) IES = 2, and (ii) a common demand shifter, i.e., we introduce demand shocks that affect all countries (Albuquerque et al., 2016). In this section, we are agnostic about the exposure of each country to global demand shocks and we set it to be identical across countries.[5] Given this assumption, global demand shocks do not alter currency risk premia, because they affect all countries to the same extent. Equivalently, demand shocks affect the variance of local yields without affecting their cross-sectional properties.

We enrich our preferences by introducing a process, Λ_t, that functions as a demand shifter:

$$U_{i,t} = \left\{ (1-\delta) \Lambda_t C_{i,t}^{1-\frac{1}{\psi}} + \delta E_t \left[U_{i,t+1}^{1-\gamma} \right]^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}}.$$

These preferences imply the following real stochastic discount factor,

$$m^{\text{real}}_{i,t+1} = \theta \log \delta + \theta \Delta\lambda_{t+1} - \frac{\theta}{\psi} \Delta c_{i,t+1} + (\theta - 1) r^c_{i,t+1}$$

where $\Delta\lambda_{t+1}$ evolves as follows:

$$\Delta\lambda_{t+1} := \log(\Lambda_{t+1}/\Lambda_t) = x_{d,t},$$

[5] An analysis of heterogeneous exposure to demand shocks is left for future research.

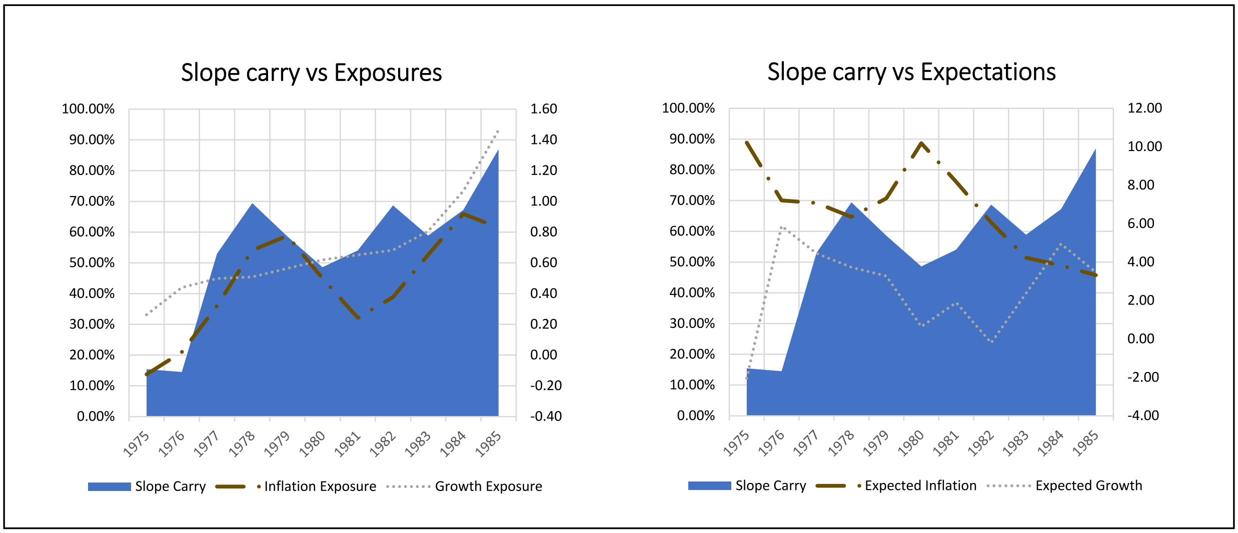


Fig. 7. Slope Carry, Exposures, and Expectations: 1975–1985. The left panel reports the cumulative Slope Carry Excess return (shaded area), the cumulative difference of inflation exposures between the extreme portfolios (dash-dot line), and the cumulative difference of GDP growth exposures between the extreme portfolios (dotted line). The right panel reports the cumulative Slope Carry Excess return (shaded area), the G10 expected inflation rates (dash-dot line), and the expected GDP growth rates (dotted line).

