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A historical examination of optimal real return portfolios for non-US investors

Salvatore Bruno [a,1], Ludwig Chincarini [a,b,*]

[a] IndexIQ, 800 Westchester Avenue, Suite N-611, Rye Brook, NY 10573, United States
[b] Department of Economics, Pomona College, 425 N. College Avenue #211, Claremont, CA 91711, United States

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ABSTRACT

The objective of this paper is to explore and identify inflation as it is embedded in a broad range of asset classes beyond simply TIPS, oil, gold and real estate. The analysis is conducted primarily from the perspective of investors in a range of countries that span the developed and emerging world including resource intense economies and those that have previously experienced hyperinflation. We find that an investor who is looking for a reasonable positive real return of 4.5% while minimizing the downside risk with respect to inflation will have an allocation that consists primarily of short-term bonds, longer-term bonds, some gold, some oil, and some emerging market equities. The weight of gold and oil together is less than 10% of the portfolio and is not always relevant for all countries. We find that achieving stable real returns during hyperinflationary periods is virtually impossible without access to a vast array of short-term fixed income instruments. Despite this, the out-of-sample performance of the real return optimizations is quite promising, providing an emulative inflation protection strategy for international investors of all sorts.

1. Introduction

In order to alleviate some of the effects of the financial crisis of 2007–2008, the Federal Reserve as well as other central banks worldwide has lowered interest rates close to zero levels and has been using other mechanisms to supply the markets with liquidity. One of the worries that market participants have is that this will eventually lead to higher inflation. Although the short-term numbers suggest that we are in a period of deflation, driven in part by the reduction in housing values, transportation, and commodity prices, there is still a danger that inflation may come in the future.[2] Whether we have inflation in the near future or not, it brings up the question of what the average investor should do to hedge against inflation or rather what is the best way to achieve a positive real return.

Despite this being such an important question to investors, there is relatively little quantitative research aimed at answering this question (Mukherji, 2003; Chua, 1999; Attié & Roache, 2009). There are probably several reasons for this. First, any attempt to maximize real returns is effectively the same as maximizing nominal returns. Of course, there is a lot of research on this question. Recent research includes Rapach and Wohar (2009), Bai and Green (2010), You and Daigler (2010), Driessen and Laeven (2007), and Alexander and Baptista (2006). Second, there is very little theoretical work on the asset classes and the proportion of those asset classes in one's portfolio that should be good inflation hedges. Third, it might be very hard to find statistical models that provide a good hedge against inflation in all periods (for example, high inflationary and low inflationary periods).

There has been a small literature dedicated to using asset returns to forecast macroeconomic variables, such as inflation, and these studies find that there is some forecasting ability of the markets (Adrangi et al., 1999; Bodie, 1976; Lamont, 2001; Campbell and Ammer, 1993; Cozier & Rahman, 1988; Fama, 1975; Hayes, 2001; Titman & Warga, 1989). Our paper approaches the issue from a different perspective.

First, we do not attempt to forecast inflation. Rather, we attempt to discover which assets provide the best hedge against inflation contemporaneously. Second, we use a class of asset returns and attempt to find the relation between inflation and these asset classes over a variety of historical investment periods beginning in 1930 for many countries. Third, we investigate the hedging approach by finding the optimal portfolio which minimizes the tracking error of the portfolio versus inflation while providing a given real return (the portfolio approach).

We study the asset class hedges for a wide variety of countries, including Argentina, Australia, Brazil, Chile, France, Germany, Hong

* Corresponding author. Department of Economics, Pomona College, 425 N. College Avenue #211, Claremont, CA 91711, United States. Tel.: +1 909 621 8881; fax: +1 909 621 8576.
E-mail addresses: sbruno@indexiq.com (S. Bruno), chincarinil@hotmail.com (L. Chincarini).
[1] Tel.: +1 914 697 4962; fax: +1 914 697 4995.
[2] As Milton Friedman stated "inflation is always and everywhere a monetary phenomenon".

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Kong, India, Italy, Japan, Mexico, Peru, Singapore, South Korea, Spain, UK, and the USA.[3] We chose the countries both for geographical representation, as well as to represent countries with a varying degree of inflation histories.

The paper is organized as follows: Section 2 discusses the methodology for constructing optimized portfolio inflation hedges as well as the data used in the paper; Section 3 discusses the empirical results; and Section 4 concludes.

2. Construction of inflation hedges

2.1. Theoretical considerations

There is surprisingly very little theoretical work on what sorts of asset classes might be natural hedges against inflation. Brennan and Xia (2000) have a simple theoretical model that the optimal strategy consists of investments in cash, equity, and a single nominal bond with an optimally chosen maturity. Several other authors have constructed models that relate monetary policy to inflation and the stock market, including Stulz (1986), Bakshi and Chen (1996), and Hess and Lee (1999). With the exception of these articles, much of the work has been empirical.

The stock market measures the present discounted value of dividends or profits. To the extent that inflation pushes all prices up, one might expect that the future dividends will be bid up too as future profits in nominal terms and hence prices will keep pace with inflation. Naturally, there are certain types of inflation that may hinder the functioning of the economy and/or cause firms to reduce their margins, which then might offset this. Inflation may also affect sectors of the equity market differently.

The academic literature has been focused on how stock returns relate to inflation, but there is disagreement on the direction. This includes work on money illusion and taxes (Modigliani & Cohn, 1979; Hendershott 1981; Summers, 1981). There has been a small amount of papers dedicated to studying the relationship between inflation and inflation hedging within the context of the stock market, including Modigliani and Cohn (1979) and Reilly et al. (1970).

A common perception is that gold is a good hedge against inflation. There are several common reasons used to explain this. First, if everyone believes that gold is a good hedge, then it will tend to rise as demand for gold rises with expected oncoming inflation. Second, for a US investor, if inflation is accompanied by the depreciation of one's currency, then the price of a fixed asset in terms of USD will tend to rise as the currency depreciates. This might not be true for investors of other countries, however. Third, we might expect other commodities to be a hedge against inflation, since sometimes inflation is supply-side driven and as inputs to production rise, so does inflation. When inflation is of this kind, one might expect that commodity prices will rise along with the consumer price index (CPI).

A strand of empirical literature has focused on the relationship between commodities and inflation. Early work showing the importance of commodities for hedging inflation includes Greer (1978) and Bodie (1983). Froot (1995) finds that contrary to perceived wisdom, real estate indices provide relatively weak-hedges for diversified portfolios, while commodities with a high energy component enhance the return–risk tradeoff. Anson (1998) shows that adding commodity futures to a standard stock and bond portfolio can move the efficient frontier outwards. Strongin and Petsch (1997) have shown that a commodity index does well relative to stock and bonds during periods of rising inflation. Ankrim and Hansel (1993) find that adding the Goldman Sachs Commodity Index (GSCI) improved the return–risk characteristics of a bond and equity portfolio. Schneeweis and Spurgin (1997) and Halpern and Warsager (1998) find that energy-based commodity index products provide better returns than traditional asset classes during periods of high inflation. Gorton and Rouwenhorst (2006) also show that commodity futures returns are more highly correlated with inflation than stocks and bonds especially over longer horizons of 1–5 years.

Short-term government bonds or short-term bank deposits might also serve as a good hedge (Patel and Zeckhauser, 1987). The argument is that this cash is given a fixed interest rate for a short period of time. The interest rate will have expected inflation built into it. To the extent that there is unexpected inflation, the rates will adjust for the next period of investment and since each period of investment is so small, the investor has a better chance of keeping up with both expected and unexpected inflation, even if with a delay.

In particular, inflation protected bonds are thought of to be good investments against inflation. In fact, several advisors have noticed a massive flood of money into US Treasury Inflation Protected Securities (TIPS)-related funds in 2009. These instruments promise a real return to investors. Thus, if inflation is higher than expected, the bonds adjust their interest payments to keep the investor's real return at the expected level. A principle of all fixed income instruments is that their prices are affected by movements in interest rates. Thus, if an inflation protected security is held to maturity, it will provide a desired real return, however its actual return in any sub-period may be much more volatile and fluctuate quite dramatically as interest rates change. Thus, depending on an investor's goals and investment horizon, inflation protected bonds may or may not be the best inflation protecting investment.

In the context of inflation protected securities, in particular TIPS, there is a series of papers that study the impacts of these instruments on one's investment portfolio, including Hunter and Simon (2005), Mamun and Visaltanachoti (2006), Roll (2004), and Siegal and Waring (2004). The empirical papers closest to our work that attempt to study this relationship on a broader set of asset classes include Siegal and Waring (2004) and Mustafa and Nishat (2008).

Real estate has always been thought of as a good hedge for inflation, since as the prices of goods in the economy rise, so will the prices of relatively scarce goods, such as land. Thus, one would think that real estate would make a good inflation hedge.

Finally, foreign exchange might be a particularly good hedge for hyperinflationary countries. A country that is experiencing hyperinflation will find it difficult to find many asset classes that keep up with their inflation. In these hyperinflation countries the exchange rate is either depreciating fast or devalued in large lumps very frequently. In fact, one of the best decisions might be to hold one's money in a stable, safe currency like the USD. This is equivalent to shorting one's own currency.

2.2. Data considerations

Due to natural data limitations, the choice of the historical data horizon and the instruments will be related, since some instruments simply do not have a long history. In theory, we would like to use a historical data horizon as large as possible so as to capture as many inflationary periods for each country that existed. In practice, this is very difficult since most of our main asset classes lack history prior to1970. Thus, in this paper, we have chosen to use several historical data horizons. The first time period (starting January 1930) was selected as it covers the deflationary period from the inception of the Great Depression of the 1930s. Over the 39 month period from January 1930 to March 1933, the CPI for the United States fell over 26%. Many European countries also experienced significant deflation during the 1930s. The second time period (starting January 1970) was selected to coincide with the move from the gold standard and fixed exchange rate system in place from the end of World War II to the floating exchange rate system starting in 1971–1973. This period also

[3] For details on China and Russia which did not have sufficient sample periods for this study, please see Bruno and Chincarini (2010).

Table 1
The currency returns used for various countries.

Country	Local currency code	FX1	FX2	FX3
Argentina	ARS vs.	USD	BRL	MXN
Australia	AUD vs.	USD	JPY	EUR
Brazil	BRL vs.	USD	ARS	MXN
Chile	CLP vs.	USD	BRL	MXN
France	FRF vs.	USD	EUR	GBP
Germany	DEM vs.	USD	EUR	GBP
Hong Kong	HKD vs.	USD	CNY	JPY
India	IND vs.	USD	CNY	JPY
Italy	ITL vs.	USD	EUR	GBP
Japan	JPY vs.	USD	EUR	CNY
Mexico	MXN vs.	USD	ARS	BRL
Peru	PEN vs.	USD	MXN	BRL
Singapore	SGD vs.	USD	JPY	CNY
South Korea	KRW vs.	USD	JPY	CNY
Spain	ESP vs.	USD	EUR	GBP
United Kingdom	GBP vs.	USD	EUR	JPY
United States	USD vs.	JPY	EUR	GBP

Note: the acronyms for the currencies are the following: BRL for Brazilian Real, JPY for Japanese Yen, ARS for Argentine Peso, EUR for the Euro, MXN for the Mexican peso, and CNY for China Renminbi.

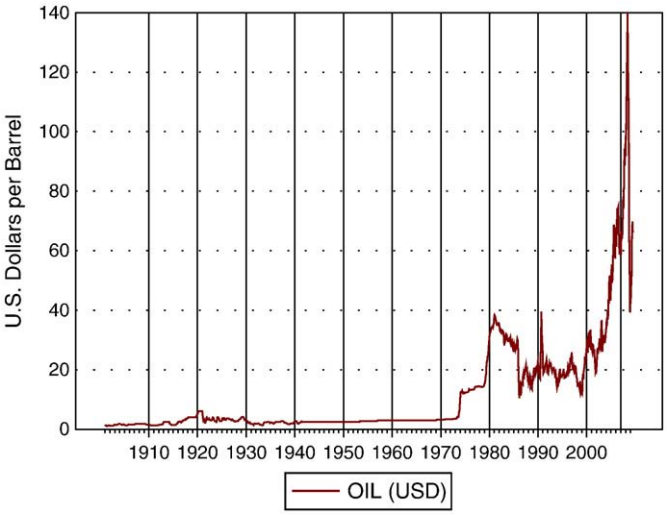

Fig. 1. West Texas intermediate oil prices ($ per Barrel).

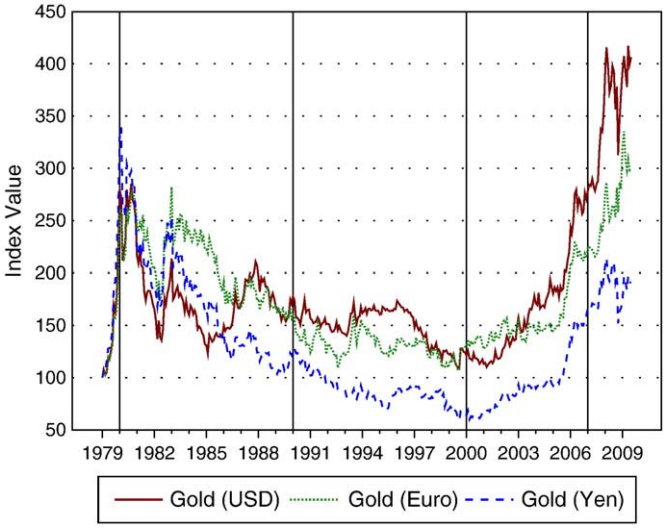

Fig. 2. Gold index in three reference currencies (USD, EUR, and YEN).

contains the period of stagflation in the late 1970s. Amongst all the major asset classes, we use all relevant data for any country provided that it existed at the beginning of our starting period.[4]

Unfortunately, for many countries some seemingly important series are missing for the longer time periods. For example, we could only find housing related data from 1989 for most countries and even in the best case, the US, we only found it from 1972. For each country, we also use three exchange rates which are described in Table 1. Each country's currency against the dollar and two of their most proximate trading partners were chosen.

