PRELIMINARY DRAFT

# Worry-free Inflation-indexing for Sovereigns

## How governments can effectively deliver inflation-indexed returns to their citizens and retirees

**Zvi Bodie, Joseph Cherian, Wee Kang Chua**

**Original version: September 2010**

**This version: 5/9/2011**

**Abstract**

In this paper we explore how small countries such as Malaysia, Singapore, and Taiwan, can offer their aging populations the means to protect their retirement income against inflation without the governments directly issuing inflation-protected bonds. While inflation swaps are a well-known means by which to attain this, we show how an inflation index-replication strategy is also feasible. With this ability to provide inflation-adjusted returns, governments, pension funds, and other institutions can begin to offer a broad suite of inflation-indexed products, ranging from retirement annuities to inflation-linked insurance policies. This will improve the functioning of national pension systems, and hence the welfare of retirees. The added benefit of such structures is that they allow governments to broadly replicate their local Consumer Price Index (CPI) returns without disrupting their traditional financing structures. Given the potential of reinsuring national default risks across borders via currency and credit default swap facilities at the federal level, there is a unique role for the government in this process as the reinsurer of last resort.[1]

[1] We are aware that derivatives can be used by governments to conceal, rather than reveal, the nature of the government's true indebtedness. But our focus in this paper is the appropriate use of derivatives, i.e., for proper risk management and risk transfer as opposed to creative government accounting.

## 1. Introduction

Retired people living on fixed incomes are more vulnerable to the risk of inflation than working people, whose income should, in theory, keep pace with inflation. Two ways that some governments currently offer citizens to protect themselves against inflation risk in old age are: (1) automatic inflation-indexation of social security benefits, and (2) the issuance of government-backed inflation-indexed bonds (e.g., TIPS in the US, Index-linked Gilts in the UK, etc.)[2] Curiously, the governments of many Asian countries, which have traditionally cared deeply about the economic welfare of their population and provided social safety nets in a variety of ways for the most vulnerable members of society, do not offer any inflation-protected retirement benefits to their respective citizenry. A recent exception has been Hong Kong, which recently announced plans to issue around US$1 billion of three-year inflation-linked bonds in 2011. India and Thailand are expected to do the same within the year.

Government is the natural institution to provide inflation-linked benefits because tax revenues (both income and sales taxes) are automatically indexed to inflation. However, as observed in the sovereign debt crisis in Greece and Ireland, the ability of small-country governments to guarantee inflation-proof income is limited. Nevertheless, new mechanisms for international risk transfer have developed in recent years. The rise of sovereign wealth funds, currency swap facilities between central banks, portfolio replication strategies, and the derivatives markets for credit default and CPI swaps, has vastly expanded the scope for reallocating risk across various markets and nations. This has the potential effect of making the risk transfer process more efficient and transparent.

The three fundamental issues the average investor is concerned about during retirement are: receiving a reasonable level payout every month, which lasts for as long as the investor lives, and which is indexed to his or her cost of living. In other words, investors, upon retiring, would at a minimum like to receive a level *real* payout (i.e., one that is inflation-indexed) for life that enables them to maintain their standard of living. The most commonly-cited product that meets this need is an inflation-linked retirement annuity, which aims to convert accumulated investment capital to lifetime real cash flows for retirement consumption and expenditures.[3] Furthermore, the ageing population and changing demographic landscape in Asian countries such as Japan, Hong Kong, Malaysia and Singapore will serve to increase the demand for such retirement annuity products. In this respect, the CPF Lifelong Income Scheme offered by the Central Provident Fund in Singapore since 2009 took steps in the right direction as far as

[2] In a recent comprehensive report entitled, "Global Aging Report (2010)", Standard & Poor's discusses how sovereigns will have to face the varying aging problems - and their adverse attendant costs to long-term public finances - in their respective regions.

[3] To this end, a US company called Income Solutions (http://incomesolutions.com) has developed an indexed annuity delivery platform designed to enable transitioning US employees in need of creating lifelong income to have on-line access to competitively bid, institutionally priced, immediate annuities (both inflation-indexed and nominal).

meeting the first two criteria are concerned.[4] However, the monthly payouts in the various CPF Life plans do not have an inflation-indexing feature.

Taking the cue from economically-developed nations such as the G8 countries, the simplest way for a US, Japanese, Australian, or British investor to achieve a real, level payout for retirement spending purposes, apart from buying an inflation-linked retirement annuity, is to purchase a laddered portfolio of inflation-indexed bonds from her respective sovereign during her working life, with the first maturity of the ladder occurring at retirement to finance that year's expenses, and the final one at the expected mortality date, with some amount of hedging or insurance against longevity risk wrapped in.[5] Ideally, this laddered product would be purchased within a tax-deferred retirement program. If that option is not available, the investor could alternatively construct it within a taxable investment account.

On the supply side, governments traditionally issue inflation-linked bonds so that investors, pension funds, insurance companies, and corporations can obtain inflation-indexed cash flows to meet their various liabilities and obligations that may grow with changes in the Consumer Price Index (CPI). Governments that do issue inflation-indexed bonds include the US (TIPS), UK (Index-linked Gilts), Japan (JGBi), France (OATi), Canada (RRBs), Sweden (SGILs), and Australia (CAINs). In a small number of cases, municipalities, utilities, and infrastructure funds, which receive inflation-indexed cash flows, have also been suppliers of indexed bonds, notes and swaps. More recently, India, Hong Kong and Thailand have expressed plans to issue inflation-linked bonds in 2011.

