Hedging inflation risk in a developing economy: The case of Brazil

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ABSTRACT

Inflation shocks are one of the pitfalls of developing economies and are usually difficult to hedge. This paper examines the optimal strategic asset allocation for a Brazilian investor seeking to hedge inflation risk at different horizons, ranging from one to 30 years. Using a vector-autoregressive specification to model intertemporal dependency across variables, we measure the inflation hedging properties of domestic and foreign investments and carry out a portfolio optimisation. Our results show that foreign currencies complement traditional assets very efficiently when hedging a portfolio against inflation: around 70% of the portfolio should be dedicated to domestic assets (equities, inflation-linked (IL) bonds and nominal bonds), whereas 30% should be invested in foreign currencies, especially the US dollar and the euro.

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1. Introduction

Inflation is a serious risk in emerging economies, which are likelier than developed countries to experience major inflationary shocks, both sporadic and persistent. This is significant insofar as many investors are highly sensitive to inflation risk, not only long-term institutional investors (especially pension funds and insurers, which operate under inflation-related liability constraints) but also retail

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investors, for whom consumption and capital protection is a key concern. Accordingly, finding the best asset allocation for hedging inflation risk is crucially important.

The issue has been studied in the case of developed countries (Attié and Roache, 2009; Amenc et al., 2009), but not for emerging economies. This is important because emerging countries have special characteristics that distort comparisons with their developed counterparts. They are subject to much sharper bouts of inflation, often caused by a crisis affecting their currency (a devaluation is passed through to domestic inflation) or their government debt. What is more, emerging country investors generally have a narrower range of domestic assets to choose from than do investors in developed countries.

Many institutional investors in emerging economies, notably pension funds, are invested chiefly in domestic government bonds and cash instruments. This is due to three main factors: equity markets are usually small and often undiversified, government debt burdens are substantial, and there is a widely held belief that govies and cash are the safest investments. But for long-term investors, cash is risky because it is exposed to the risks of reinvestment and short-term inflation surprises. Bond investments expose investors to a principal risk if interest rates rise and also to a long-term inflation risk, since coupon payments and principal redemption are nominally fixed. The only asset class providing protection from uncertainty about real interest rates and inflation is inflation-linked (IL) bonds, but not all developing countries issued IL bonds and these markets tend to be narrow and less liquid than their nominal-bond counterparts.

An alternative way for investors to hedge inflation risk is through foreign investments. Campbell et al. (2003b) show that holding short-term bonds denominated in foreign currencies with stable inflation and real interest rates is a way to protect investments against inflation. Moreover, reserve or "safe haven" currencies have the compelling property of being negatively correlated to risky assets: they tend to appreciate when equity markets fall (Campbell et al., 2010). This is particularly interesting from a portfolio construction perspective, because it offers diversification and protection when investors crucially need it. Safe haven currencies help to make a portfolio "crisis-robust" (Brière and Szafarz, 2008). The benefits of foreign currencies have been shown by Campbell et al. (2003b) from a developed country perspective. But for an emerging country investor, safe haven currencies have other valuable properties. Since many inflation shocks in emerging countries are caused by currency crises, holding currencies is a direct way to gain protection against these shocks.

We consider the case of a Brazilian investor investing in nominal assets but facing inflation risk and having a target real return. She can invest either in domestic assets (nominal bonds and equities) or in foreign investments (dollar, yen and euro cash). Two questions need to be answered. (1) What is the inflation hedging potential of domestic and foreign investment? (2) What is the optimal diversified allocation for hedging inflation risk on a given investment horizon? As far as we know, these questions have not been addressed from the perspective of an emerging market investor.

Among developing countries, Brazil is interesting in many ways. It is a big country with highly developed financial markets (its domestic government bond market is the largest in Latin America) and a thriving financial industry. Institutional investors such as mutual funds, pension funds and insurance companies are particularly prominent. Despite implementing large-scale macroeconomic stabilisation policies, including government debt reduction and inflation targeting (for which the central bank introduced an annual range), the country has been subject to strong macroeconomic instability caused by two financial crises, in 1999 and 2002, which triggered major inflation shocks.

Protecting a portfolio against inflation is one of the seminal questions in finance. Solnik (1978) and Manaster (1979) derived analytically, in a static one-period framework, the set of efficient frontiers and market equilibrium conditions of an investor maximising his real wealth. Introducing a multi-period setting, Merton (1971) studied the intertemporal portfolio choice problem with time-varying investment opportunities and introduced the concept of intertemporal hedging demand for financial assets. Theoretically, the optimal portfolio composition for hedging inflation risk can be decomposed into three parts: (1) a mean variance tangency portfolio, (2) a portfolio that best correlates with inflation, (3) an additional investment hedge against changes in the investment opportunity set. Campbell and Viceira (2002) developed an approximation technique in a discretised framework and showed that when assets follow an autoregressive process with partial predictability, the term structure effects modify the assets' correlations with inflation and the demand for risky assets in the long run.