The data for this study was obtained from multiple data sources including Global Financial Data (GFD), Bloomberg L.P., the National Association of Real Estate Investment Trusts (NAREIT), and Factset Research Systems (FRS). We obtained central bank interest rates, LIBOR[5], commercial paper yields, commodity indices, commodity prices, consumer price indices, stock indices, total return stock indices, and wholesale price indices from GFD. We obtained equity sector returns for each country and exchange rates from Factset. We obtained inflation protected fixed income securities from Bloomberg and Lehman TIPS indices from FactSet. We obtained real estate investment trust returns from NAREIT. More details on the data we used can be found in Appendix A to this paper.

Wherever possible, total return indices are used. All index values are transformed into percentage change for comparability with the inflation series. For the purposes of this paper, the rate of inflation is reported as the Year-on-Year (YoY) change in an inflation index, usually represented by a government reported measure of consumer prices. The use of the year-on-year inflation number is also to reduce seasonal and cyclical effects present in inflation numbers. To remain consistent with this convention, all of the returns of assets in this paper are computed on a year-on-year basis. All returns for asset classes endemic to the country being analyzed have been extracted in local currency terms. Returns for global asset classes that are reported in U.S. Dollars (global equity, global bonds, emerging market equities, emerging market bonds, and commodities) have been converted to local currency using the prevailing exchange rate consistent with the time period of the asset return.

While gathering the raw data from multiple sources and extending back to 1930, there were several data issues that needed to be addressed and others which might be relevant to highlight. First, many series for various countries did not exist or started much too late to be included in the analysis. Second, some countries, such as Australia report consumer price inflation quarterly, thus, we filled in all three months of that quarter with the same value of the CPI variable.[6]

Third, the oil price series that we use in this paper (West Texas Intermediate Oil) did not fluctuate very much and was constant for many months from 1919 until the 1970s. This was primarily due to two organizations. From 1919 until later in the century, the Texas Railroad Commission was widely believed to set oil prices for the world.[7] Later in the century, there was also oil price fixing by OPEC

[4] In a working paper, Bruno and Chincarini (2010) also consider the time periods starting in January 1901 so as to evaluate the long term relationship between the variables selected and inflation, as well as the time period starting in January 1990 so as to include real estate variables and to examine any differences after the end of the Cold War.

[5] For all countries, we use a LIBOR rate when available. For the United States, we do not use LIBOR, rather we use the 1-month CD rate.

[6] While this might have an effect on the results, we felt that it was the only solution to keeping the data comparable to the other countries. Further research might examine whether the results change significantly by performing the same estimation on quarterly data.

[7] The Texas Railroad Commission (TRC) evolved from its founding in 1891 to a multi-divisional regulatory commission that oversaw not only railroads but also a number of other industries central to the modern American economy: petroleum production, natural gas utilities, and motor carriers.

Table 2
Inflation and nominal returns of asset classes in various countries.

Country	Nobs	Inflation		Equities	Fixed income				Real estate	Commodities			
		CPI	PPI	Main	Govt.	Corp.	H. Yield	I.P.	Main	Gold	Silver	Oil	Wheat
1930													
Argentina	953.00	180.73	174.63	.	.	.	.	.	.	.	.	.	.
Australia	953.00	4.71	4.64	7.40	.	.	.	.	.	.	.	.	.
Brazil	953.00	181.69	.	.	.	.	.	.	.	.	.	.	.
Chile	953.00	38.62	55.24	.	.	.	.	.	.	.	.	.	.
France	953.00	8.50	7.77	.	.	.	.	.	.	.	.	.	.
Germany	953.00	2.32	.	9.78	.	.	.	.	.	.	.	.	.
Hong Kong	.	.	.	.	.	.	.	.	.	.	.	.	.
India	953.00	5.91	6.90	.	.	.	.	.	.	.	.	.	.
Italy	953.00	12.91	12.08	17.76	.	.	.	.	.	.	.	.	.
Japan	953.00	14.40	13.90	16.06	6.53	.	.	.	.	.	.	.	.
Mexico	953.00	17.68	16.58	.	.	.	.	.	.	.	.	.	.
Peru	953.00	174.45	.	200.72	.	.	.	.	.	.	.	.	.
Singapore	.	.	.	.	.	.	.	.	.	.	.	.	.
South Korea	.	.	.	.	.	.	.	.	.	.	.	.	.
Spain	953.00	7.48	6.98	.	.	.	.	.	.	.	.	.	.
UK	953.00	4.52	5.04	7.15	.	.	.	.	.	.	.	.	.
USA	953.00	3.32	.	11.13	5.69	7.05	.	.	.	6.67	8.03	7.47	.
1970													
Argentina	473.00	347.69	334.69	.	.	.	.	.	.	382.10	373.40	429.53	360.99
Australia	473.00	6.06	5.68	8.22	.	.	.	.	.	12.22	12.03	14.72	7.68
Brazil	473.00	345.43	351.65	417.47	.	.	.	.	.	320.43	325.96	321.36	307.04
Chile	473.00	55.74	88.37	.	.	.	.	.	.	100.51	102.85	123.72	100.29
France	473.00	5.05	4.07	.	.	.	.	.	.	10.55	10.73	14.79	7.40
Germany	473.00	2.98	.	6.63	.	.	.	.	.	7.88	7.84	11.81	4.81
Hong Kong	473.00	5.87	.	.	.	.	.	.	.	11.77	11.83	14.82	8.24
India	473.00	7.93	7.60	.	.	.	.	.	.	16.00	15.71	19.18	12.79
Italy	473.00	7.68	7.58	13.46	.	.	.	.	.	13.33	13.36	17.38	10.08
Japan	473.00	3.23	1.89	8.83	6.57	.	.	.	.	8.27	9.10	12.21	4.76
Mexico	473.00	27.92	27.53	57.30	.	.	.	.	.	39.33	39.97	39.37	32.72
Peru	473.00	343.19	.	403.21	.	.	.	.	.	130.42	125.13	152.70	144.01
Singapore	473.00	3.09	.	11.81	.	.	.	.	.	8.79	8.81	11.82	5.08
South Korea	473.00	8.22	7.11	.	20.07	.	.	.	.	16.36	15.88	18.19	11.55
Spain	473.00	8.09	6.53	.	.	.	.	.	.	12.60	12.61	15.99	8.89
UK	473.00	6.29	6.14	9.52	10.31	.	.	.	.	11.98	11.67	15.38	8.77
USA	473.00	4.63	4.03	11.01	8.85	9.76	.	.	.	11.33	11.06	14.24	7.71
1990													
Argentina	233.00	381.79	336.08	.	.	.	.	.	.	317.33	274.91	359.48	274.29
Australia	233.00	2.87	2.45	6.21	.	.	.	.	.	5.57	6.75	10.91	5.28
Brazil	233.00	530.42	541.96	592.85	.	.	.	.	.	480.90	495.31	473.33	449.21
Chile	233.00	7.07	8.84	.	.	.	.	.	.	9.67	10.45	15.53	9.46
France	233.00	1.87	0.70	6.18	.	.	.	.	.	3.84	5.35	10.02	3.99
Germany	233.00	2.03	.	6.46	.	.	.	.	.	3.90	5.41	10.12	4.06
Hong Kong	233.00	3.35	.	.	.	.	.	.	.	5.32	6.68	11.66	5.88
India	233.00	7.43	6.72	.	.	.	.	.	.	11.32	12.57	17.13	11.91
Italy	233.00	3.31	3.10	8.69	.	.	.	.	.	5.63	7.20	11.65	5.70
Japan	233.00	0.55	0.06	−1.46	4.56	4.34	.	.	.	3.87	5.37	9.68	4.57
Mexico	233.00	13.12	12.72	29.90	.	.	.	.	.	15.52	16.55	21.74	16.54
Peru	233.00	413.21	368.63	535.92	.	.	.	.	.	72.34	66.47	90.33	61.11
Singapore	233.00	1.76	0.83	7.26	4.07	.	.	.	.	3.58	5.07	9.41	3.81
South Korea	233.00	4.50	2.65	.	12.73	.	.	.	.	9.15	10.87	14.08	9.09
Spain	233.00	3.72	2.72	9.22	.	.	.	.	.	5.68	7.36	11.62	5.66
UK	233.00	2.60	2.30	5.06	8.52	.	.	.	.	5.73	6.72	11.19	5.89
USA	233.00	2.88	2.28	9.72	8.21	7.88	8.10	.	11.22	5.35	6.70	11.66	5.89

Note: this table reports mean returns for various asset classes in various countries from the beginning of the listed period until May 2009. Means are reported in percentage terms.

(Organization of the Petroleum Exporting Countries). The price of oil began to fluctuate more during and after the 1970s (see Fig. 1).

Fourth, due to the fixed exchange rate system based on the gold standard that was in place in many countries until the early 1970s, the spot price of Gold went through sustained periods where it did not change. For example, the price of Gold was $20.67 from before 1900 until 1933 when it was reset, over a 12 month period, to $35. The price remained in a range between $35 and $40 from 1935 until 1971.

Fifth, another interesting point that can be seen from this graph is that gold is not always an inflation hedge depending on an investor's reference currency. The typical analysis of gold is from a very US-centric position. Fig. 2 shows the index of gold with respect to the dollar, yen, and euro. One can easily see that the movement of gold prices in different base currencies is different. Thus, while gold might be a hedge against inflation at times for a US investor, it might not be for investors in other countries.

Sixth, the Euro became the common currency for the European Union in January of 1999. From January 1985 until the advent of the Euro in 1999, the ECU (European Currency Unit) represented the returns of a European currency and thus we include the ECU returns in the Euro time series from 1985 to 1999. Prior to 1985, there was no common currency. However, as the currencies that form the European Union are represented proportionately by their economic size (e.g. GDP), we use the currency return of the largest country (German Deutschemark) to represent the EU prior to 1985. For the currencies that were replaced by the Euro in 1999 (i.e. the German Deutschemark, French Franc, Italian Lira, and the Spanish Peseta) the monthly percent changes reflect the change in the Euro from the time that the country switched to the Euro.

Table 3
Correlation of asset classes with cpi inflation in various countries.

Country	Nobs	Inflation	Equities	Fixed income				Real Estate	Commodities			
		PPI	Main	Govt.	Corp.	H. Yield	I.P.	Main	Gold	Silver	Oil	Wheat
1930												
Argentina	953.00	0.98	.	.	.	.	.	.	.	.	.	.
Australia	953.00	0.83	−0.02	.	.	.	.	.	.	.	.	.
Brazil	953.00	.	.	.	.	.	.	.	.	.	.	.
Chile	953.00	0.91	.	.	.	.	.	.	.	.	.	.
France	953.00	0.91	.	.	.	.	.	.	.	.	.	.
Germany	953.00	.	0.02	.	.	.	.	.	.	.	.	.
Hong Kong	.	.	.	.	.	.	.	.	.	.	.	.
India	953.00	0.83	.	.	.	.	.	.	.	.	.	.
Italy	953.00	0.94	0.31	.	.	.	.	.	.	.	.	.
Japan	953.00	0.93	−0.03	−0.06	.	.	.	.	.	.	.	.
Mexico	953.00	0.97	.	.	.	.	.	.	.	.	.	.
Peru	953.00	.	0.95	.	.	.	.	.	.	.	.	.
Singapore	.	.	.	.	.	.	.	.	.	.	.	.
South Korea	.	.	.	.	.	.	.	.	.	.	.	.
Spain	953.00	0.56	.	.	.	.	.	.	.	.	.	.
UK	953.00	0.80	0.11	.	.	.	.	.	.	.	.	.
USA	953.00	.	0.05	−0.09	−0.03	.	.	.	0.30	0.28	0.36	.
1970												
Argentina	473.00	0.98	.	.	.	.	.	.	0.68	0.64	0.67	0.69
Australia	473.00	0.89	−0.06	.	.	.	.	.	0.34	0.21	0.33	0.05
Brazil	473.00	1.00	0.72	.	.	.	.	.	0.97	0.93	0.97	0.94
Chile	473.00	0.91	.	.	.	.	.	.	0.75	0.75	0.75	0.69
France	473.00	0.64	.	.	.	.	.	.	0.42	0.28	0.35	0.15
Germany	473.00	.	−0.13	.	.	.	.	.	0.37	0.24	0.32	0.26
Hong Kong	473.00	.	.	.	.	.	.	.	0.32	0.27	0.23	0.30
India	473.00	0.80	.	.	.	.	.	.	0.40	0.25	0.37	0.26
Italy	473.00	0.80	0.09	.	.	.	.	.	0.44	0.31	0.32	0.12
Japan	473.00	0.82	−0.02	−0.05	.	.	.	.	0.37	0.25	0.50	0.21
Mexico	473.00	0.99	0.54	.	.	.	.	.	0.61	0.53	0.50	0.63
Peru	473.00	.	0.94	.	.	.	.	.	0.61	0.57	0.66	0.47
Singapore	473.00	.	−0.10	.	.	.	.	.	0.45	0.31	0.57	0.45
South Korea	473.00	0.89	.	0.23	.	.	.	.	0.41	0.30	0.44	0.12
Spain	473.00	0.88	.	.	.	.	.	.	0.39	0.24	0.24	0.11
UK	473.00	0.92	0.14	0.20	.	.	.	.	0.33	0.25	0.29	0.01
USA	473.00	0.91	−0.12	−0.33	−0.34	.	.	.	0.44	0.35	0.47	0.13
1990												
Argentina	233.00	0.98	.	.	.	.	.	.	0.68	0.70	0.66	0.69
Australia	233.00	0.73	−0.26	.	.	.	.	.	0.24	−0.17	0.29	0.09
Brazil	233.00	1.00	0.70	.	.	.	.	.	0.97	0.93	0.97	0.94
Chile	233.00	0.43	.	.	.	.	.	.	−0.10	−0.06	0.18	0.08
France	233.00	0.04	−0.26	.	.	.	.	.	−0.02	−0.18	0.13	0.10
Germany	233.00	.	0.02	.	.	.	.	.	0.01	0.07	−0.06	0.20
Hong Kong	233.00	.	.	.	.	.	.	.	−0.22	−0.12	−0.24	−0.02
India	233.00	0.62	.	.	.	.	.	.	0.12	0.05	−0.26	0.16
Italy	233.00	0.54	−0.31	.	.	.	.	.	−0.15	−0.23	−0.10	0.06
Japan	233.00	0.36	−0.27	0.18	0.19	.	.	.	−0.28	−0.20	−0.16	−0.22
Mexico	233.00	0.97	0.17	.	.	.	.	.	0.21	0.13	0.23	0.28
Peru	233.00	1.00	0.96	.	.	.	.	.	0.69	0.65	0.76	0.58
Singapore	233.00	0.18	−0.08	0.02	.	.	.	.	−0.05	−0.16	0.10	0.09
South Korea	233.00	0.48	.	−0.04	.	.	.	.	0.14	0.14	−0.08	0.04
Spain	233.00	0.37	−0.27	.	.	.	.	.	−0.07	−0.12	0.09	0.10
UK	233.00	0.51	−0.04	0.29	.	.	.	.	−0.09	−0.25	−0.12	−0.04
USA	233.00	0.80	0.05	−0.03	0.02	−0.02	.	0.05	0.16	−0.04	0.48	0.04