The government faces two risks when issuing inflation-indexed bonds. The risk of the real interest rate going up, as well as the risk of inflation rising. In both cases, it increases the government's cost of borrowing. The fiscal, monetary, and counter-cyclical tools usually available to the government enable it to somewhat control both risks. If all else fails, there are price controls, which some governments - such as Israel through its Economic Stabilization Policy - have successfully employed to suppress the runaway inflation of the 70's and 80's. Indeed, Israel's hyperinflation years saw its inflation rate spiral to a peak of 445% in 1984!

Singapore, too, has had its share of high CPI, albeit many orders of magnitude smaller than Israel's experience. In 1973 the annualized inflation rate in Singapore was 19.6%, followed by 22.3% the subsequent year. More recently, the Department of Statistics reported that Singapore's year-over-year inflation in January 2011 rose 5.5%, which was a 25-month high. This same CPI rate ranged between 5.5% and 7.5% in 2008. Being smaller, trade-based economies, Singapore and Israel are more susceptible to imported inflation as compared to the bigger economies, albeit the more recent inflation experience in Singapore has been demand-led, given rising transportation and housing costs. In the

[4] The CPF's monthly payouts are not strictly level, rather a function of the prevailing CPF interest rates and mortality experience. These parameters are reviewed annually and may be adjusted as often, albeit in a "smooth and stable" fashion.

[5] In the US, the money manager, PIMC0, offers mutual fund products called Real Income Funds, which not only provide regular inflation-indexed distributions over time like an annuity, but also offer the liquidity inherent in open-end mutual funds.

former case, counter-cyclical tools, such as currency appreciation, can be used in an effective manner to manage inflation.

While the issuance of sovereign inflation-indexed bonds is the most direct route to offer citizens the means to protect retirement income against inflation, we outline two other ways a small, trade-based country's government can provide inflation-indexed returns for retirement planning purposes. One would be the use of derivatives, such as inflation swaps. Since derivatives are usually unfunded, or only require nominal margin collateral postings, such prescriptions enable the government to offer inflation-indexed returns without altering its current portfolio of investments and economic activity, nor its monetary and fiscal policies. Another would be the use of inflation-index replication strategies, which utilizes a basket of correlated foreign inflation-linked bonds to broadly replicate the local inflation-indexed returns. The details of the latter methodology are discussed below. These methods allow governments to offer inflation-linked products to their citizens on a worry-free basis.

## 2. Manufacturing Inflation-Indexed Returns

In this section we discuss the three ways in which the small (or "local") government can provide "risk-free" inflation hedging opportunities for its citizens. These recommendations are certainly not meant to be exhaustive. Indeed, innovations in the inflation-indexed business continue to yield many new forms of inflation hedging opportunities.

The first and most straightforward way of providing risk free inflation hedging is for a government to issue inflation-indexed bonds. For example, the US Government issues Treasury Inflation-Protected Securities (TIPS), which are marketable securities whose face value (or principal) is adjusted by changes in the Consumer Price Index. TIPS pay interest semiannually, and have maturities of 5, 10, and 30 years. Similarly, I Savings Bonds are another low-risk savings product by the US Government that earns an inflation-indexed interest rate on a tax-deferred, money market-type savings account.[6]

The second, and perhaps more creative way of generating real returns at the sovereign level, is via derivatives. As mentioned in the Introduction, since derivatives are usually unfunded, financial engineering technology enables the government to offer inflation-indexed bonds without altering its current portfolio of investments and economic activity, or its monetary and fiscal policies. We will not go into this methodology in great detail in this paper since there already exists a number of well-written industry guides on this topic. For an exhaustive description of the types of inflation-linked derivatives that are available in financial markets, please see Appendix B. There are nevertheless key elements in

[6] The US form of CPI is generally a short-hand for CPI-U, a price index that covers the out-of-pocket expenses of all urban consumers. In a recent working paper, Barnes, Bodie, Triest, and Wang (2009) provide evidence that TIPS indexed to CPI-U indeed provides hedges against unexpected changes in inflation for different types of US investors, since the various US inflation measures are very highly correlated.

the methodology described in the third approach below, which can be beneficially ported to the extant derivatives technology available in the inflation-indexed industry.[7]

The third suggested way to achieve this objective is for the local government to carve out a portion of its sovereign investment portfolio and invest it in a suitably-weighted portfolio of other sovereigns' inflation-indexed bonds. For example, if Country A trades most with the US, Australia, Japan, and the UK, and the domestic demand for inflation-indexed bonds is US$1 billion, Government A can carve a billion dollars out of its sovereign wealth and invest in, say, a trade-weighted basket of US, Australian, Japanese, and UK inflation-indexed government securities.[8]

Theoretically, this weighted-average CPI replication methodology should succeed if strict purchasing power parity holds. In that case there would be no difference in real risk-free interest rates across markets. In reality, PPP does not hold, so the methodology will work only if the deviation from PPP is relatively small.

in Table 1, we summarize the pros and cons of 3 proposed methods for manufacturing the local inflation index, while the next section describes in greater detail our weighted-average inflation-index replication strategy.

[7] Needless to say, there are numerous potential risks involved in this and other replicating technologies discussed in this paper, including the default risk of the local government and/or of the governments whose bonds it might invest in. We address some of these issues in the next section of the paper.