Our paper tries to supplement the literature on the inflation hedging properties of assets and strategic asset allocation, but with the original perspective of a developing country investor, which has hardly been studied in the literature. Following Brennan et al. (1997), Campbell and Viceira (2002), Campbell et al. (2003a), we use a vector-autoregressive (VAR) specification to model inter-temporal dependency across variables, and then simulate long-term holding portfolio returns up to 30 years. We use the simulated returns to measure the inflation hedging properties of each asset class and to carry out a portfolio optimisation that hedges inflation risk. For each maturity, we derive the real efficient portfolio hedge against inflation risk. We show that foreign currencies complement domestic assets very efficiently when hedging a portfolio against inflation: whereas 70% of the portfolio should be dedicated to domestic assets (nominal and IL bonds, equities), around 30% should be dedicated to foreign currencies. A larger weight should be attributed to the dollar rather than to euro, notably when the investment horizon is very long. The US dollar shows the highest diversification with domestic assets as well as attractive performances during currency depreciation due to its safe haven properties. Euro and yen become more attractive when the investor is looking for higher real returns.

The remainder of this paper is structured as follows. Section 2 presents economic developments in Brazil; Section 3 presents our analytical framework; Section 4 presents our results; and Section 5 concludes.

2. Economic developments in Brazil

During the 1990s, Brazil initiated an extensive process of economic reform, liberalising trade, privatising public enterprises and relaxing price controls. However, the country experienced two major crises, in 1999 and 2001–2002, which led to currency depreciation and, with a certain lag and different amplitude, to strong increases in the domestic inflation rate.

The 1999 crisis happened after a period of improving economic conditions. Between 1994 and 1998, the Brazilian government used high domestic interest rates and privatisation to attract foreign capital and sustain an appreciated exchange rate. A policy of exchange rate targeting ("crawling peg") was instituted, permitting the currency to depreciate at a controlled rate against the dollar. The new currency, in combination with high interest rates (in excess of 30%) stabilised inflation for the first time in decades. Attracted by high interest rates, investors poured money into the Brazilian economy. In 1997, foreign direct investment grew by 140% over the year. But during that period, unemployment climbed and government budget deficits began to rise strongly. In 1998, the Russia's default led to a panic among emerging countries, and international investors suddenly lost confidence in Brazil's economy. In January 1999, Brazil announced that pegging was over and its exchange rate would be allowed to float. By the end of the month, the real depreciated 66% against the dollar. The inflation rate rose by 8.9% in December 1999. The initial response of the Brazilian Central Bank was to hike rates to stop capital flight and reduce the pass-through of exchange rate depreciation to inflation. In May 1999, after the exchange rate had stabilised at a high level, the government announced that it would start targeting inflation.

Brazil suffered a second crisis in 2001–2002, either a major public debt and a currency crisis. The real lost more than 80% of its value against dollar, and inflation rose by 17.2% in May 2003 (Fig. A1 in Appendix A). This crisis was due to the combination of several shocks, both international and domestic: an increase in worldwide risk aversion arising from the corporate scandals in developed markets and the 9/11 terrorist attacks, the slowdown in developed economies (US and Europe), and the collapse of Argentina's economy, which led to a sharp widening of credit spreads among all emerging countries. Two domestic factors also played an additional role: a severe energy shock leading to a rationing of electricity, and uncertainty surrounding the presidential elections.

Since 1998, exchange rate movements have been a key determinant of the Brazilian inflation rate. This phenomenon is known as the pass through effect (Belaisch, 2003) and is due to different factors: the high level of general inflation in Brazil, the high degree of openness of the Brazilian economy, and more specific factors linked to Brazil's policy: during the period of privatisation, the government allowed the price of some public utilities to follow a price index that was heavily influenced by the exchange rate.

Brazilian investors therefore face a dilemma. They can either invest in domestic assets and thus enjoy high average returns (but without necessarily hedging inflation, as inflationary shocks tend to coincide with currency depreciation, equity market downturns and interest rate rises due to the increase in the sovereign risk premium); or they can turn to foreign markets, where their investments will earn much lower average returns but perform exceptionally well when the real depreciates. That exceptional performance will help to hedge the resulting inflation shock, at least partially.