Table 11
The Role of IES. This table reports both empirical and simulated moments for both the traditional and the slope carry strategies. All moments are (i) computed as GDP-weighted averages within each portfolio, (ii) annualized, and (iii) multiplied by 100 (except for β_c and β_π). For the traditional (slope) carry, the "high" portfolio, P3, comprises countries with high short-term interest rates (steeper yield curve slopes). The opposite is true for the "low" portfolio, P1. The entries for the moments are based on 1000 simulations of 100 quarters. All parameters are set to their benchmark values reported in Table 6, and the IES is also allowed to be 2. $E(\Delta FX)$ refers to the average exchange rate depreciation. $E(\beta_c)$ ($E(\beta_\pi)$) measures the portfolio-level exposure to global expected consumption growth (inflation). The numbers in parentheses denote standard errors.

	Traditional carry			Slope carry		
	Data	IES=1	IES=2	Data	IES=1	IES=2
$E(carry)$ (Full Sample)	5.21	2.75	2.07	1.89	2.36	3.85
	(1.92)			(2.20)		
$E(carry)$ (Post-08/07)	1.12	1.48	1.11	4.75	7.65	9.42
	(1.39)			(2.08)		
$E(sortingvar)$ P3 - $E(sortingvar)$ P1	3.83	1.91	1.80	1.44	1.75	1.79
	(0.96)			(0.30)		
$E(sortingvar)$ P3 - $E(sortingvar)$ P1 (Post-08/08)	2.65	1.52	1.44	1.08	1.98	2.16
	(1.64)			(0.25)		
$E(\Delta FX)$ P3 - $E(\Delta FX)$ P1	1.39	0.85	0.28	0.92	2.32	1.74
	(1.83)			(2.34)		
$E(\Delta FX)$ P3 - $E(\Delta FX)$ P1 (Post-08/08)	−1.53	−0.02	−0.31	3.40	4.03	3.03
	(1.28)			(2.26)		
$E(\beta_c)$ P3 - $E(\beta_c)$ P1	−0.63	−0.17	−0.16	0.11	−0.06	−0.06
$E(\beta_c)$ P3 - $E(\beta_c)$ P1 (Post-08/08)	−0.56	−0.06	−0.04	−0.27	−0.20	−0.21
$E(\beta_\pi)$ P3 - $E(\beta_\pi)$ P1	−0.11	0.29	0.28	0.00	0.16	0.29
$E(\beta_\pi)$ P3 - $E(\beta_\pi)$ P1 (Post-08/08)	−0.35	−0.07	−0.10	0.19	0.55	0.63

and

$$x_{d,t} = \rho_d x_{d,t-1} + \sigma_{x,d}\epsilon_{d,t}.$$

We assume that the innovation to the demand shifter are *i.i.d.N(0,1)* and simulate our model under two different scenarios. First, we assume that no additional demand shock takes place at $t^* = 2008$. Under the second scenario, instead, we assume that at the time of the break, i.e., $t = t^*$, our agents receive also a negative demand shocks, similarly to what we did with expected global inflation and growth. Across both scenarios, we set $\sigma_d = 5e^{-4}$ and $\rho_d = .9742$, two values that are conservative with respect to Albuquerque et al. (2016).

We report our simulation results in Table 12. First of all, we note that our main results are preserved when we introduce demand shocks. The traditional carry declines by 65 basis points, whereas our slope carry decreases by about 300 basis points. Both moments, however, remain empirically plausible. The risk-free rates, the slopes and the exchange rate depreciation rates show no significative change across portfolios. Second, we point out the inclusion of a global drop in demand is immaterial for our analysis.

Furthermore, turning our attention to panel B of Table 12, we see that including demand shocks enables us to reduce significantly the share of volatility of local yields explained by inflation shocks. This result confirms that global news shocks about inflation can be a key determinant of international carry strategy even though they explain a small portion of the dynamics of local yield curves.