[8] In a recent research note similar to ours, Nomura's Fixed Income Research Department analyze how Asian investors can use inflation instruments available in the US, Europe and French markets, and conclude that these instruments can help hedge Asian inflation.

| Method of manufacturing local inflation returns | **Advantages** | **Risks** | **Mitigating methods** |
|---|---|---|---|
| Direct issuance of sovereign inflation-indexed bonds | • Simple, direct, exact.<br>• Government tax revenues & receipts rise naturally with inflation. | • Sovereign bears full brunt of inflation risk.<br>• Taxable income and GDP may be adversely affected by inflation. Receipts may not rise sufficiently quickly. | • Caps and floors on inflation payouts.<br>• Government has control over inflation via fiscal and monetary policies, and price controls. |
| Entering into inflation swaps | • Unfunded, requires minimal upfront capital.<br>• Sovereign bears minimal inflation risk. | • Financial institution counterparty risk. | • Direct sovereign or central-bank level swap arrangements. |
| Replication using basket of correlated foreign inflation-indexed bonds | • Sovereign bears low to moderate residual inflation risk.<br>• Practical & feasible.<br>• Currency, interest rate and default risk can be hedged. | • Basket can sometimes underperform the local inflation index.<br>• Requires carving out of a portion of the sovereign investment portfolio.<br>• Hedging may be costly and/or impractical for the required time horizons. | • Risk can be minimized by passing through the basket's returns directly to investors.<br>• Sovereign reserve and wealth portfolios usually already contain some foreign (especially G3/G7) bonds.<br>• Currency hedging via swaps can be directly arranged at the sovereign or central bank level. |

**Table 1: Pros & cons of 3 proposed methods to manufacture the local inflation index**

## 3. Inflation-Index Replication

### 3.A. Preamble

The objective here is to assist small, trade-based countries, such as Singapore, to offer her investors an investment product whose rate of return tracks the local inflation rate as measured by the local Consumer Price Index (CPI). For this purpose, we construct a basket of liquid investible instruments whose returns track the CPI of a particular country as closely as possible. We refer to this as inflation-index replication.

The perspective we adopt here is that of an asset manager with a mandate to deliver returns at least equal to that of a target index's return, but having only instruments which are imperfectly correlated to this index available at his disposal. Here the target index is the local inflation index, while the imperfectly correlated instruments are the foreign inflation-indexed bonds. It is thus appropriate to use standard risk metrics and "performance" measures from the asset management industry to measure and quantify the "performance" of our inflation-index replication strategy. The industry standard measures we use include correlation, tracking error, alpha, information ratio, and the probability of shortfall.

There are many ways in which this inflation-index replication can be carried out. Choices include static or dynamic replication where the components of the basket could comprise G8 inflation-indexed bonds, commodity indices, and inflation-indexed ETFs. The weighting scheme employed for the static or dynamically-weighted basket could have as inputs the balance of trade, housing indices, GDP, money supply, equity indices, and OECD leading indicators, and with time horizons varying from short (1 - 2 years), medium (3 - 5 years) and long term (10 - 30 years). Tracking accuracy would normally be measured as the absolute or squared deviation of average basket returns from the local CPI's.

The simplest strategy would be to use 100% maturity-matched US TIPS with the foreign currency exposure swapped out. *Indeed, from 1971 to 2009, the US annual inflation rate has been lower than that of Singapore's in only 5 years.* A more complex strategy would be to form a portfolio of dynamically-weighted and rebalanced basket of G8 inflation-indexed bonds to best match or optimize annual or maturity-matched inflation returns. The dynamic weighting scheme could be based on economic indicators, time horizon, and expectations, implemented via systematic quantitative trading.

Needless to say, there are numerous potential pitfalls in attempting to replicate a local inflation index using a basket of foreign inflation-indexed bonds, which we will refer to as the "Weighted-average CPI Replication Methodology". The first is model risk given historical CPI correlations between countries may not hold in the future. This can be caused by changes in a country's reference inflation index. An example would be when the UK government switched from the Retail Prices Index measure (RPI) to the Consumer Prices Index (CPI) as their reference inflation index in 2010. The UK CPI is in general lower; it was higher than the UK RPI in only 3 months out of the last 20 years. The second is "representativity" risk, which is when headline CPI may understate actual price inflation for consumers on the ground. This

is particularly pronounced in countries like India where recent headline CPI has been moderately high, but food and fuel price increases on the ground have been much higher.

Thirdly, currencies can be quite volatile, especially between the developed and developing markets. As a consequence, currency forward hedging, especially cross currency hedges, for horizons of more than a year is difficult and costly in terms of price spreads. And once the hedge is put on, it will likely be illiquid and difficult to unwind or adjust. Furthermore, for a small, trade-dependent country like Singapore, which is susceptible to imported inflation, inflation will tend to spike when the local currency is weak. On the other hand, unhedged currency exposures could hurt if the foreign currency collapses due to a crisis. One way around the costly cross currency hedging issue is for the sovereigns involved to enter bi-lateral or multi-lateral currency swap agreements using their respective central banks. In a way, this is a form of reinsurance of national default risk across transnational borders as the government-to-government currency swap is essentially a credit default swap. There is hence a unique role for the government in this process as the reinsurer of last resort.

The fourth risk is interest rate risk. Interest rates can fluctuate. This in turn causes the prices of nominal bonds to fluctuate. Indeed, the prices of inflation indexed bonds can fluctuate more as they are determined by both interest rates as well as inflation expectations. Finally, sovereign risk in the form of sovereign defaults may become significant, as evidenced by events in Europe in early 2010. Icelandic and Greek sovereign bonds would have caused much grief for their investors. This can be mitigated somewhat by avoiding bonds of weak or debt-ridden sovereigns when forming the inflation-index replication strategy, instead sticking to higher grade sovereigns such as the G8.