3. Data and methodology

3.1. Data

We consider the case of Brazilian investors able to invest in domestic stocks (MSCI Brazil Total Return Stock Index), domestic nominal government bonds (JPM Global Bond Index Emerging Broad Brazil) and IL bonds (3-5Y Barclays Capital Brazil Government Inflation-Linked Bond Index[1]). They are also able to invest abroad in three foreign currencies: dollar, euro and yen, through a money market investment at the 1-month interbank rate.[2] All data are available since 2002 except for IL bonds, available only since 2004. Following the methodology of Kothari and Shanken (2004), we reconstruct a time series of real rates approximated by the nominal bond yield minus the series of 1-year ahead inflation expectations of the Central Bank of Brazil, and a time varying inflation risk premium (IRP). In recent years, a number of studies have empirically proved that the inflation risk premium highly varied over time (Buraschi and Jiltsov (2005) among others), mainly in response to inflation fluctuations and instability of inflation expectations. Considering the economic turbulence that flowed into an inflationary shock in 2002, we estimate a time varying inflation premium depending on the volatility of inflation (Evans, 1998).[3] We consider monthly returns over the time period January 2002–February 2011.

Fig. A2 in Appendix A presents the cumulative monthly returns of the six asset classes converted into Brazilian real over the sample period January 2002–December 2009. Domestic investments out-performed foreign investments during the period, but the risk was non-negligible notably for equities, which lost more than 50% in five months at the peak of the subprime crisis (from June to October 2008). The superior performance of foreign investments during this episode, but also during the Brazilian crisis of 2002, provides evidence of the benefits of foreign currencies during periods of stress.

Table B1 in Appendix B presents the descriptive statistics of monthly returns over the period January 2002-December 2009. The hierarchy of returns is the following: Brazilian equities have the highest total return (22.9% nominal return, 15.3% real return), followed by IL bonds (15.6% nominal, 8.6% real) and nominal bonds (13.6% nominal, 6.4% real). The nominal rate of return in the three foreign money market investments is only 1.1% in average. The rate of return of a US dollar investment is even slightly negative (−1.8%) due to dollar depreciation over the sample period, whereas the yen and euro investments both have positive nominal returns (1.6% and 3.6% respectively). All foreign money market investments exhibit negative real performances. Turning to risk, equities show the highest volatility (24.7%) while nominal and IL bonds have the lowest (7.5% and 13.5% respectively). Foreign currencies appear very volatile for a Brazilian investor, with volatilities comprised between 20.3% and 22.3%, but they show positive skewness (between 1.4 for the yen and 2.1 for the dollar), contrary to

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[1] The choice of considering the 3–5 year segment index is to ensure the best duration match with the nominal bond index. The market in Brazilian local currency debt securities grew substantially in the period 2005–2007, with a gradual extension of the maturity of sovereign domestic debt, and in consequence a significant lengthening of the duration of the nominal bond index. Even if debt patterns cause a duration gap between IL bonds and nominal bonds at the beginning of the sample, this better reflects the real situation that investors face in terms of fixed income availability.

[2] Note that among domestic investments, we deliberately excluded money market investments, which offered exceptional returns in Brazil over the studied period (15% in average), much higher than other domestic investments, for a very low level of risk. This is particular to the Brazilian market and may not last in the future.

[3] A linear relationship between inflation risk premium and the 2 years rolling volatility of inflation is estimated economet-rically over the period January 2004 and December 2009, and the estimated coefficients are used to extrapolate the inflation risk premium before that date.

domestic assets, marked by high negative asymmetry of the return distribution (skewness of −0.1 for IL bonds, −0.4 for equities and −0.7 for nominal bonds).

Table B2 in Appendix B presents the correlations of monthly nominal returns[4]. Foreign investment (dollar, euro or yen) shows strong diversification with traditional asset classes, around −30% correlation with nominal bonds, −50% with IL bonds and equities. Currencies investments are closely correlated (around 85%). Brazilian nominal and IL bonds have 67% correlation, a result that is consistent with the experience in developed markets (Brière and Signori, 2009). Both diversify equally with equities, with 37% correlation.

3.2. Methodology

3.2.1. VAR estimation

In order to overcome the lack of historical data and to capture the evolution of and interdependencies between multiple asset classes, we follow the approach of Barberis (2000), Campbell et al. (2003a), Fugazza et al. (2007) among others, using the VAR structure as a tool to simulate returns in the presence of macroeconomic factors. The dynamics of monthly returns follow a first-order VAR model for the six asset classes, using inflation and the dividend yield as predictive factors (Kandel and Stambaugh, 1996; Barberis, 2000; Lynch, 2001). This allows us to simulate different scenarios for returns and inflation.