Note: this table reports the correlation of asset class returns and PPI inflation with the CPI inflation of each country from the period of concern to May 2009.

The data is summarized in Tables 2 and 3. Table 2 lists the mean returns of key variables over 3 different time periods beginning in January 1930, January 1970, January 1990 and all ending in May 2009 for all countries included in the paper.[8] The key variables are CPI, the producer price index (PPI), broad equities, government bonds, corporate bonds, high yield bonds, IP (Inflation protected bonds), real estate, gold, silver, oil and wheat all in local currency terms. All of the variables are defined in Section A of the Appendix A. The number of observations with valid data is also noted for each country and each time period.

The reader will notice that for countries that experienced hyperinflation during the 1970–2009 and 1990–2009 time periods, that is, where the mean YoY change in CPI is very high (predominantly Latin American countries), the mean returns of certain assets denominated in their own currency are also very high. For example, while the price of gold in USD would have risen an average of 11.33% from 1970 to 2009, the price of gold denominated in Brazilian Real would have risen, on average, 320% reflecting the massive depreciation of the Brazilian currency over the same time period. The improving price stability across most countries is apparent by

[8] The mean return is the average monthly value of the year-on-year percentage changes of the variables.

comparing the 1970 and 1990 panels reflecting the greater emphasis on price stability by the world's central banks. For example, the average YoY change in CPI for the United States went from 4.63% from 1970–2009 to 2.88% from 1990–2009.

Table 3 has a similar structure to Table 2 in terms of time periods, countries and key variables however the data being displayed are the correlation of the year-on-year percentage changes of the variables with the year-on-year percentage changes in the CPI. We note that PPI generally is very highly correlated with CPI. Also, the correlations tend to be higher for those countries with hyperinflation than for other countries. Countries that experience hyperinflation will typically experience a very large depreciation (or an outright devaluation in the case of fixed exchange rate regimes) of their currencies. This makes the price level of the asset variables higher as they become more expensive to buy using the depreciated currency. Thus hyperinflation leads to high correlations between inflation and the price level of the assets denominated in that currency. Again, this predominantly affects the Latin America countries.

For most other countries, the correlation of most asset classes to CPI is relatively low or negative. For example, the correlation of the YoY change in CPI with the 12 month return of the US Stock index is 0.05 from 1990 to 2009. A similar pattern holds for other countries and other asset classes. However, the opposite is true when looking at oil and gold where we see some higher positive correlations to the YoY change in CPI. Again, looking at the United States, the correlations of oil and gold to the YoY change in CPI from 1990 to 2009 are 0.16 and 0.48 respectively. This is consistent with the general notion that gold and perhaps oil might serve as good inflation hedges for investors. We note that the relationship between PPI and CPI appears to have become weaker as we moved from the 1970s period to the 1990s period. This is true across all countries. We also note that correlation of commodity asset classes with CPI decreased and in some case became negative over the 1990–2009 period as opposed to the 1970–2009 period. Although we cannot precisely say why this occurred, we postulate that most of the inflation shocks of the 1970s were supply-side shocks from OPEC's oil cartel, thus making for a higher correlation between oil and some of the other commodities in the earlier period.

2.3. Generating real return portfolios

Since the concern of most investors will be to find a combination of assets that provide a sufficient real return while protecting the portfolio on the downside versus inflation, we chose to create a set of mean–variance optimized portfolios.

In order to make the objective function of an investor related to inflation, we need to specify one that incorporates an investor's preoccupation with inflation. One such objective function would be to

Table 4
Asset class real return optimizations by European region and the USA.

	France		Germany		Italy		Spain		UK		USA	
	1930-	1970-	1930-	1970-	1930-	1970-	1930-	1970-	1930-	1970-	1930-	1970-
Real return target	−1.55	4.50	4.50	4.50	4.50	4.50	−0.50	4.50	2.63	4.50	4.50	4.50
Asset class												
Equity index	.	.	37.97	0.00	96.00	0.00	.	.	100.00	0.00	9.16	0.00
Small-cap	.	.	.	.	.	.	.	.	.	.	.	.
Value	.	.	.	.	.	.	.	.	.	.	.	.
Growth	.	.	.	.	.	.	.	.	.	.	.	.
S. CD	.	.	.	.	.	.	.	.	.	.	.	.
S. CS	.	.	.	.	.	.	.	.	.	.	.	.
S. energy	.	.	.	.	.	.	.	.	.	.	.	.
S. finance	.	.	.	.	.	.	.	.	.	.	.	.
S. Health	.	.	.	.	.	.	.	.	.	.	.	.
S. Indust.	.	.	.	.	.	.	.	.	.	.	.	.
S. IT	.	.	.	.	.	.	.	.	.	.	.	.
S. material	.	.	.	.	.	.	.	.	.	.	.	.
S. telcomm	.	.	.	.	.	.	.	.	.	.	.	.
S. utility	.	.	.	.	.	.	.	.	.	.	.	.
Bill govt.	0.00	52.85	28.06	39.34	0.00	64.45	100.00	14.62	0.00	0.00	9.72	0.00
10-yr govt.	.	.	.	.	.	.	.	.	.	25.40	0.17	0.00
30-yr govt.	100.00	27.63	33.98	44.03	4.00	7.58	.	47.22	.	.	0.00	0.00
Corp. bond	.	.	.	.	.	.	.	.	.	.	54.31	26.60
HY bond	.	.	.	.	.	.	.	.	.	.	.	.
IP bond	.	.	.	.	.	.	.	.	.	.	.	.
Commodity	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
Oil	.	5.81	.	4.76	.	6.53	.	10.53	.	4.88	9.39	6.13
Gold	.	6.04	.	3.29	.	6.77	.	8.27	.	4.28	0.99	3.92
Silver	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	2.06	0.00
Wheat	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
FX1	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
FX2	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
FX3	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
LIBOR	.	.	.	.	.	.	.	.	.	59.17	.	53.73
R. estate	.	.	.	.	.	.	.	.	.	.	.	.
World eq.	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	0.00	0.00
World bond	.	0.00	.	0.00	.	1.20	.	0.00	.	0.00	0.00	0.00
Emerge eq.	.	7.67	.	8.59	.	13.46	.	19.35	.	6.27	14.21	9.63
Emerge bond	.	.	.	.	.	.	.	.	.	.	.	.
Tracking error	19.3	4.5	13.1	4.0	49.3	6.2	9.0	9.3	20.0	4.3	8.3	4.3
Return/risk	−0.08	1.00	0.34	1.13	0.09	0.72	−0.06	0.48	0.13	1.05	0.54	1.05

Note: the asset class weights are the weights from an optimization to minimize the portfolio returns monthly tracking error with inflation, while producing the desired real return target listed. The weights of the asset classes are constrained to be greater than 0 (i.e. no shorting) and the weights must sum to 1 (i.e. fully-invested). Mathematically, the optimization is $min_w w'\Sigma w - 2w'\gamma$ s.t. $w'\mu = \bar{\mu}_P + \pi_{t,t+k}$. The . represents asset classes whose returns did not exist at the starting period, while 0.00 indicates an asset class whose data existed at the starting period, but the optimization led to a zero weighting. Tracking error represents the annualized tracking error of the portfolio versus inflation and Return/Risk represent the real return of the portfolio divided by the tracking error.

characterize an investor as wanting to maximize his real return subject to some minimization of the nominal return deviation from inflation. That is,

$$min\left[V\left(r_{P,t,t+k}-\pi_{t,t+k}\right)\right] \quad \text{s.t.} \quad r_{P,t,t+k}-\pi_{t,t+k} = \tilde{\mu}_P \tag{1}$$

where $r_{P,t,t+k}$ is the return of the investor's portfolio from time t to $t+k$, $\pi_{t,t+k}$ is the inflation rate from time t to $t+k$, and $\tilde{\mu}_P$ is the real return target of the portfolio.[9] We will want to select the group of assets for the investor that achieves this goal. Thus, the problem can be rewritten as:

$$\min_{w_i}\left[V\left(\sum_{i=1}^{N} w_{i,t}r_{i,t,t+k}-\pi_{t,t+k}\right)\right] \quad \text{s.t.} \quad \left(\sum_{i=1}^{N} w_{i,t}r_{i,t,t+k}-\pi_{t,t+k}\right) = \tilde{\mu}_P \tag{3}$$

We can write this in matrix notation as:[10]

$$\min_{\mathbf{w}} \mathbf{w}'\Sigma\mathbf{w}-2\mathbf{w}'\gamma \quad \text{s.t.} \quad \mathbf{w}'\mu = \tilde{\mu}_P + \pi_{t,t+k} \tag{4}$$

where Σ is the variance–covariance matrix of returns of the asset classes and inflation, $\mathbf{w}$ represents the weights of the portfolio of asset classes, and γ is an N-dimensional vector of the covariances between individual asset returns and the inflation rate over the horizon from t to $t+k$. That is,

$$\gamma = \begin{bmatrix} Cov(r_1, \pi_{t,t+k}) \\ \vdots \\ Cov(r_N, \pi_{t,t+k}) \end{bmatrix}, \tag{5}$$

where *Cov* represents the covariance function. In addition, constraints are added to prohibit short selling of asset classes and that the portfolio weights sum to 1. The reader should note that this is the same objective function as performing a mean–variance analysis on real returns.

The *investment horizon* also is critically important. An investor may care little or not at all about whether his portfolio beats inflation over a monthly horizon, but may be very concerned that it beat inflation over a 10 or 15 year horizon. For example, intuitively, someone who needs to protect their assets from inflation for the next 5 years might very well just purchase inflation protected bonds, while someone that cares to maximize a real return with some protection from inflation over 20 years might choose to invest in a balance of short-term treasuries, equities, and commodities. One may wish to look at many investment horizons. However, the longer the investment horizon, the less data points we will have to measure the out-of-sample effectiveness of a particular investing strategy. In this paper, we use a twelve month horizon to evaluate performance. That is, we attempt to hedge the investor's exposure to rolling twelve month inflation.[11]

Finally, we will have to consider the *estimation horizon*. For this study, we estimate the in-sample optimizations from the beginning of the period of 1930 or 1970 to May 2009. For the out-of-sample optimizations, we estimate from the beginning of the period (1930 or 1970) plus five additional years. This estimate is used to construct inflation hedges or portfolios for the next month. We then expand the estimation window forward by one month and re-estimate and form new hedges and portfolios. We continue this process until the very last month of April 2009. For example, the estimation period might be from January 1930 to December 1934. We use this data to construct the in-sample optimal portfolio weights. We then apply these weights for January 1935 and compute the real portfolio return. We then re-estimate the optimal weights using data from January 1930 to January 1935. We then use these optimal in-sample weights for the period February 1935 and so on and so forth. This is how we construct our out-of-sample portfolio performance.[12]

3. Empirical results

Since the focus of this paper is on non-US investors, we do not directly analyze the US investor case, however the results are presented as a benchmark to compare with.