**3.B. Quantitative methodology**

For our analysis, we will assume that currency risk, interest rate risk, as well as sovereign default risk can be hedged out at negligible cost. This takes care of points 3 - 5 in the pitfalls mentioned heretofore. Also, since our objective is simply the replication of the local CPI index returns, we need not concern ourselves with point 2. That leaves us with only model risk, which is a risk that is inherent in any quantitative model. The adverse effects on our model from changes or adjustments in the reference inflation index should be low as local measures of inflation tend to be highly correlated. We take the universe of countries with an investible inflation-indexed bond market of sufficient depth and liquidity to be the US, UK, France, Europe, Canada, Japan and Sweden (hereafter referred to as “the universe”). We then examine inflation rates in Singapore, Malaysia, Taiwan and Hong Kong (hereafter referred to as “countries of interest”) with respect to the investible universe. For each country of interest, we look at the longest overlapping period of reported headline consumer price index data between that country

and each country in the investible universe.[9] We then calculate the monthly, quarterly and yearly CPI returns of that country up to Dec 2009, and take it to be a benchmark.[10] We then consider the historical performance of each country in the investible universe with respect to this benchmark. Various "performance" metrics such as the mean alpha or "excess returns", tracking error, information ratio, historical shortfall, and correlation against the benchmark are also calculated and compared.

---

This weighted-average CPI replication methodology approach has merit based on the notion that as long as there are free capital flows globally or at least for the economies under consideration, and assuming purchasing power parity (PPP) holds, there will be no difference in real risk-free rates across markets as differences in interest rates reflect differences in expected inflation. In Appendix C, we prove that this weighted-average CPI methodology is a sound one by starting with the PPP relationship. We go on to demonstrate that asset price changes in local terms are the same as asset price changes in foreign terms if there is either no change in exchange rates or if exchange rates are fully hedged using currency swaps, forwards or futures. However, as mentioned previously, PPP does not hold in reality, hence the methodology will only work if deviations from PPP are moderate. We will next examine some strategies that are middle-of-the-road in the complexity spectrum. The historical performance statistics of simple replication strategies, such as a portfolio consisting of 100% US TIPS, are readily apparent when calculating the benchmarks.

## 4. Results and Discussion

In this section we compare the performance of CPIs of countries in the investible universe against the various countries of interest (the benchmark) using measures such as the mean alpha or excess returns, tracking error, information ratio, historical shortfall, and correlation. Our justification for using such measures is because the test experiment being conducted here is no different from that of an asset manager with a mandate to deliver returns at least equal to that of a target index's return, but having only instruments which are imperfectly correlated to this index available at his disposal.

[9] Country CPI data are obtained from Thomson Reuters Datastream.

[10] We found that monthly and even quarterly data were too volatile, so we will only focus on yearly data. Returns and excess returns are calculated on a continuously-compounded annualized basis.

*Singapore*

| Country | Start | End | Period length | Mean alpha (%) | Tracking error (%) | Information ratio | Historical Shortfall (%) | Correlation |
|---|---|---|---|---|---|---|---|---|
| US | Dec 1961 | Dec 2009 | 48 years | 1.52 | 3.89 | 0.42 | 18.8 | 0.54 |
| UK | Dec 1961 | Dec 2009 | 48 years | 3.25 | 5.97 | 0.64 | 10.4 | 0.36 |
| France | Dec 1990 | Dec 2009 | 19 years | 0.06 | 1.42 | 0.04 | 36.8 | 0.39 |
| Europe | Dec 1996 | Dec 2009 | 13 years | 0.62 | 1.67 | 0.38 | 23.1 | 0.45 |
| Canada | Dec 1961 | Dec 2009 | 48 years | 1.55 | 3.92 | 0.43 | 20.8 | 0.55 |
| Japan | Dec 1970 | Dec 2009 | 39 years | -0.13 | 3.32 | -0.04 | 61.5 | 0.72 |
| Sweden | Dec 1961 | Dec 2009 | 48 years | 2.31 | 4.96 | 0.52 | 27.1 | 0.36 |

**Table 2: Performance of CPIs of countries in investible universe compared to CPI of Singapore**[11]

When comparing the performance of CPIs of countries in the investible universe against Singapore's CPI, Table 2 indicates that the UK has the longest period, highest excess returns, highest information ratio and lowest historical shortfall. Nevertheless it also has the lowest correlation and the worst tracking error against the CPI of Singapore. Meanwhile, Japan has nearly exactly the opposite characteristics. It has the lowest (even negative) alpha, the worst (negative) information ratio and historical shortfall, but the highest correlation.

Even though a high correlation is desirable, the US and UK have the most liquid inflation-indexed markets when compared to Japan's. Furthermore, the US has the 3rd best correlation at 0.54 after Canada. The US also has the 2nd best historical shortfall. Japan's historical shortfall percentage is too high due to the poor mean alpha caused by deflation.

As a consequence, it is our view that a combination of US & UK CPI will be able to best improve correlation and tracking error, with the least effect on historical shortfall and information ratio.

*a) Malaysia*

| Country | Start | End | Period length | Mean alpha (%) | Tracking error (%) | Information ratio | Historical Shortfall (%) | Correlation |
|---|---|---|---|---|---|---|---|---|
| US | Dec 1972 | Dec 2009 | 37 years | 0.68 | 2.81 | 0.25 | 35.1 | 0.59 |
| UK | Dec 1972 | Dec 2009 | 37 years | 2.43 | 5.27 | 0.51 | 32.4 | 0.42 |
| France | Dec 1990 | Dec 2009 | 19 years | -1.26 | 1.87 | -0.89 | 73.7 | -0.08 |
| Europe | Dec 1996 | Dec 2009 | 13 years | -0.60 | 1.64 | -0.38 | 61.5 | -0.35 |
| Canada | Dec 1972 | Dec 2009 | 37 years | 0.70 | 2.96 | 0.24 | 37.8 | 0.59 |
| Japan | Dec 1972 | Dec 2009 | 37 years | -1.08 | 2.94 | -0.39 | 75.7 | 0.79 |
| Sweden | Dec 1972 | Dec 2009 | 37 years | 1.23 | 3.99 | 0.32 | 40.5 | 0.41 |

**Table 3: Performance of CPIs of countries in investible universe compared to CPI of Malaysia**[12]

[11] Yellow highlights denote the best metrics for each category while red denotes the worst.
[12] Yellow highlights denote the best metrics for each category while red denotes the worst.