VAR(1) can be written as:

$$z_t = \phi_0 + \phi_1 z_{t-1} + u_t \qquad (1)$$

where ϕ_0 is the vector of intercepts; ϕ_1 is the coefficient matrix; z_t is a column vector whose elements are the log returns on the six asset classes (to reduce multicollinearity, investment returns in euro and yen are expressed as differences from the dollar investment return) and the values of the two state variables; u_t is the vector of a zero mean innovation process. Finally, to overcome the problem of correlated innovations of the VAR(1) model we identify structural innovations ε_t characterised by a iid process, imposing a set of economic restrictions according to the standard procedure described in Amisano and Giannini (1997). Constraints follow the rationale that "external" shocks on foreign currencies affects contemporaneously the prices of Brazilian domestic assets classes and inflation, but not vice versa. Equities are also affected by dividend yield shocks.

We use the iid structural innovations to perform Monte Carlo simulations on the fitted model for the portfolio analysis. We draw iid random variables from a multivariate normal distribution for the structural innovations and we obtain 5000 simulated paths for returns and inflation of length T (T varying from 1 month to 30 years). The results are thus used, on the one hand, to measure the inflation hedging properties of each asset class, and on the other hand to carry out a portfolio optimisation using the appropriate expected returns and covariance matrices at different horizons (1, 5, 10, and 30 years).

Tables B3 and B4 in Appendix B present the results of our VAR model. Looking at the significance of the coefficients of the lagged state variables, inflation is mainly helpful in predicting IL bond returns, whereas, unsurprisingly, dividend yield has better explanatory power for equities. The high positive correlation coefficient of the residuals between nominal and IL bonds (68%) confirms the strong interdependency between the two asset classes dominated by the common component of real rates. Equities have a strong negative innovation correlation coefficient with the US dollar (−59%), implying that a negative shock in equities has a positive contemporaneous effect on dollar returns and vice versa, thus confirming the safe haven role of the dollar. Other results are in line with the common findings and the intuition that a currency shock has a positive impact on inflation and a contemporaneous negative impact on nominal bonds returns through the inflation expectations component.

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[4] The correlations of monthly real returns present a very similar picture.

3.2.2. Portfolio optimization

We consider that the investor seeks to minimise the variance of the real returns at different invest-ments horizons. A standard mean-variance approach provides the mix of assets with the smallest risk for every level of the real return target. We thus solve the following problem:

$$\text{Min}_w w' \Sigma w$$

$$\sum_{i=1}^{n} w_i R_{iT} = \bar{R}$$

$$\sum_{i=1}^{n} w_i = 1$$

$$w_i \geq 0$$

where $R_T = (R_{1T}, R_{2T}, \ldots, R_{nT})$ are the annualised real returns of the n assets in the portfolio over the investment horizon T, $w = (w_1, w_2, \ldots, w_n)$ the vector of weights invested in each asset, $\bar{R}$ the target real return, and Σ is the covariance matrix of real returns simulated through the econometric times series analysis of returns (VAR model).

We derive the corresponding efficient frontier. For each investment horizon T (T = 1 year, 5 years, 10 years, 30 years), we draw the efficient portfolios and present the optimal composition of (1) minimum risk, and (2) 6% real return target portfolios.

4. Results

4.1. Inflation hedging properties of individual assets

The inflation hedging properties of asset classes can be analysed by examining their correlations with inflation. Fig. A3 in Appendix A displays correlation coefficients between asset returns and infla-tion based on our VAR model, depending on the investment horizon, from 1 month to 30 years. Among asset classes, IL bonds are certainly the best assets to hedge against inflation, for an obvious reason: the impact of a rising inflation rate has a direct positive impact on performances through the coupon indexation mechanism (even if a rise in real rates can undermine the inflation component of the return during some periods). The correlation with inflation increases with the investment horizon, reaching 70% on a 30-year horizon.[5] Consistent with intuition, nominal bond returns are negatively correlated with inflation, especially in the short run, since changes in expected inflation and bond risk premi-ums are traditionally the main source of variation in nominal yields. In the long run, this correlation becomes close to zero.

Equities have an interesting behaviour. They appear negatively correlated in the short run, but positively correlated with inflation in the medium to long run (close to 40%), a result that is consistent with the empirical literature on emerging markets (Erb et al., 1995; Boyd et al., 2001; Bekaert and Wang, 2010) but in contrast to traditional findings on developed economies (Attié and Roache, 2009), which document a negative correlation with inflation. A positive relationship is consistent with the Fisher hypothesis, whereby the nominal interest rate (and, by extension, stock market returns) should fully reflect the available information concerning possible future values of the inflation rate. This theory has suffered from empirical contradictory evidence on developed equity markets, with different interpretations: (1) as inflation hurts the real economy, the dividend growth rate should fall, leading to a fall in equity prices (Fama, 1981); (2) high expected inflation has tended to coincide with periods of greater uncertainty about real economic growth, raising the equity risk premium (Brandt and Wang, 2003; Bekaert and Engstrom, 2009); and (3) stock market investors are subject to inflation illusion