3.1. European countries

3.1.1. In-sample results

3.1.1.1. Optimal weights. The in-sample optimizations for the five European countries are contained in Table 4. We focus on the 1970 weights. France has 53% in government bills, 28% in 30-year government bonds, 6% in oil, 6% in gold, and 7% in emerging equity. Germany has 39% in government bills, 44% in 30-year government bonds, 5% in oil, 3% in gold, and 9% in emerging equities. Italy has 64% in government bills, 8% in 30-year government bonds, 7% oil, 7% gold, 1% world bond, and 13% emerging equity. Spain has 15% government bills, 47% 30-year government bonds, 11% oil, 8% gold, and 19% emerging equity. The UK has 26% 10-year government bonds, 5% oil, 4% gold, 59% LIBOR, and 6% emerging equity. A consistent theme in all of these optimizations is the heavy presence of short-term bond instruments and the little amount of equity holdings.

3.1.1.2. Performance. Most of the optimization portfolios achieve their target returns with low volatility (see Table 5). For example, Germany achieves the 4.50% real return with a tracking error of 3.98%. The worst year-on-year underperformance of the portfolio versus inflation was −6.14%. The portfolio underperforms inflation about 12% of the monthly periods. Fig. 3 shows the optimized portfolio returns of Germany against the actual year-on-year inflation rate. The countries that do less well in terms of protecting the investor are Italy and Spain. We discuss these in more detail below.

In order to get a sense of the quality of these optimized results, we provide the real return statistics of three static investment strategies; an all equity position, a position consisting of 50% equities and 50% short-term government bills, and a position of 100% short-term government bills. These statistics are presented in Table 5 for the period from January 1970 to May 2009.

For Germany, an all equity position has a lower mean real return of 3.65% (versus 4.5%) and a standard deviation that is more than five times higher (22.52% versus 3.98%). The optimized portfolio also does better in terms of a fewer percentage of negative real returns (46% versus 13%). On the other extreme, a 100% bill position has a lower risk profile along some dimensions like standard deviation, but has a mean real return that is 44% of the optimal portfolio.

Since Italy and Spain's multi-asset approach did not look as impressive, it would make even more sense to compare against the static portfolios. For Italy, the average real return is achieved with a

[9] In cases where return distributions depart from normality, it may be more accurate to specify the investor's optimization problem in terms of minimizing downside-risk, rather than variance. one such choice is semi-variance as our measure of downside risk and thus the investor's objective function becomes:

$$\min_{w_i}\frac{1}{T}\sum_{j=1}^{T}\left[min\left(\sum_{i=1}^{N} w_{i,t}r_{i,t,t+k}-\pi_{t,t+k},0\right)^2\right] \quad \text{s.t.} \quad \left(\sum_{i=1}^{N} w_{i,t}r_{i,t,t+k}-\pi_{t,t+k}\right) = \tilde{\mu}_P$$

[10] See Chincarini and Kim (2006).

[11] In a working paper, we considered other horizons and did not find much change in the qualitative nature of the results.

[12] We did not include transaction costs for the monthly rebalanced portfolios.

Table 5
Real Return Portfolio Results for the European Region and USA.

Country	Period	Ex-Ante			Max		Min		Number $\leq\pi$	MAE	RMSE	Nobs
		Target	Mean	S.D.	Value	Date	Value	Date				
Multi-asset in-sample results												
France	1930	−1.55	−1.55	19.33	45.94	1935:01	−101.45	1948:02	42.92	12.12	19.38	953
France	1970	4.50	4.50	4.52	20.24	1993:08	−6.96	1975:02	14.16	5.02	6.37	473
Germany	1930	4.50	4.50	13.09	148.27	1948:06	−64.74	1949:06	34.21	9.40	13.84	953
Germany	1970	4.50	4.50	3.98	15.80	1993:08	−6.14	1970:06	12.47	5.08	6.01	473
Italy	1930	4.50	4.50	49.33	514.51	1947:04	−378.49	1944:12	42.60	28.67	49.51	953
Italy	1970	4.50	4.50	6.23	28.48	1993:08	−19.10	1975:02	19.87	5.97	7.68	473
Spain	1930	−0.50	−0.50	8.96	19.02	1932:12	−67.94	1940:03	43.34	5.24	8.97	953
Spain	1970	4.50	4.50	9.33	37.79	1993:08	−21.46	1975:02	34.04	8.05	10.35	473
UK	1930	2.63	2.63	19.98	111.33	1975:12	−77.26	1974:11	42.29	15.75	20.14	953
UK	1970	4.50	4.50	4.29	14.87	2000:02	−12.67	1975:05	9.94	5.34	6.22	473
United States	1930	4.50	4.50	8.34	45.34	1933:06	−24.54	1947:05	24.66	7.23	9.47	953
United States	1970	4.50	4.50	4.30	15.43	2000:02	−11.69	2008:10	13.11	5.12	6.22	473
Multi-asset out-of-sample results												
France	1930	6.39	−1.95	9.84	17.03	1949:01	−27.14	1946:08	47.14	1.76	2.84	893
France	1970	4.50	4.40	4.51	5.63	1988:01	−3.74	1987:09	39.71	1.02	1.35	413
Germany	1930	4.48	3.13	11.18	32.04	1949:10	−62.42	1948:07	42.67	1.55	3.23	893
Germany	1970	4.50	4.35	4.45	5.45	1970:07	−4.35	1981:02	38.26	1.01	1.33	413
Italy	1930	3.86	3.52	32.69	58.82	1948:04	−144.58	1944:01	47.48	5.40	9.44	893
Italy	1970	4.50	3.95	5.10	6.19	1992:09	−4.78	1987:10	40.44	1.16	1.51	413
Spain	1930	2.20	−0.84	6.28	5.42	1930:05	−47.67	1939:07	42.78	0.66	1.81	893
Spain	1970	4.50	5.04	9.40	19.72	1977:07	−8.07	1987:09	44.55	2.02	2.74	413
UK	1930	1.75	2.15	16.59	49.98	1970:01	−27.09	1987:10	41.10	3.23	4.79	893
UK	1970	4.50	4.42	5.19	5.87	1979:09	−4.42	1987:10	41.16	1.16	1.54	413
United States	1930	4.50	3.52	6.83	8.49	2009:05	−10.97	1980:03	40.87	1.45	1.99	893
United States	1970	4.50	3.38	3.92	4.81	2009:05	−5.03	2008:10	38.01	0.87	1.16	413
Static portfolios and optimized with equities, bonds, and bills												
France	100% Bill	.	2.69	2.90	9.32	1992:11	−2.77	1979:08	19.03	3.11	3.95	473
France	IS Equity/Bill/Bond†	4.50	4.50	10.30	38.14	1986:08	−28.09	1980:03	32.77	8.81	11.22	473
France	OS Equity/Bill/Bond†	2.77	4.42	4.91	6.62	1988:01	−4.33	1989:02	36.56	1.03	1.46	413
Germany	100% Equity	.	3.65	22.52	72.26	1986:04	−53.23	2003:03	45.67	18.11	22.79	473
Germany	50/50 Equity/Bill	.	2.86	11.34	38.49	1986:04	−25.67	2003:03	41.44	18.11	11.69	473
Germany	100% Bill	.	2.08	1.87	8.15	1991:01	−3.35	1972:12	12.26	2.35	2.79	473
Germany	IS Equity/Bill/Bond	4.50	4.50	7.18	20.26	1986:04	−13.20	1980:03	26.85	7.03	8.46	473
Germany	OS Equity/Bill/Bond	3.96	4.70	5.74	6.50	1980:04	−7.79	1981:02	38.98	1.30	1.70	413
Italy	100% Equity	.	5.78	37.98	179.78	1981:05	−55.16	1974:10	46.30	27.40	38.38	473
Italy	50/50 Equity/Bill	.	4.11	19.37	90.47	1986:04	−34.39	1974:10	44.40	27.40	19.78	473
Italy	100% Bill	.	2.44	4.34	11.00	1993:03	−13.62	1974:10	22.41	3.98	4.97	473
Italy	IS Equity/Bill/Bond	4.50	4.50	17.05	60.33	1986:05	−45.81	1974:12	39.53	12.65	17.61	473
Italy	OS Equity/Bill/Bond	3.47	4.36	13.81	25.12	1986:03	−17.52	1981:09	43.34	2.32	4.00	413
Spain	100% Bill	.	1.18	4.93	9.61	1993:03	−15.74	1977:08	33.62	4.03	5.06	473
Spain	IS Equity/Bill/Bond†	2.29	2.29	11.42	40.85	1985:01	−24.14	1980:01	39.96	8.80	11.63	473
Spain	OS Equity/Bill/Bond†	2.40	2.37	3.92	3.14	1996:09	−8.13	1987:04	34.62	0.83	1.15	413
UK	100% Equity	.	3.23	21.94	111.33	1975:12	−77.26	1974:11	37.21	16.94	22.16	473
UK	50/50 Equity/Bill	.	2.75	11.42	48.49	1975:12	−41.71	1974:11	34.25	16.94	11.74	473
UK	100% Bill	.	2.27	4.47	8.97	1986:05	−16.30	1975:08	23.26	4.33	5.01	473
UK	IS equity/bill/bond	4.02	4.02	8.33	36.98	1982:10	−20.33	1980:04	26.85	7.44	9.24	473
UK	OS equity/bill/bond	3.37	2.60	14.09	13.55	1989:01	−27.09	1987:10	44.55	2.81	4.07	413
United States	100% equity	.	6.38	18.43	58.60	1983:06	−50.89	1974:09	31.71	16.03	19.49	473
United States	50/50 equity/bill	.	3.88	9.76	32.36	1983:06	−27.43	1974:09	31.71	16.03	10.50	473
United States	100% bill	.	1.38	2.47	7.56	1982:04	−4.34	1974:12	30.02	2.29	2.83	473
United States	IS equity/bill/bond	4.50	4.50	10.23	39.70	1983:06	−24.40	1974:09	36.36	8.51	11.17	473
United States	OS equity/bill/Bond	3.32	4.29	9.09	10.66	1984:08	−15.26	1987:10	43.34	1.84	2.65	413

Note: the table reports the in-sample and out-of-sample results for the multi-asset approach, for a static investment in various asset classes, and the in-sample and out-of-sample results for an optimized portfolio of just equities, bonds, and bills. The results are computed over the period January 1970–May 2009, except where indicated that the analysis started in 1930. Period is the set of variables and time period used in the optimization, Ex-Ante Target represents the target real return that the portfolio was optimized to achieve while minimizing the tracking error with inflation, Mean is the monthly average of the difference between year-on-year inflation and the model's return, S.D. is the standard deviation of the real returns, Max and Min are the largest (smallest) monthly difference between year-on-year inflation and the model's value, Number $\leq\pi$ is the percentage of months where the model's return is lower than the year-on-year inflation for that month, MAE is the mean absolute error of the errors, RMSE is the root mean squared error between model values and year-on-year inflation, and nobs is the number of monthly observations used to compute the performance statistics. All values are multiplied by 100, except for nobs. For the three asset class optimization, a † indicates that the country only had bills and bonds for optimization. †† indicates that the country only had equities and bills for the optimization. If a country is missing an entry, it indicates that the entry would have had missing values due to missing asset classes.

tracking error of 6.23%, a worst year-on-year performance of −19.10%, and underperforms inflation almost 20% of the time. Even though this is not as impressive as Germany, it is still better than a static allocation of 50% equity and 50% bonds (see Table 5), which has a lower average real return of 4.11%, a higher tracking error of 19.37%, a worst year-on-year monthly performance of −34%, and underperforms inflation 44.40% of the time.

Spain also has much more volatility than Italy. For Spain, we did not have equities since 1970, but we did have bonds and bills. For Spain, 100% bills had a much lower return–risk ratio and did not achieve the desired real return of 4.5%. In general, even for the European countries where the optimal portfolios look worse than the US and Germany, these allocations may still be better at protecting against inflation than simply holding equities or bonds.