6. Conclusion

In this paper, we provide novel empirical evidence regarding the performance of carry trade strategies based on sorting the cross section of currencies on the level and on the slope of their yield curves. In particular, we revisit the conclusion of the extant literature concerning the near zero average excess return associated to being long in steeper yield curve countries and short in flatter yield curve countries (slope carry). We note that the risk premium on this strategy is slightly negative before 2008 and it turns sharply positive in more recent years. Equivalently, the null excess return over a long sample conceals the profitability of the slope carry over different sub-samples.

We explain these empirical findings by augmenting an otherwise standard international asset pricing model with two sources of empirically motivated cross-country heterogeneity. Namely, we focus on heterogeneous exposure to news shocks about both expected global consumption growth and inflation. We document that in our equilibrium model, heterogeneity about expected economic growth explains the performance of portfolios sorted on the level of the yield curve (traditional carry), whereas heterogeneity with respect to inflation is key to account for the average returns of the slope carry within different sub-samples.

Future developments should extend this setting to international real business cycle models to study the role of international investment flows and international frictions for the cross section of currency risk premia. They should also analyze the role of the zero lower bound (see, among others, Caballero et al., 2016) on the profitability of currency strategies in the aftermath on the Global Financial Crisis.

Table 12
The Role of Demand Shocks. This table reports both empirical and simulated moments for both the traditional and the slope carry strategies. All moments are (i) computed as GDP-weighted averages within each portfolio, (ii) annualized, and (iii) multiplied by 100 (except for β_c and β_π). For the traditional (slope) carry, the "high" portfolio, P3, comprises countries with high short-term interest rates (steeper yield curve slopes). The opposite is true for the "low" portfolio, P1. The entries for the moments are based on 1000 simulations of 100 quarters. All parameters are set to their benchmark values reported in Table 6, except the IES that is set to 2. When the demand shock is present, we set $\sigma_d = 5e^{-4}$ and $\rho_d = .9742$. When we include a downward jump in the demand process, we set it equal to -1StDev(x_d). $E(\Delta FX)$ refers to the average exchange rate depreciation. $Slope$ and hpr^∞ refer to the slope and the holding period return of an infinite-maturity bond, respectively. The share of volatility refers to the simple average of the country-level shares. The numbers in parentheses denote standard errors.

Panel A: International Moments

	Traditional Carry			Slope Carry		
Demand shock	yes	yes	no	yes	yes	no
Demand shock downward jump	yes	no	–	yes	no	–
$E(carry)$ (Full Sample)	1.42	1.42	2.07	0.98	0.98	3.85
$E(carry)$ (Post-08/07)	0.47	0.47	1.11	5.50	5.50	9.42
$E(sortingvar)$ P3 - $E(sortingvar)$ P1	1.74	1.74	1.80	1.66	1.66	1.79
$E(sortingvar)$ P3 - $E(sortingvar)$ P1 (Post-08/08)	1.43	1.43	1.44	1.83	1.83	2.16
$E(\Delta FX)$ P3 - $E(\Delta FX)$ P1	−0.30	−0.30	0.28	1.53	1.53	1.74
$E(\Delta FX)$ P3 - $E(\Delta FX)$ P1 (Post-08/08)	−0.93	−0.93	−0.31	2.58	2.58	3.03

Panel B: Local Moments

Share of volatility due to inflation	hpr^∞	$Slope$	ΔFX
With demand shock	9.6%	58.6%	25.2%
Without demand shock	79.2%	81.0%	28.5%

CRediT authorship contribution statement

Spencer Andrews: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Riccardo Colacito:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mariano M. Croce:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Federico Gavazzoni:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author declares that he has no relevant or material financial interests that relate to the research described in this paper.

Data availability

ACCG_Replication_File (Original data) (Mendeley Data)

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Appendix A. Internet appendix

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jfineco.2024.103874.

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