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[5] When holding an IL security to maturity guarantee a complete protection against inflation, our investor in an IL bond portfolio index is exposed to adverse movements of real rates (the portfolio is rebalanced every month to match the index duration). The real rate return component can compromise the inflation return, lowering the correlation with inflation.

and fail to adjust the dividend growth rate to the inflation rate as much as they do for the discount rate (Modigliani and Cohn, 1979; Campbell and Vuolteenaho, 2004).

The first two explanations imply that the relationship between equities and inflation actually depends on the link between economic activity and inflation, since output growth is closely tied to equity returns, in both developed and emerging countries. Where strong growth is consistent with high inflation (i.e. procyclical inflation regimes), the link between equities and inflation is positive; conversely, with countercyclical inflation, it becomes negative. Bekaert and Wang (2010) document a positive correlation between equities and inflation, particularly strong for Latin American countries, which have experienced high inflation shocks. Boyd et al. (2001) show the presence of a nonlinear relationship between inflation and nominal equity returns: for economies with medium rates of inflation, the correlation is negative, but with high average rates of inflation, the correlation becomes positive.

Among foreign currency investments, the results are contrasted. The euro definitely has a strong contemporaneous correlation with inflation, both in the short and the long run. This can hardly be explained by structural economic factors but may be due to the fact that, during the study period, high inflation in Brazil coincided with periods of appreciation of the euro. Dollar and yen money market investments are almost zero-correlated with inflation on average during the study period. The main attraction of foreign currencies is their exceptional performance during financial or economic crises that could trigger domestic inflation shocks.

4.2. Inflation hedging portfolios

We examine the case of investors wishing to hedge inflation on their investment horizon i.e. to minimise the volatility of real return during the investment horizon. Fig. 1 shows the efficient frontiers describing the tradeoff between the expected value and standard deviation of the portfolio's real returns. Each curve represents a different investment horizon (1, 5, 10 and 30 years).

The first observation, common to all investment horizons, is that efficient frontiers are upwardly sloped. This is consistent with intuition: the higher the required real return, the greater the volatility of the portfolio. The volatility of the portfolio's real return decreases strongly with the investment horizon: from 6.29% with a 1-year horizon to 1.26% with a 30-year horizon for the minimum risk portfolio, a result consistent with the results of Campbell and Viceira (2002). Table 1 shows the optimal portfolio composition and the descriptive statistics of minimum risk portfolios for each investment horizon.

Whatever the horizon, a Brazilian investor willing to hedge inflation risk should hold around 70% traditional investments and 30% foreign currencies. The optimal portfolio composition of traditional asset classes is relatively stable: between 33% and 37% of portfolio should be dedicated to IL bonds, a slightly smaller weight should be dedicated to nominal bonds (between 21% and 31%), and a weight between 8% and 12% to equities. For foreign currencies, by contrast, optimal weights differ depending on the horizon. US dollars always represent the largest share (between 22% and 30%); among foreign currencies, it shows the highest diversification with domestic assets as well as
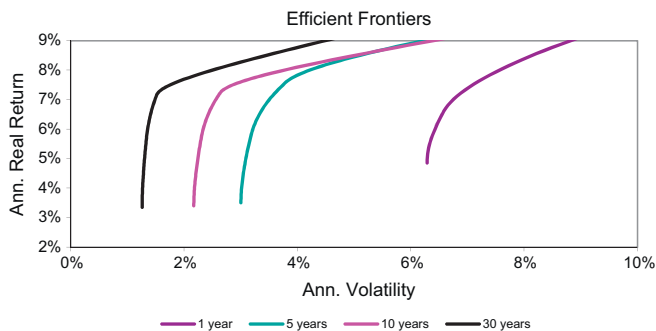

Fig. 1. Efficient frontiers depending on the investment horizon.

Table 1
Minimum variance portfolios, descriptive statistics and optimal weights, January 2002–February 2011.