For Malaysia (Table 3), once again the UK indexed bonds have the best excess returns, highest information ratio and lowest historical shortfall. But they also have the worst tracking error. Best tracking error goes to Europe, with France a close 2nd. Best correlation goes to Japan, with US and Canada tied for 2nd place, and the US edging out Canada for tracking error, information ratio and historical shortfall. Thus US is hence a very good addition to the portfolio to boost the overall correlation, with the least adverse impact on the other metrics.

*b) Taiwan*

| Country | Start | End | Period length | Mean alpha (%) | Tracking error (%) | Information ratio | Historical Shortfall (%) | Correlation |
|---|---|---|---|---|---|---|---|---|
| US | Dec 1959 | Dec 2009 | 50 years | -0.20 | 4.51 | -0.04 | 34.0 | 0.69 |
| UK | Dec 1959 | Dec 2009 | 50 years | 1.55 | 5.57 | 0.29 | 26.0 | 0.51 |
| France | Dec 1990 | Dec 2009 | 19 years | -0.19 | 1.46 | -0.12 | 57.9 | 0.50 |
| Europe | Dec 1996 | Dec 2009 | 13 years | 0.91 | 1.48 | 0.75 | 15.4 | 0.37 |
| Canada | Dec 1959 | Dec 2009 | 50 years | -0.18 | 4.79 | -0.04 | 42.0 | 0.60 |
| Japan | Dec 1970 | Dec 2009 | 39 years | -1.36 | 3.91 | -0.37 | 71.8 | 0.82 |
| Sweden | Dec 1959 | Dec 2009 | 50 years | 0.64 | 5.35 | 0.12 | 40.0 | 0.47 |

**Table 4: Performance of CPIs of countries in investible universe compared to CPI of Taiwan**

As Table 4 indicates, for Taiwan, UK CPI has the highest mean alpha and also the best information ratio and historical shortfall outside of Europe. It has the worst tracking error. Japan still has the worst alpha, information ratio and historical shortfall. To boost correlation, one can add a US component, which has the 2nd highest correlation after Japan.

*c) Hong Kong*

| Country | Start | End | Period length | Mean alpha (%) | Tracking error (%) | Information ratio | Historical Shortfall (%) | Correlation |
|---|---|---|---|---|---|---|---|---|
| US | Dec 1980 | Dec 2009 | 29 years | -1.36 | 4.29 | -0.33 | 58.6 | 0.57 |
| UK | Dec 1980 | Dec 2009 | 29 years | -0.60 | 3.79 | -0.16 | 58.6 | 0.63 |
| France | Dec 1990 | Dec 2009 | 19 years | -1.11 | 4.40 | -0.25 | 57.9 | 0.40 |
| Europe | Dec 1996 | Dec 2009 | 13 years | 1.74 | 3.24 | 0.61 | 38.5 | 0.06 |
| Canada | Dec 1980 | Dec 2009 | 29 years | -1.38 | 4.33 | -0.33 | 65.5 | 0.51 |
| Japan | Dec 1980 | Dec 2009 | 29 years | -3.70 | 5.30 | -0.95 | 79.3 | 0.79 |
| Sweden | Dec 1980 | Dec 2009 | 29 years | -0.89 | 3.52 | -0.26 | 72.4 | 0.70 |

**Table 5: Performance of CPIs of countries in investible universe compared to CPI of Hong Kong**[13]

It has turned out to be very challenging to replicate and outperform Hong Kong's CPI, see Table 5. Europe has the best alpha, tracking error, information ratio and historical shortfall but the worst correlation, while Japan has exactly the opposite result, with a negative alpha that is of a much larger magnitude than Europe's positive alpha. UK and Sweden would be the best candidates to boost correlation without decreasing alpha too badly. UK, as compared to Sweden, is superior in terms of mean alpha, information ratio and historical shortfall, while losing out in terms of tracking error and

[13] Yellow highlights denote the best metrics for each category while red denotes the worst.

correlation.