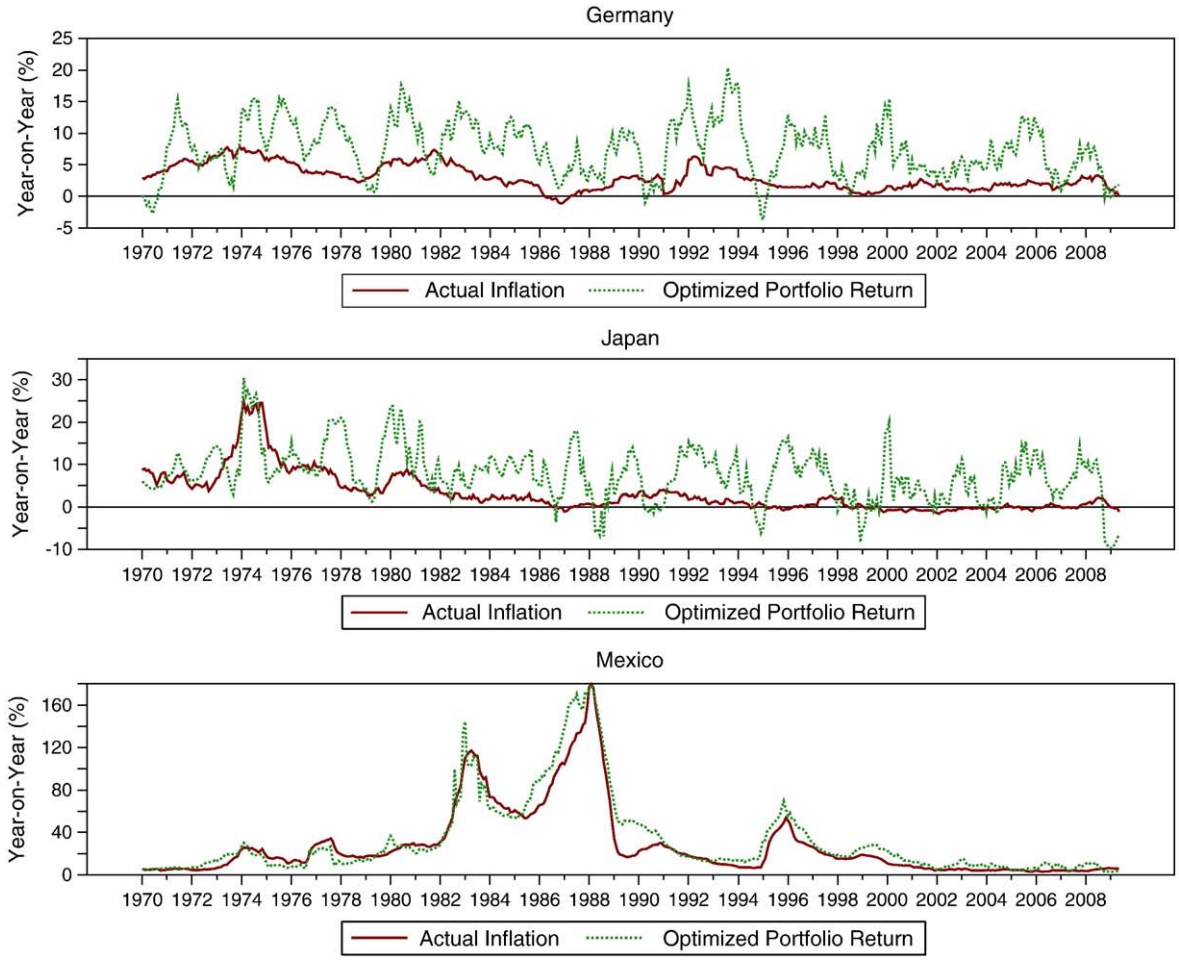

Fig. 3. Germany, Japan, and Mexico optimized portfolio returns for a 4.5% real return versus inflation (Year-on-Year).

In addition to these static portfolios, we wanted to understand if the multi-asset approach performed better than a simple mean–variance optimization with the three standard asset classes: equities, bonds, and bills.[13] These performance results for both in-sample and out-of-sample are contained in Table 5. Without exception, for every European country, the in-sample performance results are better than simply optimizing over the three standard asset classes. By better, we mean achieving the same mean target return with lower volatility.

3.1.2. Out-of-sample results

3.1.2.1. Optimal weights. The average optimal weights are contained in Table 6. We focus on the results for the 1970 period. The optimizations generally indicate a healthy weight in government bills or LIBOR, slightly under 10% in gold and oil, a good portion in 30-year or 10-year government securities, and some weight in emerging equities. For example, for Germany to achieve a 4.50% real return over the 1970 period, the average optimal weights consist of 37% government bills, 42% 30-year government bonds, 4.68% oil, 4.36% gold, 2.18% wheat and 10.46% emerging equity. Overall, the weights do not differ significantly from the in-sample weights.

3.1.2.2. Performance. The out-of-sample performance is very good for most European countries (see Table 5). The real return targets in all cases were 4.5% and the actual results ranged from a low of 3.95% to a high of 5.04%. Generally, the results are quite encouraging for European investors as well. The tracking error or standard deviation of real returns is also reasonable. The highest value is 9.40% for Spain and the other countries are between 3.9% and 5.20%.

In comparison to that static allocations in Table 5, the out-of-sample optimizations do not compare as favorably as the in-sample results with respect to downside measure of real returns, but are still relatively good to other alternatives. In addition to these static portfolios, we also created out-of-sample performance results for portfolios optimized for just three standard asset classes: equities, bonds, and bills. Once again, the multi-asset hedging approach dominates a simple three asset class optimization. First, in almost all cases, the three asset class optimization is not even able to achieve on average the ex-ante target real return. Second, in all cases, the performance results are weaker. By weaker, we mean lower Sharpe ratios or smaller average returns for similar risk levels. For example, the three asset class portfolio results for Italy have an average real return of 4.36% (versus 3.95% for the multi-asset approach) but with a standard deviation of real returns that is 13.81% versus 5.10%. Spain is the only country whose three asset class optimization achieves a better return–risk tradeoff than the multi-asset approach, but even then it does not come very close to the ex-ante target real return of 4.5%.

3.2. Latin American countries

3.2.1. In-sample results

3.2.1.1. Optimal weights. The asset class optimizations over the 1970 period are quite dissimilar to that of Europe and the US (see Table 7).

[13] Some countries were excluded due to lack of data availability.

Table 6
Out-of-sample asset class real return optimizations for European Region and USA (avg. weights).

	France		Germany		Italy		Spain		UK		USA	
	1930	1970	1930	1970	1930	1970	1930	1970	1930	1970	1930	1970
Real return target	6.39	4.50	4.48	4.50	3.86	4.50	2.20	4.50	1.75	4.50	4.50	4.50
Asset class												
Equity index	.	.	38.50	0.00	93.05	0.39	.	.	87.76	2.46	14.97	1.10
Small-cap	.	.	.	.	.	.	.	.	.	.	.	.
Value	.	.	.	.	.	.	.	.	.	.	.	.
Growth	.	.	.	.	.	.	.	.	.	.	.	.
S. CD	.	.	.	.	.	.	.	.	.	.	.	.
S. CS	.	.	.	.	.	.	.	.	.	.	.	.
S. energy	.	.	.	.	.	.	.	.	.	.	.	.
S. finance	.	.	.	.	.	.	.	.	.	.	.	.
S. health	.	.	.	.	.	.	.	.	.	.	.	.
S. indust.	.	.	.	.	.	.	.	.	.	.	.	.
S. IT	.	.	.	.	.	.	.	.	.	.	.	.
S. material	.	.	.	.	.	.	.	.	.	.	.	.
S. telcomm	.	.	.	.	.	.	.	.	.	.	.	.
S. utility	.	.	.	.	.	.	.	.	.	.	.	.
Bill govt.	5.71	62.69	54.47	36.57	4.29	64.83	100.00	31.62	12.24	0.00	8.88	0.00
10-yr govt.	.	.	.	.	.	.	.	.	.	23.13	7.66	0.00
30-yr govt.	94.29	10.96	7.03	41.74	2.66	0.92	.	16.19	.	.	0.23	0.00
Corp. bond	.	.	.	.	.	.	.	.	.	.	45.32	15.96
HY bond	.	.	.	.	.	.	.	.	.	.	.	.
IP Bond	.	.	.	.	.	.	.	.	.	.	.	.
Commodity	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
Oil	.	4.82	.	4.68	.	5.69	.	10.36	.	7.62	5.39	6.03
Gold	.	7.02	.	4.36	.	8.66	.	8.65	.	5.23	0.37	3.07
Silver	.	0.00	.	0.01	.	0.00	.	0.00	.	0.00	3.15	0.01
Wheat	.	0.00	.	2.18	.	0.00	.	0.01	.	0.00	.	0.00
FX1	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
FX2	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
FX3	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
LIBOR	.	.	.	.	.	.	.	.	.	48.05	.	62.71
R. estate	.	.	.	.	.	.	.	.	.	.	.	.
World Eq.	.	0.97	.	0.00	.	1.92	.	1.91	.	0.15	3.99	0.01
World bond	.	0.67	.	0.00	.	4.32	.	4.67	.	0.58	0.00	0.00
Emerge eq.	.	12.87	.	10.46	.	13.26	.	26.58	.	12.78	10.05	11.10
Emerge bond	.	.	.	.	.	.	.	.	.	.	.	.
Tracking error	21.7	5.2	12.2	4.4	54.2	6.3	11.5	10.5	17.4	6.0	9.7	4.1
Return/risk	0.29	0.87	0.37	1.02	0.07	0.72	0.19	0.43	0.10	0.76	0.46	1.10

Note: the asset class weights are the weights from an optimization to minimize the portfolio returns monthly tracking error with inflation, while producing the desired real return target listed. The weights of the asset classes are constrained to be greater than 0 (i.e. no shorting) and the weights must sum to 1 (i.e. fully-invested). Mathematically, the optimization is $min_w w'\Sigma w - 2w'\gamma$ s.t. $w'\mu = \bar{\mu}_P + \pi_{t,t+k}$. The . represents asset classes whose returns did not exist at the starting period, while 0.00 indicates an asset class whose data existed at the starting period, but the optimization led to a zero weighting. Tracking error represents the annualized tracking error of the portfolio versus inflation and Return/Risk represent the real return of the portfolio divided by the tracking error.

Argentina's optimal weight is 80.29% world bond and 18.93% FX2, which is the equivalent of taking a short position in the Argentinian peso versus the Brazilian reale. Brazil's optimal weight is 49.79% oil, 8.38% FX1, 13.09% world bond, and 28.75% world equity. Chile's optimal weight is 61.33% government bills, 9.81% oil, 16.56% world equity, 4.99% world bond, and 7.31% emerging equity. Mexico's optimal position is 83.05% government bills, 2.67% general commodities, 3% oil, 5.95% gold, 1.98% silver, 2.92% wheat, and 0.42% FX3. Peru's allocation is 75% equities and 25% emerging equities.

In the cases of Argentina, Brazil, Chile, and Peru the tracking error is huge; as high as 1240% for Argentina. Essentially, for these countries attempting to build a portfolio to provide a positive real return while protecting the investor from inflation is virtually impossible. This is primarily due to the large hyperinflationary episodes, which make hedging inflation impracticable with the available instruments. The lack of bills and bonds in these countries makes it that much harder to find an asset class that keeps up with inflation especially during extreme inflationary periods. Mexico does much better with a tracking error of 10.25%, in part due to the availability of many other instruments and the lower severity of the inflationary period. Overall, with few domestic instruments, the best option for a domestic investor in a hyperinflation country is to short his currency and invest in other currencies.[14]

3.2.1.2. Performance. Although in many cases, it is hard to find investments that adequately track inflation, some investments provide sufficient real returns. For Argentina, an 80% weighting in bonds and shorting the domestic currency leads to a real return of 4.5% over the time horizon (see Table 8). The standard deviation or tracking error of these returns is enormous. For Brazil, Chile, and Peru, the story is similar to Argentina's. They can achieve the average real return of 4.5%, but are not really tracking inflation and at times are underperforming it by large amounts. Mexico, on the other hand, seems to achieve a 4.5% real return over the period, with a reasonable management of the downside risk with respect to inflation of 10.25%. Fig. 3 shows the monthly year-on-year performance of the portfolio versus year-on-year inflation.

[14] The late Rudiger Dornbusch used to tell students of Latin American countries right after crises to ask their parents where their money was. The answer was always Miami. It was actually perfectly rational for them to do this and perhaps their only option.

Table 7
Asset class real return optimizations by Latin America Region.

	Argentina		Brazil		Chile		Mexico		Peru	
	1930	1970	1930	1970	1930	1970	1930	1970	1930	1970-
Real return target	.	4.50	.	4.50	−14.42	4.50	.	4.50	26.27	4.50
Asset class										
Equity index	.	.	.	0.00	.	.	.	0.00	100.00	74.58
Small-cap	.	.	.	.	.	.	.	.	.	.
Value	.	.	.	.	.	.	.	.	.	.
Growth	.	.	.	.	.	.	.	.	.	.
S. CD	.	.	.	.	.	.	.	.	.	.
S. CS	.	.	.	.	.	.	.	.	.	.
S. energy	.	.	.	.	.	.	.	.	.	.
S. finance	.	.	.	.	.	.	.	.	.	.
S. health	.	.	.	.	.	.	.	.	.	.
S. indust.	.	.	.	.	.	.	.	.	.	.
S. IT	.	.	.	.	.	.	.	.	.	.
S. material	.	.	.	.	.	.	.	.	.	.
S. telcomm	.	.	.	.	.	.	.	.	.	.
S. utility	.	.	.	.	.	.	.	.	.	.
Bill govt.	.	.	.	.	100.00	61.33	.	83.05	.	.
10-yr govt.	.	.	.	.	.	.	.	.	.	.
30-yr govt.	.	.	.	.	.	.	.	.	.	.
Corp. bond	.	.	.	.	.	.	.	.	.	.
HY bond	.	.	.	.	.	.	.	.	.	.
IP bond	.	.	.	.	.	.	.	.	.	.
Commodity	.	0.00	.	0.00	.	0.00	.	2.67	.	0.00
Oil	.	0.00	.	49.79	.	9.81	.	3.00	.	0.00
Gold	.	0.00	.	0.00	.	0.00	.	5.95	.	0.00
Silver	.	0.00	.	0.00	.	0.00	.	1.98	.	0.00
Wheat	.	0.00	.	0.00	.	0.00	.	2.92	.	0.00
FX1	.	0.00	.	8.38	.	0.00	.	0.00	.	0.00
FX2	.	18.93	.	0.00	.	0.00	.	0.00	.	0.00
FX3	.	0.78	.	0.00	.	0.00	.	0.42	.	0.00
LIBOR	.	.	.	.	.	.	.	.	.	.
R. estate	.	.	.	.	.	.	.	.	.	.
World eq.	.	0.00	.	0.00	.	16.56	.	0.00	.	0.00
World bond	.	80.29	.	13.09	.	4.99	.	0.00	.	0.00
Emerge eq.	.	0.00	.	28.75	.	7.31	.	0.00	.	25.42
Emerge bond	.	.	.	.	.	.	.	.	.	.
Tracking error	.	1239.7	.	181.0	77.0	65.4	.	10.2	403.4	387.1
Return/risk	.	0.00	.	0.02	−0.19	0.07	.	0.44	0.07	0.01

Note: the asset class weights are the weights from an optimization to minimize the portfolio returns monthly tracking error with inflation, while producing the desired real return target listed. The weights of the asset classes are constrained to be greater than 0 (i.e. no shorting) and the weights must sum to 1 (i.e. fully-invested). Mathematically, the optimization is $min_w w'\Sigma w - 2w'\gamma$ s.t. $w'\mu = \tilde{\mu}_P + \pi_{t,t+k}$. The . represents asset classes whose returns did not exist at the starting period, while 0.00 indicates an asset class whose data existed at the starting period, but the optimization led to a zero weighting. Tracking error represents the annualized tracking error of the portfolio versus inflation and return/risk represent the real return of the portfolio divided by the tracking error.