Horizon	1 year	5 years	10 years	30 years
Ann. real return	4.86%	3.50%	3.40%	3.35%
Real return volatility	6.29%	3.00%	2.17%	1.26%
Min real return	−14.37%	−6.78%	−5.06%	−1.74%
Max real return	28.13%	15.16%	12.78%	7.42%
Skewness	0.17	0.07	0.09	−0.01
Kurtosis	3.01	2.95	3.09	2.95
Weights				
Cash USD	22%	30%	28%	28%
Cash EUR	9%	0%	0%	0%
Cash JPY	0%	0%	0%	0%
Nom bonds	21%	25%	30%	31%
IL bonds	37%	34%	33%	33%
Equities	12%	11%	9%	8%

attractive performances during currency depreciation due to its safe haven properties. In the short run, 9% of the portfolio should also be dedicated also to euros. The yen is never represented in optimal asset allocations. Combined with domestic investments, forex offers risk reduction for investors willing to hedge inflation risk, precisely because it performs well during periods of sharply rising inflation. Among foreign currencies, the dollar is particularly attractive to Brazilian investors. During a crisis, its "safe haven" qualities allow them to diversify their domestic assets more effectively than with other currencies. All the constructed portfolios have substantial real returns (from 3.35% annualised real returns for the 30-year horizon to 4.86% for the 1-year horizon for the minimum risk portfolio).

The optimal basket of foreign currencies dramatically changes when higher real returns are targeted. Table 2 shows the optimal portfolios for a 6% real return target. Compared with minimum risk portfolios there are two main differences. First, the investor should always prefer euros and yen to US dollars, increasing the yen weight as the horizon lengthens. Second, a larger share of portfolio should be invested in domestic asset classes (from 76%% to 89%), providing higher real returns than foreign currencies: the investor should prefer nominal bonds (the weight varies from 29% for 1-year to 54% for 30-year horizon), particularly attractive in Brazil in terms of risk-return tradeoff, then IL bonds (from 36% to 29%) and finally equities (from 11% to 6%), which provide the most attractive return but with particularly high volatility.

Table 2
Optimal portfolios with 6% target real return, descriptive statistics and optimal weights, January 2002–February 2011.

Horizon	1 year	5 years	10 years	30 years
Ann. real return	6.00%	6.00%	6.00%	6.00%
Real return volatility	6.43%	3.21%	2.34%	1.36%
Min real return	−14.93%	−5.53%	−2.67%	0.64%
Max real return	29.91%	16.73%	15.06%	10.55%
Skewness	0.16	0.05	0.07	−0.02
Kurtosis	3.03	2.91	2.98	2.92
Weights				
Cash USD	8%	0%	0%	0%
Cash EUR	15%	5%	3%	2%
Cash JPY	1%	9%	9%	9%
Nom bonds	29%	47%	53%	54%
IL bonds	36%	30%	28%	29%
Equities	11%	8%	7%	6%

All these portfolios achieve a 6% real return with only a slight increase in risk with respect to the minimum risk portfolios. These results underscore the importance of how optimally diversifying the allocation into foreign currencies allows investors to significantly improve the risk adjusted returns of their portfolios.

5. Conclusion

Considerable attention has been paid to the question of hedging inflation in developed markets, especially the United States (see Attié and Roache, 2009 for a detailed literature review). The relationships between asset returns and inflation have been extensively studied. The situation in developing countries is very different, however. It warrants closer attention since a number of very large investors, notably pension and sovereign wealth funds, now originate from these countries. This is important since developing countries are prone to harsher inflation shocks, often linked to rising commodity prices, or to currency crises that culminate in devaluation. So the issue of how to put together a portfolio that hedges inflation is particularly relevant. Brazil is an interesting case to study. A big country with highly developed financial markets, it suffered two major inflation shocks, in 1999 and 2002.

Brazilian investors can choose between investing in domestic equities and bonds (nominal or inflation-linked) and thus enjoy high returns (but with low inflation hedging properties during financial crises) or turning to foreign markets, where their investments will earn much lower average returns but perform exceptionally well when the real depreciates. That exceptional performance will help to hedge the resulting inflation shock, at least partially.

We show that, among domestic assets, an investment in IL bonds indices have excellent inflation hedging properties. This is because the impact of a rising inflation rate has a direct positive impact on performances through the coupon indexation mechanism, even if a rise in real rates can undermine the inflation component of the return during turbulent periods. In Brazil, unlike in developed countries, also nominal bonds and equities are good for hedging inflation and are important asset classes for the portfolio. But our work also shows that domestic assets alone are not enough to reduce the volatility of the portfolio's real return to a minimum. A total of 30% should be invested in foreign currencies, especially the US dollar and the euro, which display excellent inflation hedging qualities during bouts of sharply rising inflation.

A seminal contribution to the unexplored question of inflation hedging in emerging market economies, this paper suffers from econometric drawbacks. The main issue probably relates to the underlying probability distributions of emerging market returns, which depart from normality, but also high tail dependence since they are likely to suffer large losses during international financial crises. One useful development of our work would be to examine alternative risk measures (expected shortfall, etc.) in the context of non-normal returns. Furthermore, our research into the case of Brazil could usefully be extended to other emerging markets. The nature of an inflation shock can significantly affect the inflation-hedging capacities of domestic and foreign assets. Accordingly, a country comparison would be a very interesting development of our work.