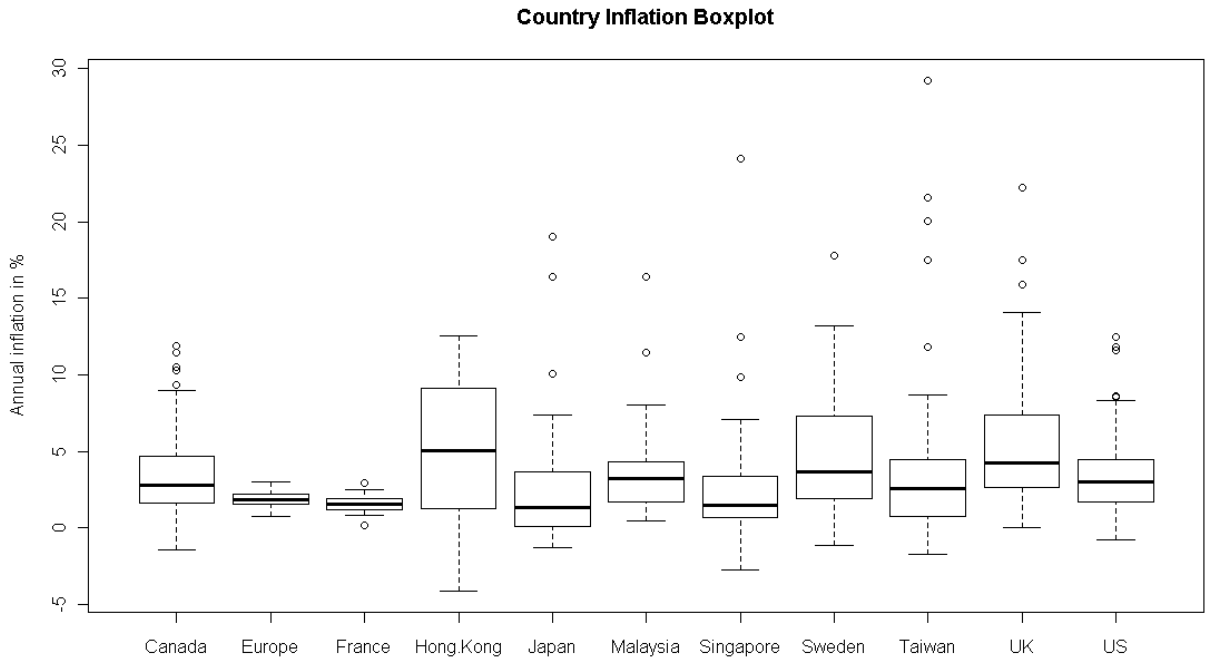



**Figure 1: Summary CPI statistics for various countries/regions**

The boxplot in Figure 1 graphically shows the summary CPI statistics for various countries and regions. This includes the median, 25$^{th}$ and 75$^{th}$ percentiles, minima and maxima, and also outliers, which is defined as data points that are 1.5 times the interquartile range beyond either quartile, as individual points. The boxplot ranges for Europe and France are much smaller than the other countries because the HICP data (on which the inflation indexed bonds are based on) have a shorter history.

| | US | UK | Japan | Canada | Sweden | France | Europe | Singapore | Malaysia | Taiwan | HK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 3.7% | 5.5% | 2.8% | 3.7% | 4.8% | 1.6% | 1.8% | 2.6% | 3.7% | 4.2% | 4.5% |
| Std Dev | 2.8% | 4.6% | 4.4% | 3.2% | 3.8% | 0.6% | 0.6% | 4.3% | 3.1% | 6.0% | 4.8% |
| Min | -0.7% | 0.0% | -1.3% | -1.4% | -1.1% | 0.2% | 0.7% | -2.8% | 0.5% | -1.7% | -4.1% |
| 25th Percentile | 1.7% | 2.6% | 0.1% | 1.6% | 1.9% | 1.2% | 1.5% | 0.7% | 1.7% | 0.8% | 1.3% |
| Median | 3.0% | 4.3% | 1.4% | 2.8% | 3.7% | 1.6% | 1.8% | 1.5% | 3.2% | 2.6% | 5.1% |
| 75th Percentile | 4.3% | 7.2% | 3.5% | 4.6% | 7.2% | 1.9% | 2.1% | 3.3% | 4.2% | 4.4% | 9.0% |
| Max | 12.5% | 22.2% | 19.1% | 11.9% | 17.8% | 2.9% | 3.0% | 24.1% | 16.4% | 29.2% | 12.6% |

**Table 6: Summary CPI statistics for various countries/regions (table format)**

Table 6 provides the summary statistics, such as mean, standard deviation, minima, maxima, and 25$^{th}$ & 75$^{th}$ percentiles, of the CPI of all countries of interest.

| | Singapore | US | UK | France | Europe | Canada | Japan | Sweden | Malaysia | Taiwan | HK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Singapore | 1.00 | 0.55 | 0.38 | 0.55 | 0.62 | 0.49 | 0.71 | 0.38 | 0.86 | 0.75 | 0.51 |
| US | 0.55 | 1.00 | 0.83 | 0.75 | 0.82 | 0.87 | 0.71 | 0.69 | 0.61 | 0.60 | 0.55 |
| UK | 0.38 | 0.83 | 1.00 | 0.55 | 0.62 | 0.81 | 0.79 | 0.77 | 0.45 | 0.46 | 0.60 |
| France | 0.55 | 0.75 | 0.55 | 1.00 | 0.96 | 0.54 | 0.39 | 0.65 | 0.31 | 0.49 | 0.29 |
| Europe | 0.62 | 0.82 | 0.62 | 0.96 | 1.00 | 0.70 | 0.48 | 0.82 | 0.33 | 0.53 | 0.23 |
| Canada | 0.49 | 0.87 | 0.81 | 0.54 | 0.70 | 1.00 | 0.72 | 0.77 | 0.55 | 0.50 | 0.47 |
| Japan | 0.71 | 0.71 | 0.79 | 0.39 | 0.48 | 0.72 | 1.00 | 0.64 | 0.74 | 0.78 | 0.75 |
| Sweden | 0.38 | 0.69 | 0.77 | 0.65 | 0.82 | 0.77 | 0.64 | 1.00 | 0.43 | 0.41 | 0.66 |
| Malaysia | 0.86 | 0.61 | 0.45 | 0.31 | 0.33 | 0.55 | 0.74 | 0.43 | 1.00 | 0.86 | 0.50 |
| Taiwan | 0.75 | 0.60 | 0.46 | 0.49 | 0.53 | 0.50 | 0.78 | 0.41 | 0.86 | 1.00 | 0.59 |
| HK | 0.51 | 0.55 | 0.60 | 0.29 | 0.23 | 0.47 | 0.75 | 0.66 | 0.50 | 0.59 | 1.00 |