Given that the multi-asset portfolios do not really provide a steady inflation hedge, we compare to the alternative of static investments and/or standard three asset class optimizations. First, in many Latin American countries the absence of public financial markets made inflation hedging extremely difficult. For example, Argentina did not have a viable equity or bond market for investors. Brazil and Peru had only equities, while Chile had only bills. This fact makes the multi-asset approach more of a realistic option for investors. For Brazil, equities provided a higher real return and a better risk-adjusted return, but with an extreme volatility of 756%. For Chile, bills provided a negative real return with higher volatility. For Mexico, the multi-asset approach was better than stand-alone investments and was better on a risk-adjusted return basis than the standard optimization of the three asset classes. For Peru, equities had a better risk-adjusted real return. Thus, the in-sample results provide mixed evidence for the usefulness of the multi-asset approach in Latin America. However, for countries that had more than one domestic asset class available (i.e. Mexico), the multi-asset approach was preferable.

3.2.2. Out-of-sample results

3.2.2.1. Optimal weights. The average out-of-sample weights for the Latin American countries show a similar pattern to the in-sample estimations (see Table 9). For countries like Argentina, Brazil, Chile, and Peru, the allocations involve shorting one's currency against the US dollar (a long position in FX1), long commodities, long gold and oil, and holding quite a bit of short-term government bills when they exist. At times, the weights suggest going short their own currency versus other Latin American countries (a long position in FX2 or FX3).

3.2.2.2. Performance. The real return out-of-sample results are quite good for the Latin American countries (see Table 8). For example, in the case of Chile, the real return target was 4.50% on average and the actual annualized real return over the period was 6.62% for the 1970 period. For Brazil, Peru, and Mexico it was 5.72%, 11.88%, and 6.75% respectively. Argentina's real return is a whopping 89%, but this comes with much volatility. The out-of-sample results are quite promising, but the worse case months are still quite high for these hyperinflationary countries. For example, Peru's worst case annualized real return is −307%.

Once again, it helps to compare these results against some common alternatives. In Table 8, unfortunately, we only have equity and bill indices since 1970 for Mexico. In the Mexican case, an all equity position would have provided a real return of 29% versus 6.75% for the out-of-sample optimized portfolio. This extra return comes with a cost. The standard deviation of the equity

Table 8
Real return portfolio results for the Latin American Region.

Country	Period	Ex-ante			Max		Min		Number $\leq\pi$	MAE	RMSE	Nobs
		Target	Mean	S.D.	Value	Date	Value	Date				
Multi-asset in-sample results												
Argentina	1930	.	.	.	.	.	.	.	.	.	.	.
Argentina	1970	4.50	4.50	1241.02	15261.58	1990:02	−11800.00	1990:03	58.14	239.07	1239.71	473
Brazil	1930	.	.	.	.	.	.	.	.	.	.	.
Brazil	1970	4.50	4.50	181.22	537.04	1994:06	−2490.16	1990:03	40.38	64.52	181.08	473
Chile	1930	−14.42	−14.42	77.01	156.49	1976:05	−681.82	1974:04	51.00	28.37	78.31	953
Chile	1970	4.50	4.50	65.44	311.19	1974:01	−458.05	1974:07	18.39	29.10	65.53	473
Mexico	1930	.	.	.	.	.	.	.	.	.	.	.
Mexico	1970	4.50	4.50	10.25	44.61	1987:03	−28.90	1983:08	31.50	7.62	11.18	473
Peru	1930	26.27	26.27	403.62	10243.06	1990:09	−1981.83	1989:08	63.59	83.13	404.26	953
Peru	1970	4.50	4.50	387.50	5001.68	1990:09	−3273.63	1990:08	45.45	126.76	387.12	473
Multi-asset out-of-sample results												
Argentina	1930	.	.	.	.	.	.	.	.	.	.	.
Argentina	1970	4.81	89.41	595.67	3466.21	1982:08	−119.93	1990:03	65.62	16.82	171.91	413
Brazil	1930	.	.	.	.	.	.	.	.	.	.	.
Brazil	1970	4.50	5.72	30.00	73.83	1999:01	−73.41	1990:03	47.70	4.92	8.66	413
Chile	1930	14.85	−7.39	14.87	31.94	2008:12	−83.41	1973:10	49.94	1.92	4.34	893
Chile	1970	4.50	6.62	11.39	28.91	2008:12	−27.94	1981:01	40.44	1.98	3.33	413
Mexico	1930	.	.	.	.	.	.	.	.	.	.	.
Mexico	1970	4.50	6.75	14.28	50.82	1982:08	−17.94	1982:09	37.77	1.70	4.15	413
Peru	1930	9.84	3.76	54.29	203.36	1990:09	−269.63	1990:08	58.90	5.83	15.67	893
Peru	1970	4.47	11.88	75.21	178.28	1990:09	−306.76	1990:08	49.39	8.61	21.71	413
Static portfolios and optimized with equities, bonds, and bills												
Brazil	100% equity	.	72.04	756.08	5181.94	1994:01	−5584.56	1990:04	43.34	270.43	759.31	473
Chile	100% bill	.	−15.11	107.69	156.49	1976:05	−681.82	1974:04	24.52	40.39	108.63	473
Mexico	100% equity	.	29.38	117.51	1049.14	1987:08	−138.93	1988:07	41.86	56.27	121.01	473
Mexico	50/50 equity/bill	.	16.61	61.67	540.08	1987:08	−84.86	1982:12	40.17	56.27	63.80	473
Mexico	100% Bill	.	3.85	13.88	45.27	1989:01	−50.18	1983:01	32.35	9.37	14.39	473
Mexico	IS equity/bill/bond††	4.50	4.50	14.90	56.92	1987:08	−51.63	1983:01	28.54	9.80	15.54	473
Mexico	OS equity/bill/bond††	4.25	9.07	18.26	31.31	1984:01	−24.78	1982:05	33.90	2.72	5.32	413
Peru	100% equity	.	60.01	571.07	10243.06	1990:09	−1981.83	1989:08	50.32	155.31	573.61	473

Note: the table reports the in-sample and out-of-sample results for the multi-asset approach, for a static investment in various asset classes, and the in-sample and out-of-sample results for an optimized portfolio of just equities, bonds, and bills. The results are computed over the period January 1970–May 2009, except where indicated that the analysis started in 1930. Period is the set of variables and time period used in the optimization, Ex-Ante Target represents the target real return that the portfolio was optimized to achieve while minimizing the tracking error with inflation, Mean is the monthly average of the difference between year-on-year inflation and the model's return, S.D. is the standard deviation of the real returns, Max and Min are the largest (smallest) monthly difference between year-on-year inflation and the model's value, Number $\leq\pi$ is the percentage of months where the model's return is lower than the year-on-year inflation for that month, MAE is the mean absolute error of the errors, RMSE is the root mean squared error between model values and year-on-year inflation, and nobs is the number of monthly observations used to compute the performance statistics. All values are multiplied by 100, except for nobs. Argentina was not included in some parts of the table since it did not have a return history for any of the three basic asset classes since 1970. For the three asset class optimization, a † indicates that the country only had bills and bonds for optimization. †† indicates that the country only had equities and bills for the optimization. If a country is missing an entry, it indicates that the entry would have had missing values due to missing asset classes.

position is eight times as high. The worst annualized real return is −138% versus −18%. The 100% bill allocation has a similar risk profile to the optimal portfolio but with one-half the average real return. Overall, the results indicate that the multi-asset approach is preferable on a risk-adjusted basis to the alternatives for Mexico. The out-of-sample performance of the multi-asset approach, however was comparable to the optimization of three standard asset classes.

3.3. Asian countries

3.3.1. In-sample results

3.3.1.1. Optimal weights. The results for all countries are contained in Table 10. The optimal allocation for Australia involves 56% government bills, 14% 30-year government bonds, 7.80% oil, 4.57% gold, 6.30% world bond, and 11.73% emerging equity. Hong Kong's optimal allocation is 25% government bills, 8% oil, 7% gold, 42% world bond, and 17% emerging equity. India's optimal allocation was 57% government bills, 6% oil, 12% gold, 21% world bond, and 3% emerging equity. Japan's optimal allocation consists of 77% 10-year government bonds, 11% oil, 5% gold, and 7% emerging equity. Singapore's allocation is 2% equity, 27% government bills, 11% oil, 7% gold, 5% wheat, 35% world bond, and 13% emerging equity. South Korea's allocation is 85% government bill, 6% oil, 2% FX1 (Korean Won versus USD), and 7% FX3 (Korean Won versus Chinese Yuan).

3.3.1.2. Performance. The in-sample portfolio performance is quite good (see Table 11). In all cases, the 4.5% target real return for the 1970 period was achieved. The tracking error to inflation is reasonable between 4.67% and 8.61% for the various countries. Also, the percentage of times that the model provides negative real returns is somewhat small being around 13.32–30.87% for the 1970 period. For the 1970 period, Japan achieves the 4.50% target real return with a standard deviation of 5.89%. The worst annualized real return is −12.41% and Japan has a negative year-on-year real return 20% of the time. Fig. 3 depicts the portfolio's year-on-year return through time against the actual year-on-year inflation in Japan since 1970. Thus, generally, the in-sample performance of the tracking error models for inflation seems to do quite well for investors.

When comparing the performance to static allocations and in-sample standard three asset class optimizations, the success of the multi-asset

Table 9
Out-of-sample asset class real return optimizations for Latin American Region (avg. weights).

	Argentina		Brazil		Chile		Mexico		Peru	
	1930	1970	1930	1970	1930	1970	1930	1970	1930	1970
Real return target	.	4.81	.	4.50	14.85	4.50	.	4.50	9.84	4.47
Asset class										
Equity index	.	.	.	0.47	.	.	.	2.54	100.00	47.23
Small-cap	.	.	.	.	.	.	.	.	.	.
Value	.	.	.	.	.	.	.	.	.	.
Growth	.	.	.	.	.	.	.	.	.	.
S. CD	.	.	.	.	.	.	.	.	.	.
S. CS	.	.	.	.	.	.	.	.	.	.
S. energy	.	.	.	.	.	.	.	.	.	.
S. finance	.	.	.	.	.	.	.	.	.	.
S. health	.	.	.	.	.	.	.	.	.	.
S. indust.	.	.	.	.	.	.	.	.	.	.
S. IT	.	.	.	.	.	.	.	.	.	.
S. material	.	.	.	.	.	.	.	.	.	.
S. telcomm	.	.	.	.	.	.	.	.	.	.
S. utility	.	.	.	.	.	.	.	.	.	.
Bill govt.	.	.	.	.	100.00	56.85	.	73.04	.	.
10-yr govt.	.	.	.	.	.	.	.	.	.	.
30-yr govt.	.	.	.	.	.	.	.	.	.	.
Corp. bond	.	.	.	.	.	.	.	.	.	.
HY bond	.	.	.	.	.	.	.	.	.	.
IP Bond	.	.	.	.	.	.	.	.	.	.
Commodity	.	1.08	.	1.60	.	0.00	.	2.57	.	1.71
Oil	.	0.90	.	30.25	.	9.64	.	8.04	.	7.17
Gold	.	9.55	.	0.49	.	0.00	.	3.98	.	1.90
Silver	.	0.00	.	0.35	.	0.00	.	1.13	.	0.00
Wheat	.	0.43	.	0.52	.	0.00	.	1.66	.	0.16
FX1	.	0.00	.	8.89	.	0.00	.	0.00	.	9.75
FX2	.	24.02	.	0.49	.	0.00	.	0.00	.	1.15
FX3	.	16.65	.	3.39	.	0.00	.	0.23	.	1.12
LIBOR	.	.	.	.	.	.	.	.	.	.
R. estate	.	.	.	.	.	.	.	.	.	.
World eq.	.	0.04	.	0.74	.	22.74	.	0.00	.	6.02
World bond	.	44.43	.	27.79	.	6.48	.	0.00	.	8.50
Emerge eq.	.	2.90	.	25.04	.	4.30	.	6.81	.	15.30
Emerge bond	.	.	.	.	.	.	.	.	.	.
Tracking error	.	903.7	.	120.4	48.9	100.6	.	11.0	127.0	268.7
Return/risk	.	0.01	.	0.04	0.30	0.04	.	0.41	0.08	0.02

Note: the asset class weights are the weights from an optimization to minimize the portfolio returns monthly tracking error with inflation, while producing the desired real return target listed. The weights of the asset classes are constrained to be greater than 0 (i.e. no shorting) and the weights must sum to 1 (i.e. fully-invested). Mathematically, the optimization is $min_w w'\Sigma w - 2w'\gamma$ s.t. $w'\mu = \tilde{\mu}_P + \pi_{t,t+k}$. The . represents asset classes whose returns did not exist at the starting period, while 0.00 indicates an asset class whose data existed at the starting period, but the optimization led to a zero weighting. Tracking error represents the annualized tracking error of the portfolio versus inflation and Return/Risk represent the real return of the portfolio divided by the tracking error.

approach is evident. In all cases, the multi-asset approach has a higher risk-adjusted return level and meets its real return targets in all cases.