Appendix A.

See Figs. A1–A3.

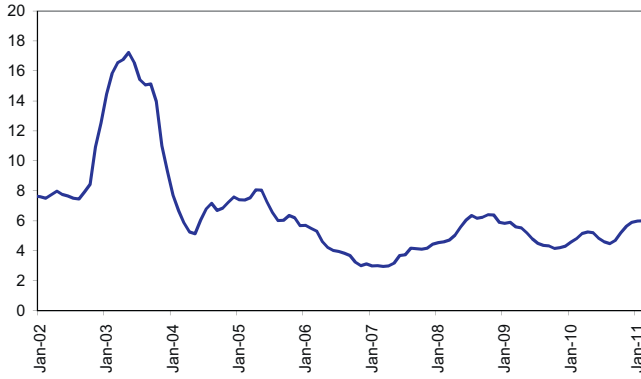**Fig. A1.** Brazil IPCA Inflation, January 2002–February 2011.
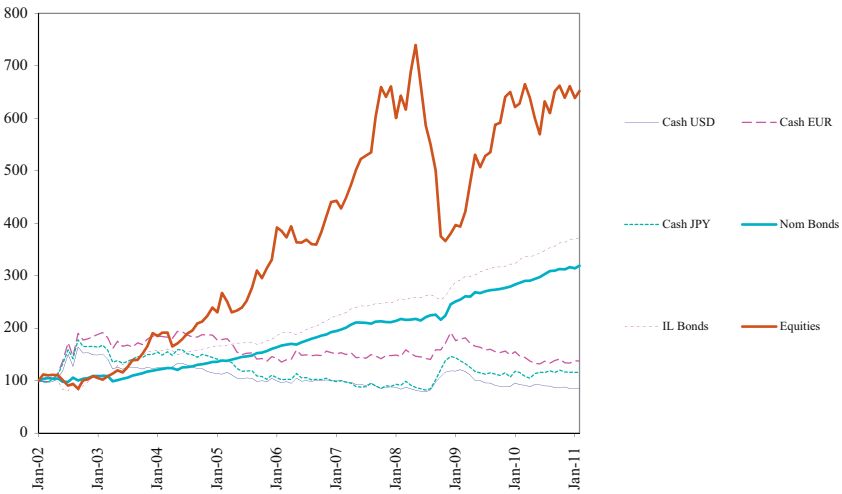

Fig. A2. Cumulative monthly returns in Brazilian real, January 2002–February 2011.
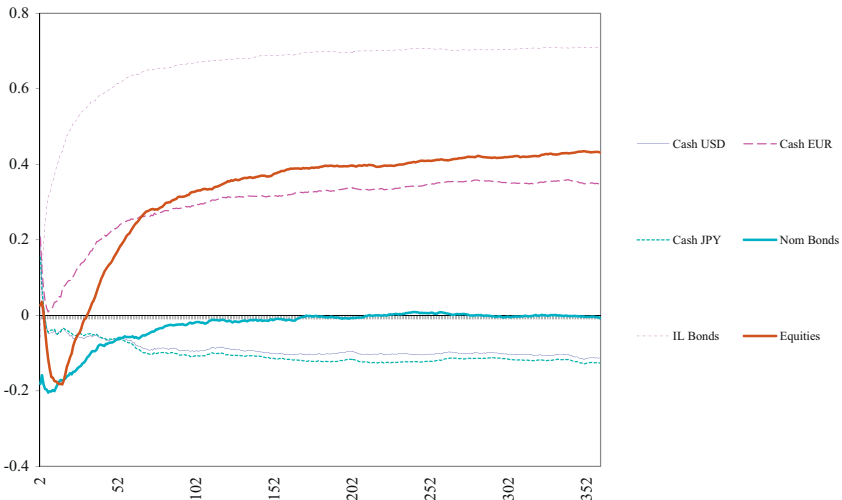

Fig. A3. Correlations between asset returns and inflation depending on the investment horizon, January 2002–February 2011.

Appendix B.

See Tables B1–B4.

Table B1
Summary statistics of monthly returns, January 2002–February 2011.