**Table 7: Correlation of Y-o-Y CPI change for various countries/regions (table format)**

Table 7 shows the correlations between the year-on-year percentage change in inflation index of countries of interest

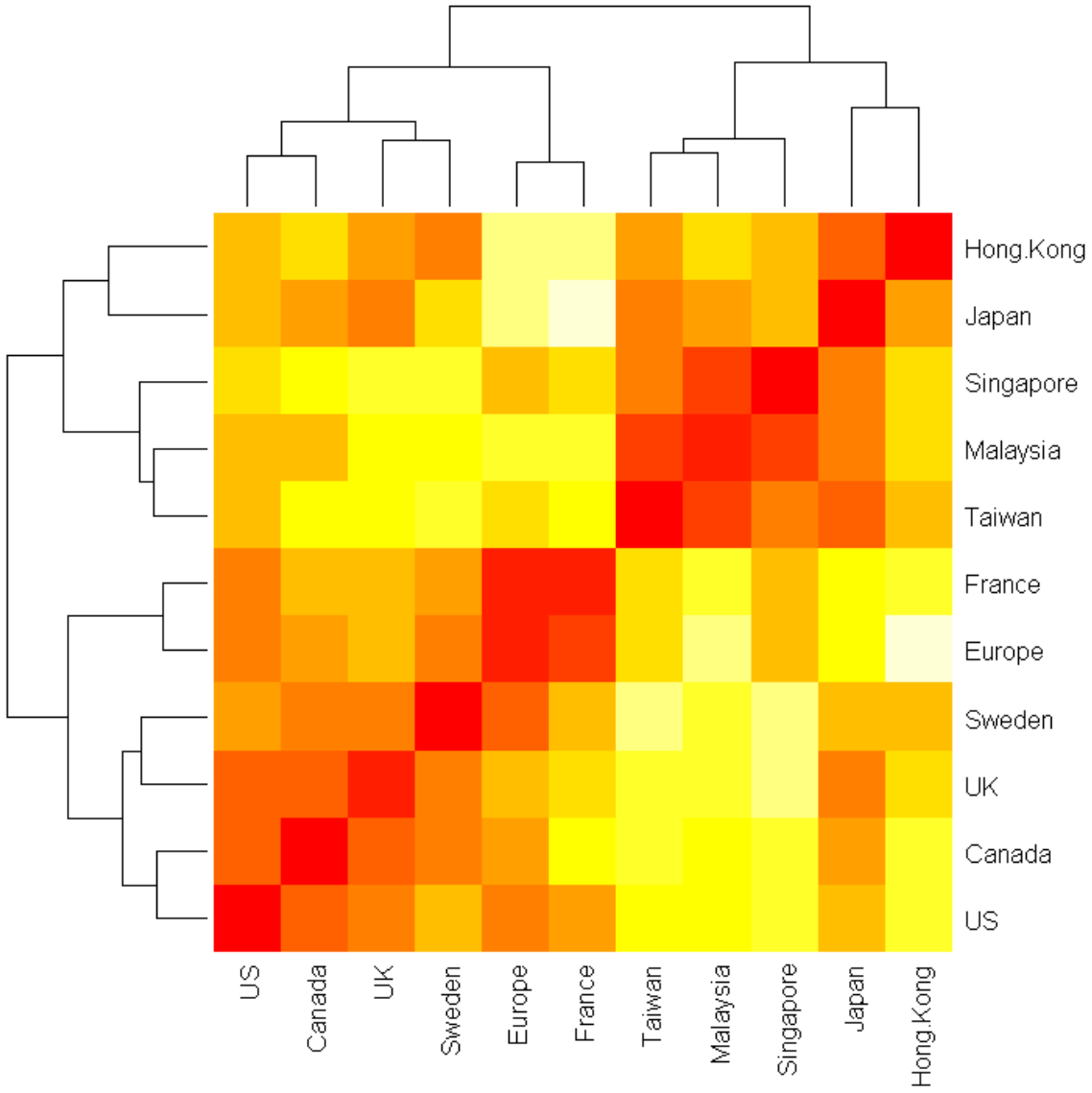



**Figure 2: Heat Map of Y-o-Y CPI change for various countries/regions**

Correlations between the year-on-year percentage change in inflation index of countries of interest are shown as a heat map in Figure 2: the stronger the red hue, the higher the correlation. Additionally, countries are grouped into clusters or cliques by correlation, with countries in the same cluster having the highest correlations. Asian countries have high cross-correlation with each other, while the Western countries form another clique. Asia further breaks down into Singapore, Malaysia and Taiwan, against Hong Kong and Japan. Malaysia and Taiwan form the smallest grouping. This makes sense as they have similar profiles, being emerging economies with both a high tech sector/industrial sector as well as a large agricultural sector. The West breaks down into the pairs France and Europe, UK and Sweden, and US and Canada. Interestingly, Sweden and UK are grouped into the same clique with Canada and the US instead of France and Europe.