3.3.2. Out-of-sample results

3.3.2.1. Optimal weights. The average weights from the out-of-sample optimizations are contained in Table 12. The optimizations indicate that generally a fair amount of government bonds or bills are required. In the case of India, 62% bills, while in the case of Japan, it is 62% 10-year government bonds. Usually, the variation is due to a country not having bills or bonds at its disposal for the period of concern. Gold, oil, and general commodities play a larger part than in the US or the European case, with around 15% of the asset allocation devoted to these three. World bond and emerging equities also play a larger role than in the US case.

3.3.2.2. Performance. The out-of-sample results are very promising (see Table 11). The actual average real returns are all positive and close to the target real returns. For Australia, a mean annualized real return of 5.02% with a standard deviation of 7.62% was achieved. The worst monthly annual real return was −7.05%. Hong Kong's mean real return was 4.43% with a 7.97% standard deviation. India's mean real return was 4.18% with a 5.46% standard deviation. Japan achieves a 4.43% return with a 7.07% standard deviation in returns. Singapore has the lowest out-of-sample mean return of 3.74% with a 6.69% standard deviation. Finally, South Korea's mean return is 4.21% with a standard deviation of 3.99%. South Korea also has the smallest worst annualized real return of −3.32% which occurred in December of 2008.

Once again, we compare these out-of-sample optimized results to more standard three asset class allocations (see Table 11). For the Asian region, we have three countries with equities and bills available since 1970. The mean real return of equities in Japan is 5.60% versus 4.43% for the optimized portfolio. Once again, the standard deviation is 3.5 times higher. The return-to-risk ratio is much higher for the optimized approach. The worst annualized real return for equities is −48% versus −8%.

The 100% bill position has one-half the risk, but with an average real return that is barely positive.

The results for the other countries are similar in spirit. The multi-asset approach also does better than a standard out-of-sample optimization of three standard asset classes for all countries, except South Korea. In general, the multi-asset optimized approach with respect to inflation offers the investor a better real return–risk profile both in- and out-of-sample.

Table 10
Asset class real return optimizations by Asian Region.

	Australia		Hong Kong		India		Japan		Singapore		South Korea	
	1930	1970	1930	1970	1930	1970	1930	1970	1930	1970	1930	1970
Real return target	3.13	4.50	.	4.50	0.55	4.50	1.66	4.50	.	4.50	.	4.50
Asset class												
Equity index	0.00	0.00	.	.	.	.	100.00	0.32	.	1.62	.	.
Small-cap	.	.	.	.	.	.	.	.	.	.	.	.
Value	.	.	.	.	.	.	.	.	.	.	.	.
Growth	.	.	.	.	.	.	.	.	.	.	.	.
S. CD	.	.	.	.	.	.	.	.	.	.	.	.
S. CS	.	.	.	.	.	.	.	.	.	.	.	.
S. energy	.	.	.	.	.	.	.	.	.	.	.	.
S. finance	.	.	.	.	.	.	.	.	.	.	.	.
S. health	.	.	.	.	.	.	.	.	.	.	.	.
S. indust.	.	.	.	.	.	.	.	.	.	.	.	.
S. IT	.	.	.	.	.	.	.	.	.	.	.	.
S. material	.	.	.	.	.	.	.	.	.	.	.	.
S. telcomm	.	.	.	.	.	.	.	.	.	.	.	.
S. utility	.	.	.	.	.	.	.	.	.	.	.	.
Bill govt.	0.00	55.95	.	24.86	0.00	56.95	0.00	0.00	.	27.18	.	85.23
10-yr govt.	.	.	.	.	.	.	0.00	76.83	.	.	.	0.00
30-yr govt.	100.00	13.65	.	.	100.00	0.00	.	.	.	.	.	.
Corp. bond	.	.	.	.	.	.	.	.	.	.	.	.
HY bond	.	.	.	.	.	.	.	.	.	.	.	.
IP bond	.	.	.	.	.	.	.	.	.	.	.	.
Commodity	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
Oil	.	7.80	.	8.17	.	6.37	.	11.23	.	11.24	.	5.89
Gold	.	4.57	.	7.36	.	12.20	.	4.64	.	7.44	.	0.10
Silver	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
Wheat	.	0.00	.	0.00	.	0.00	.	0.00	.	4.46	.	0.00
FX1	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	2.17
FX2	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
FX3	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	6.61
LIBOR	.	.	.	.	.	.	.	.	.	.	.	.
R. estate	.	.	.	.	.	.	.	.	.	.	.	.
World eq.	.	0.00	.	0.00	.	0.26	.	0.00	.	0.00	.	0.00
World bond	.	6.30	.	42.22	.	20.94	.	0.00	.	34.73	.	0.00
Emerge eq.	.	11.73	.	17.39	.	3.28	.	6.98	.	13.33	.	0.00
Emerge bond	.	.	.	.	.	.	.	.	.	.	.	.
Tracking error	12.8	5.5	.	8.6	12.0	6.5	72.8	5.9	.	7.4	.	4.7
Return/risk	0.24	0.82	.	0.52	0.05	0.69	0.02	0.76	.	0.61	.	0.97

Note: the asset class weights are the weights from an optimization to minimize the portfolio returns monthly tracking error with inflation, while producing the desired real return target listed. The weights of the asset classes are constrained to be greater than 0 (i.e. no shorting) and the weights must sum to 1 (i.e. fully-invested). Mathematically, the optimization is $min_w w'\Sigma w - 2w'\gamma$ s.t. $w'\mu = \tilde{\mu}_P + \pi_{t,t+k}$. The . represents asset classes whose returns did not exist at the starting period, while 0.00 indicates an asset class whose data existed at the starting period, but the optimization led to a zero weighting. Tracking error represents the annualized tracking error of the portfolio versus inflation and return/risk represent the real return of the portfolio divided by the tracking error.

4. Conclusion

In this paper we study the possibility of hedging inflation by using a set of available asset classes. We examined this from the perspective of investors in 17 different countries, including countries that experienced hyperinflationary episodes as well as countries that did not. We also examined this for different sets of time periods as far back as 1930.

Our study found that for an investor that wishes to achieve a given real return while minimizing the deviation of his portfolio return from inflation on the downside in any given period, the best allocation usually did not involve investing in equities. In fact, the best allocation consisted of some combination of government bills or LIBOR, government bonds, some gold, some oil, and some emerging market equity. We also found that while gold is important in providing a real return while considering the downside with respect to inflation, it's value is about 5% of one's portfolio and no more than 10%. We found that oil also plays a small role of about 5% in one's portfolio. For example, based on our analysis, for a German investor, an allocation for a 4.5% real return might look like that which was shown in Fig. 4.

We found that investors in countries that experience massive hyperinflation have few options. However, they can also achieve a reasonable target real return with albeit higher tracking error. In many cases, the best allocation is to short their own currency, buy some kind of world bond index, and buy government bills.

We found that the methodology did well out-of-sample. For almost all countries, the average realized real returns were positive and close to their target real returns. In the case of the US, Europe, and many Asian countries, this was achieved with low tracking error. For Latin American countries, however it was achieved with very high tracking error.

Future research might wish to alter the methods of the optimization technique including rolling windows and different optimization algorithms. Further research might also consider higher target real returns to match historical returns for asset classes such as equities. One might also want to examine other investment periods in which more asset classes are available to hedge inflation. Although there has been some research on conditional models, more might be attempted to determine how the asset allocation decision to protect against inflation might vary conditional upon current macroeconomic variables.

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Table 11
Real Return Portfolio Results for the Asian Region.

Country	Period	Ex-ante			Max		Min		Number $\leq\pi$	MAE	RMSE	Nobs
		Target	Mean	S.D.	Value	Date	Value	Date				
Multi-asset in-sample results												
Australia	1930	3.13	3.13	12.78	104.03	1932:09	−26.85	1951:10	39.66	8.74	13.15	953
Australia	1970	4.50	4.50	5.51	22.80	1990:01	−9.75	1975:03	20.51	5.70	7.11	473
Hong Kong	1930	.	.	.	.	.	.	.	.	.	.	.
Hong Kong	1970	4.50	4.50	8.61	30.62	2000:02	−20.73	2009:02	30.87	7.50	9.71	473
India	1930	0.55	0.55	12.02	60.20	1933:02	−51.94	1943:04	52.68	8.20	12.03	953
India	1970	4.50	4.50	6.49	24.11	1992:03	−13.42	1975:02	23.68	6.32	7.89	473
Japan	1930	1.66	1.66	72.84	181.49	1949:09	−679.37	1946:07	41.03	30.75	72.82	953
Japan	1970	4.50	4.50	5.89	20.84	2000:02	−12.41	1974:11	20.08	6.06	7.41	473
Singapore	1930	.	.	.	.	.	.	.	.	.	.	.
Singapore	1970	4.50	4.50	7.38	25.80	2000:02	−22.22	2008:12	18.60	6.93	8.63	473
South Korea	1930	.	.	.	.	.	.	.	.	.	.	.
South Korea	1970	4.50	4.50	4.67	16.62	1997:12	−12.93	1975:10	13.32	5.41	6.48	473
Multi-asset out-of-sample results												
Australia	1930	3.00	−1.13	12.88	18.20	1971:12	−44.29	1987:10	40.65	2.07	3.72	893
Australia	1970	4.50	5.02	7.62	21.80	1976:11	−7.05	1976:10	38.50	1.49	2.24	413
Hong Kong	1930	.	.	.	.	.	.	.	.	.	.	.
Hong Kong	1970	4.50	4.43	7.97	9.92	1999:03	−10.89	2008:10	42.13	1.75	2.33	413
India	1930	1.79	−1.03	7.27	15.34	2008:12	−11.15	1998:01	52.41	1.37	2.10	893
India	1970	4.50	4.18	5.46	10.43	1991:07	−5.21	2008:10	41.65	1.22	1.61	413
Japan	1930	5.28	3.06	26.06	63.48	1949:01	−93.24	1945:12	48.15	4.46	7.52	893
Japan	1970	4.50	4.43	7.07	7.91	1999:03	−7.79	2008:10	39.95	1.60	2.07	413
Singapore	1930	.	.	.	.	.	.	.	.	.	.	.
Singapore	1970	4.50	3.74	6.69	9.52	1999:03	−10.23	2008:10	42.62	1.45	1.95	413
South Korea	1930	.	.	.	.	.	.	.	.	.	.	.
South Korea	1970	4.50	4.21	3.99	6.91	1997:12	−3.32	2008:12	31.96	0.90	1.20	413
Static portfolios and optimized with equities, bonds, and bills												
Australia	100% Equity	.	2.15	22.06	72.51	1987:07	−59.27	1974:09	42.71	17.37	22.14	473
Australia	50/50 equity/bill	.	2.38	11.79	40.20	1987:07	−33.11	1974:09	36.58	17.37	12.01	473
Australia	100% bill	.	2.61	4.22	11.33	1990:07	−8.41	1973:10	21.78	4.17	4.96	473
Australia	IS equity/bill/bond	3.90	3.90	11.48	36.59	1991:10	−26.10	1974:07	37.21	9.74	12.11	473
Australia	OS equity/bill/bond	2.75	3.54	10.89	13.30	1987:07	−44.29	1987:10	37.05	1.71	3.15	413
Hong Kong	100% bill	.	−0.66	4.82	11.89	1999:08	−21.00	1973:09	56.87	3.66	4.86	473
India	100% Bill	.	1.75	6.04	22.09	1976:02	−20.79	1974:09	29.60	4.48	6.28	473
India	IS equity/bill/bond†	1.75	1.75	6.04	22.09	1976:02	−20.79	1974:09	29.60	4.48	6.28	473
India	OS equity/bill/bond†	1.26	2.62	3.27	3.86	1975:12	−3.25	1998:01	40.92	0.74	0.97	413
Japan	100% equity	.	5.60	25.01	102.36	1972:11	−48.40	1974:10	41.44	19.61	25.61	473
Japan	50/50 equity/bill	.	2.92	13.15	50.90	1972:11	−33.04	1974:10	41.44	19.61	13.45	473
Japan	100% bill	.	0.23	3.77	6.01	1987:01	−19.14	1974:02	33.40	2.38	3.78	473
Japan	IS equity/bill/bond	4.50	4.50	14.58	56.91	1972:11	−38.57	1974:10	38.05	11.65	15.25	473
Japan	OS equity/bill/bond	4.50	4.64	7.76	10.23	1986:03	−8.24	1990:09	43.34	1.69	2.27	413
Singapore	100% equity	.	8.72	32.85	146.91	1999:08	−80.07	1974:01	43.55	25.21	33.95	473
Singapore	50/50 equity/bill	.	4.67	17.37	74.10	1999:08	−54.79	1974:01	42.28	25.21	17.96	473
Singapore	100% Bill	.	0.61	5.23	8.05	1976:09	−30.51	1974:03	32.77	3.05	5.26	473
Singapore	IS equity/bill/bond††	4.50	4.50	16.74	71.08	1999:08	−53.74	1974:01	42.07	12.64	17.31	473
Singapore	OS Equity/bill/bond††	4.49	6.83	12.69	30.65	1975:01	−12.06	1987:10	43.10	2.41	3.70	413
South Korea	100% bill	.	5.11	5.52	13.65	1972:01	−14.46	1975:10	10.99	6.46	7.52	473
South Korea	IS equity/bill/bond†	4.50	5.11	5.52	13.65	1972:01	−14.46	1975:10	10.99	6.46	7.52	473
South Korea	OS equity/bill/bond†	5.21	5.18	2.82	4.81	1977:11	−2.74	1980:01	23.73	0.71	0.92	413