	Cash USD	Cash EUR	Cash JPY	Nom bonds	IL bonds	Equities
Ann. return	−1.79%	3.58%	1.60%	13.63%	15.59%	22.93%
Ann. real return	−7.84%	−2.82%	−4.67%	6.62%	8.46%	15.35%
Median	−0.62%	−0.26%	−1.04%	1.26%	1.23%	2.06%
Min monthly	−15.32%	−15.19%	−14.51%	−9.18%	−15.63%	−25.08%
Max monthly	28.90%	30.05%	25.37%	9.69%	17.89%	19.49%
Ann. vol.	20.35%	21.59%	22.34%	7.45%	13.51%	24.70%
Skewness	2.07	1.78	1.40	−0.71	−0.11	−0.41
Kurtosis	11.59	9.41	6.04	11.06	12.37	4.14

Table B2
Correlation of monthly nominal logarithmic historical returns, January 2002–February 2011.

	Cash USD	Cash EUR	Cash JPY	Nom bonds	IL bonds	Equities
Cash USD	1.00					
Cash EUR	0.86	1.00				
Cash JPY	0.90	0.84	1.00			
Nom bonds	−0.31	−0.24	−0.25	1.00		
IL bonds	−0.53	−0.45	−0.45	0.67	1.00	
Equities	−0.53	−0.51	−0.51	0.37	0.36	1.00

Table B3
Results of VAR model, parameter estimates, January 2002–February 2011.

	Cash USD(t)	Cash USD(t) − Cash EUR(t)	Cash USD(t) − Cash JPY(t)	Inflation(t)	Nom bonds(t)	IL bonds(t)	Div. yield(t)	Equities(t)
Cash USD($t-1$)	−0.31	0.05	−0.15	0.01	0.16	0.27	−0.10	0.08
	[−2.45]	[0.68]	[−2.20]	[0.70]	[3.36]	[3.38]	[−0.46]	[0.48]
Cash EUR($t-1$) − Cash USD($t-1$)	0.19	−0.05	−0.02	0.01	0.01	0.02	0.29	−0.13
	[0.97]	[−0.51]	[−0.12]	[0.72]	[0.15]	[0.10]	[0.87]	[−0.52]]
Cash JPY($t-1$) − Cash USD($t-1$)	−0.41	0.15	−0.04	−0.01	0.08	0.23	−0.37	0.22
	[−1.97]	[1.29]	[−0.41]	[−0.92]	[0.98]	[1.72]	[−1.08]	[0.83]
Inflation($t-1$)	−1.96	0.23	0.34	0.75	−0.35	1.83	2.69	−2.88
	[−1.38]	[0.29]	[0.48]	[9.74]	[−0.65]	[2.00]	[1.12]	[−1.55]
Nom bonds($t-1$)	0.28	0.49	0.22	0.01	−0.14	−0.58	0.67	−0.38
	[0.78]	[2.41]	[1.14]	[0.44]	[−1.01]	[−2.51]	[1.10]	[−0.81]
IL bonds($t-1$)	−0.25	−0.12	−0.16	−0.01	0.14	0.20	−0.04	0.10
	[−1.12]	[−1.01]	[−1.35]	[−0.90]	[1.69]	[1.36]	[−0.10]	[0.36]
Div. yield($t-1$)	0.02	−0.02	0.00	0.00	0.00	−0.01	0.93	0.07
	[1.16]	[−2.02]	[0.25]	[1.07]	[0.17]	[−0.19]	[27.86]	[2.56]
Equities($t-1$)	−0.16	−0.07	0.01	0.01	0.03	0.15	−0.17	0.12
	[−1.63]	[−1.12]	[0.06]	[2.53]	[0.64]	[2.34]	[−1.03]	[0.99]
Adj. R^2/F-stat	0.07	0.05	0.00	0.55	0.06	0.19	0.89	0.02
	[2.01]	[1.76]	[1.01]	[17.13]	[1.81]	[4.13]	[119.54]	[1.30]

t-Stat are given in parenthesis. The last row reports the adjusted-R^2 and the F-statistics of joint significance.

Table B4
VAR residuals, correlation coefficients, January 2002–February 2011.

	Cash USD(t)	Cash USD(t) − Cash EUR(t)	Cash USD(t) − Cash JPY(t)	Inflation(t)	Nom bonds(t)	IL bonds(t)	Div. yield(t)	Equities(t)
Cash USD(t)	1.00							
Cash USD(t) − Cash EUR(t)	0.20	1.00						
Cash USD(t) − Cash JPY(t)	−0.03	0.35	1.00					
Inflation(t)	0.21	0.02	0.04	1.00				
Nom bonds(t)	−0.27	−0.13	0.02	−0.17	1.00			
IL bonds(t)	−0.47	−0.00	0.01	−0.03	0.68	1.00		
Div. Yield(t)	0.37	0.18	−0.16	0.08	−0.17	−0.21	1.00	
Equities(t)	−0.58	−0.39	0.06	−0.04	0.38	0.39	−0.71	1.00

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