Note: the table reports the in-sample and out-of-sample results for the multi-asset approach, for a static investment in various asset classes, and the in-sample and out-of-sample results for an optimized portfolio of just equities, bonds, and bills. The results are computed over the period January 1970–May 2009, except where indicated that the analysis started in 1930. Period is the set of variables and time period used in the optimization, Ex-ante target represents the target real return that the portfolio was optimized to achieve while minimizing the tracking error with inflation, Mean is the monthly average of the difference between year-on-year inflation and the model's return, S.D. is the standard deviation of the real returns, Max and Min are the largest (smallest) monthly difference between year-on-year inflation and the model's value, Number $\leq\pi$ is the percentage of months where the model's return is lower than the year-on-year inflation for that month, MAE is the mean absolute error of the errors, RMSE is the root mean squared error between model values and year-on-year inflation, and nobs is the number of monthly observations used to compute the performance statistics. All values are multiplied by 100, except for nobs. For the three asset class optimization, a † indicates that the country only had bills and bonds for optimization. †† indicates that the country only had equities and bills for the optimization. If a country is missing an entry, it indicates that the entry would have had missing values due to missing asset classes.

Appendix A

Data sources and description

Data obtained from Global Financial Data (GFD)

IBOR: Interbank offered rate (IBOR) is the interest rate at which banks lend to and borrow from one another in interbank market. IBORs serve as an indicator of levels of demand and supply in all financial markets. It is also called interbank rate. Examples include LIBOR (which is the London IBOR) and FIBOR (which is the Frankfurt IBOR). This rate is applicable to the short-term international interbank market, and applies to very large loans borrowed for anywhere from one day to five years. This market allows banks with liquidity requirements to borrow quickly from other banks with surpluses, enabling banks to avoid excess holding excessively large amounts of their asset base as liquid assets. Source: InvestorWords.com.

Commodity indices: commodity indices are a composite of different commodities to determine the general direction of commodity prices.

Table 12
Out-of-sample asset class real return optimizations for Asian Region (avg. weights).

	Australia		Hong Kong		India		Japan		Singapore		South Korea	
	1930	1970	1930	1970	1930	1970	1930	1970	1930	1970	1930	1970
Real Return Target	3.00	4.50	.	4.50	1.79	4.50	5.28	4.50	.	4.50	.	4.50
Asset class												
Equity index	32.38	0.00	.	.	.	.	88.25	9.33	.	4.10	.	.
Small-cap	.	.	.	.	.	.	.	.	.	.	.	.
Value	.	.	.	.	.	.	.	.	.	.	.	.
Growth	.	.	.	.	.	.	.	.	.	.	.	.
S. CD	.	.	.	.	.	.	.	.	.	.	.	.
S. CS	.	.	.	.	.	.	.	.	.	.	.	.
S. energy	.	.	.	.	.	.	.	.	.	.	.	.
S. finance	.	.	.	.	.	.	.	.	.	.	.	.
S. health	.	.	.	.	.	.	.	.	.	.	.	.
S. indust.	.	.	.	.	.	.	.	.	.	.	.	.
S. IT	.	.	.	.	.	.	.	.	.	.	.	.
S. material	.	.	.	.	.	.	.	.	.	.	.	.
S. telcomm	.	.	.	.	.	.	.	.	.	.	.	.
S. utility	.	.	.	.	.	.	.	.	.	.	.	.
Bill govt.	13.26	51.77	.	26.84	11.93	61.77	6.47	2.94	.	43.77	.	79.85
10-yr govt.	.	.	.	.	.	.	5.28	62.19	.	.	.	0.43
30-yr govt.	54.36	2.39	.	.	88.07	0.00	.	.	.	.	.	.
Corp. bond	.	.	.	.	.	.	.	.	.	.	.	.
HY bond	.	.	.	.	.	.	.	.	.	.	.	.
IP bond	.	.	.	.	.	.	.	.	.	.	.	.
Commodity	.	1.01	.	2.92	.	0.84	.	0.23	.	1.32	.	0.00
Oil	.	9.51	.	10.82	.	7.35	.	13.93	.	12.04	.	7.59
Gold	.	3.65	.	5.23	.	10.84	.	2.66	.	4.96	.	0.00
Silver	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
Wheat	.	0.23	.	2.05	.	0.81	.	0.14	.	6.38	.	0.00
FX1	.	0.11	.	0.00	.	0.00	.	0.00	.	0.00	.	4.40
FX2	.	0.03	.	0.09	.	0.30	.	0.59	.	0.00	.	0.03
FX3	.	2.08	.	0.00	.	0.87	.	0.05	.	0.00	.	3.63
LIBOR	.	.	.	.	.	.	.	.	.	.	.	.
R. estate	.	.	.	.	.	.	.	.	.	.	.	.
World eq.	.	1.20	.	0.03	.	1.22	.	0.00	.	0.00	.	2.59
World bond	.	7.97	.	27.81	.	13.27	.	0.41	.	14.51	.	1.47
Emerge eq.	.	20.05	.	24.21	.	2.74	.	7.53	.	12.93	.	0.00
Emerge Bond	.	.	.	.	.	.	.	.	.	.	.	.
Tracking error	14.8	6.7	.	8.2	13.8	6.8	83.2	6.6	.	6.7	.	5.4
Return/risk	0.20	0.67	.	0.55	0.13	0.67	0.06	0.68	.	0.67	.	0.84

Note: the asset class weights are the weights from an optimization to minimize the portfolio returns monthly tracking error with inflation, while producing the desired real return target listed. The weights of the asset classes are constrained to be greater than 0 (i.e. no shorting) and the weights must sum to 1 (i.e. fully-invested). Mathematically, the optimization is $min_w w'\Sigma w - 2w'\gamma$ s.t. $w'\mu = \tilde{\mu}_P + \pi_{t,t+k}$. The . represents asset classes whose returns did not exist at the starting period, while 0.00 indicates an asset class whose data existed at the starting period, but the optimization led to a zero weighting. Tracking error represents the annualized tracking error of the portfolio versus inflation and Return/Risk represent the real return of the portfolio divided by the tracking error.

The indices are usually weighted according to the size of the market for each commodity.

Commodity prices: commodity prices are in US Dollars unless otherwise indicated. Since commodities are substitutes for one another, allowing for transportation costs and qualitative differences, the price of a commodity should be the same throughout the world, so the price of gold, for example, should not differ greatly from one country to the other. Whether the price is in cents or dollars and what the underlying measure is (ounces, pounds, kilograms, tons, etc.) is indicated by the commodity name.

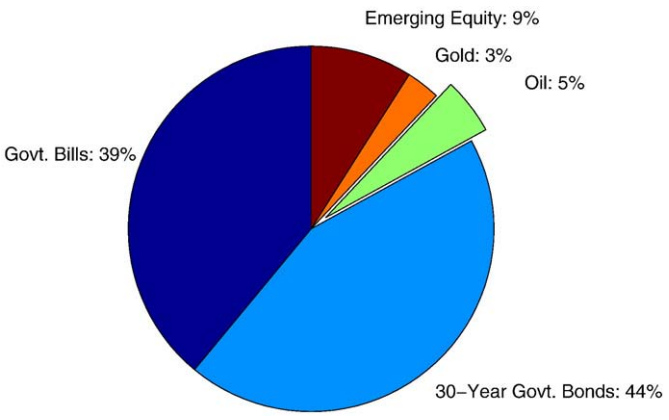

Fig. 4. Germany investment allocation with for a 4.5% real return.

Consumer price indices: consumer price indices are the most commonly used measure of the cost of living and thus inflation. GFD includes the primary CPI for each country, but no sub-indices, although most governments calculate dozens or even hundreds of sub-indices. Consumer price indices were first introduced in the 1920 s, so any data before 1920 has been put together using historical prices. Europe has introduced harmonized consumer price indices that exclude housing costs since these can differ widely from one country to another and can bias intercountry comparisons. Generally, wholesale and producer price indices measure input prices while consumer price indices measure output prices.

Stock indices:—size and style: Stock market analysts separate stocks by size and style. The size refers to whether stocks are large cap, midcap or small cap. The style refers to whether stocks are growth or value stocks. Value stocks are divided into whether they pay any dividends or whether they are dividend achievers paying significant dividends.

Total return indices, bills: total return bill indices are based upon the yields on 3-month Treasury Bills. It is assumed that the price of the bills does not change so the indices reflect the returns to “cash.”

Historically, not all countries issued treasury bills. In those cases, either the central bank discount rate or commercial paper yields have been used as a substitute for the yields on treasury bills.

Total return indices, bonds: total return bond indices are based upon the yields on 10-year Government bonds unless otherwise indicated. Bond indices assume that investors have both capital gains and capital losses as bond prices change. It is assumed that interest payments are made and reinvested at the end of each month for monthly data or when bond payments are made for daily indices. Where no 10-year bond was available, the bond closest to a 10-year bond was used.

Total return indices, stocks: total return stock indices include both the changes in the price of the stock and the dividends that are paid to investors and then reinvested. It is assumed that dividend payments are made and reinvested at the end of each month for monthly data and on a daily basis when actual dividends are paid for daily data. Historical data have been calculated using dividend yield data and stock price index data for the broadest index available for each country.

Wholesale price indices: wholesale price indices principally include commodities while producer price indices include any goods that are used as inputs by businesses. Where both indices are available, GFD has chosen to provide the producer price index since this is a broader category. However, most indices before World War II were wholesale price indices rather than producer price indices. Generally, wholesale and producer price indices measure input prices while consumer price indices measure output prices.

Data obtained from Factset

Equity sectors: FactSet Aggregates are time series composite price and return indices based on proprietary country, sector, and industry classifications. The aggregates include stocks domiciled in a given country and whose primary business is principally related to a particular sector. For example, banks and capital market firms would be included in the Financials sector while pharmaceutical companies would be included in the Health Care sector. Aggregates are valuable benchmarks for company analysis, and can also be used to compare trends at the industry, sector, and country level. FactSet Aggregates includes regions and country level aggregates. Each country can potentially be broken out into 20 sectors and 128 industries (for a possibility of 149 identifiers per country).

Exchange rates: FactSets exchange rate data comes from the WM/Reuters and are all quoted as local currency per U.S. Dollar. For countries that use the Euro, the local exchange rate was carried forward however the monthly percent changes reflect the change in the Euro from the time that the country switched to the Euro. This was January 1999 for most countries. For each country, 3 foreign currencies were selected as asset classes. For all countries except the United States, the primary foreign currency is the U.S. Dollar. The other 2 currencies (all 3 currencies for the United States) were selected on the basis of the physical proximity of the countries and /or the use of the currency as a basis for international trading. Cross rates were calculated for each using the U.S. Dollar as the crossing currency. The currencies selected for each country are detailed in Table 1.

US Treasury Inflation Protected Securities (TIPS): is a type of Treasury securities that provides protection against inflation and real return. To provide inflation protection, the principal of a TIPS increases with inflation (and decreases with deflation) as measured by the Consumer Price Index (CPI). Like other Treasuries, TIPS pay interest at a fixed rate twice a year. The rate is applied to the adjusted principal, as such, the interest payments rise with inflation and fall with deflation. At the maturity, you receive the adjusted principal or the original principal, whichever is greater—protecting you against both inflation and deflation. For the United States, we used the Barclays Capital (formerly Lehman) US Aggregate Government-Treasury-Inflation Notes Index. This index is composed of a representation of Treasury Inflation Protected notes across the yield curve. There are approximately 28 issues representing over $500 billion in market value outstanding in the index with an average maturity of approximately 400 years (as of November 2009 Source: Factset Research Systems).

Data obtained from Bloomberg

Non-US Treasury Inflation Protected Securities (TIPS): non-US: for international countries, we used the "Generic" bond series for different maturities (i.e. 10 years, 20 years, etc.). A generic bond series represents the current Government bond which the market considers to be the benchmark issue. For example, for a 10-year generic bond, there will be a single government bond with 10 years to maturity that will be selected to be the benchmark issue. Every month or quarter (depending on the issuance schedule of the government), another single bond with 10 years remaining until maturity will be selected to replace the previous bond as the benchmark issue. The returns for the individual bonds are geometrically linked to create a continuous return series. The resulting series will always have 10 years to maturity and thus is considered to be the benchmark for the 10 year bond.

Data obtained from NAREIT

Real Estate Investment Trusts (REITS): a security that sells like a stock on the major exchanges and invests in real estate directly, either through properties or mortgages. REITs receive special tax considerations and typically offer investors high yields, as well as a highly liquid method of investing in real estate.

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