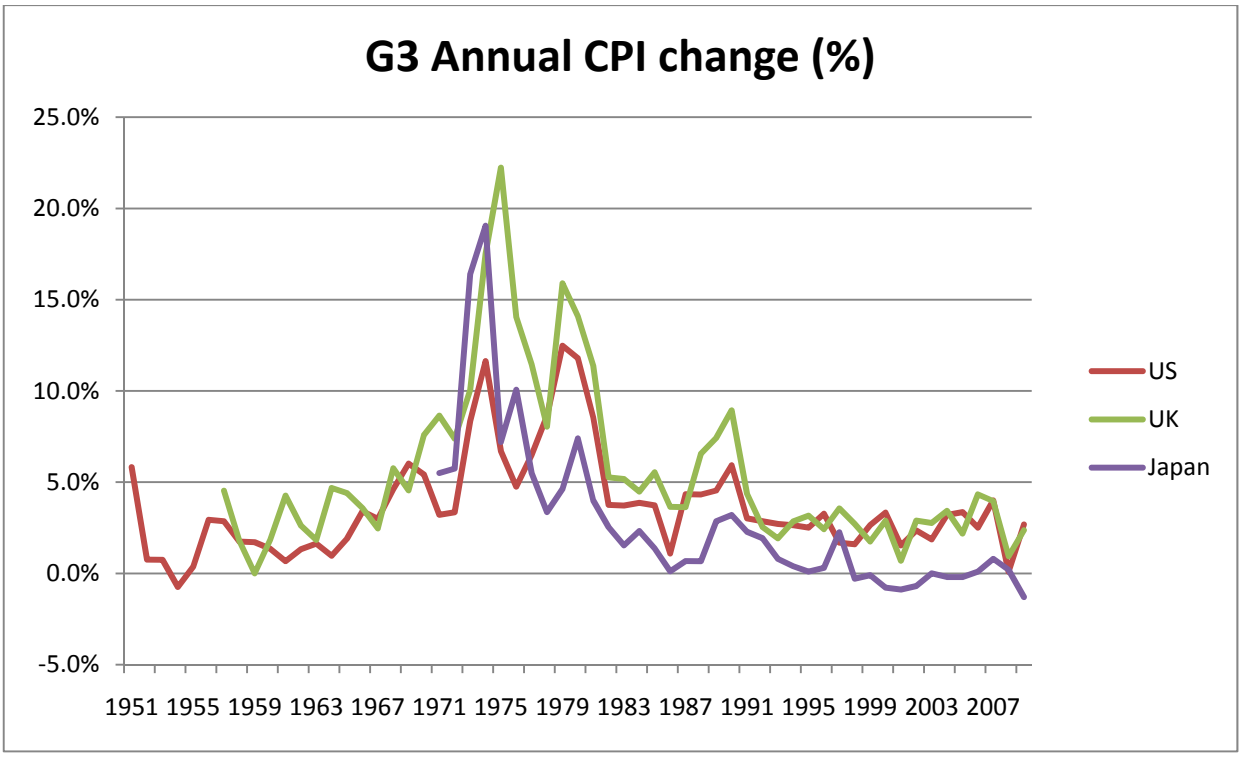



**Figure 3: Annual CPI percentage change of the G3 countries**

From the annual CPI percentage change of the G3 countries in Figure 3, we can see that their inflation changes are highly correlated. In addition, we also observe peaks in inflation in both the early and late 1970's.

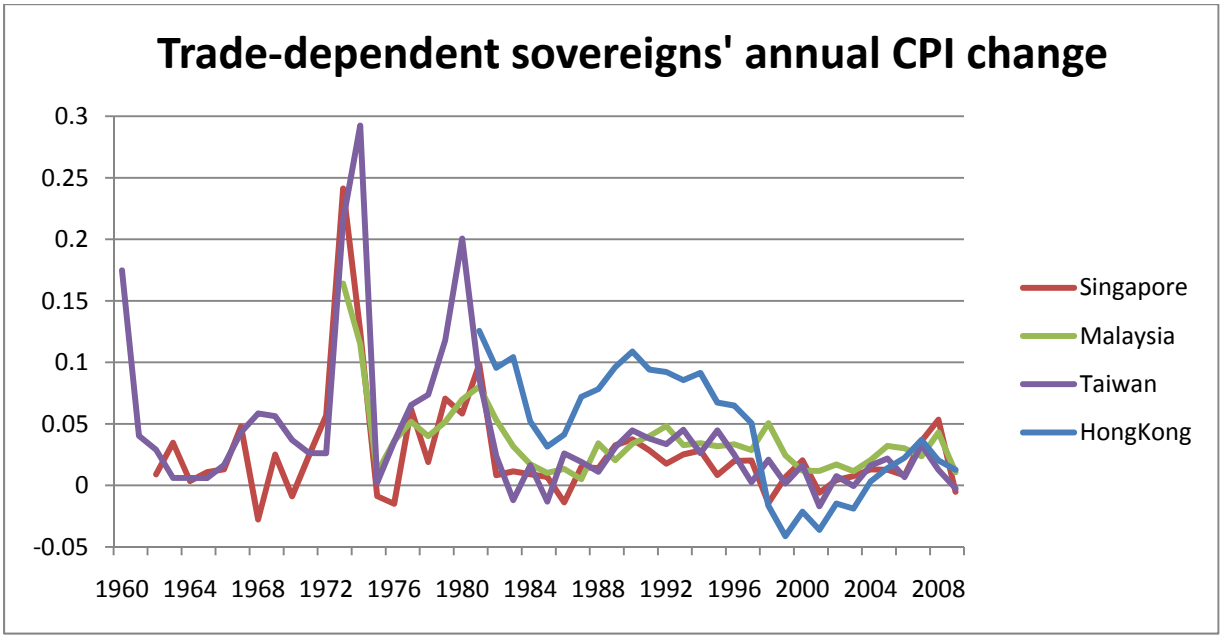



**Figure 4: Annual CPI percentage change of trade-dependent sovereigns**

From Figure 4, we notice that inflation in the smaller trade-dependent Asian countries (Singapore, Malaysia, and Taiwan, in particular) are also quite highly correlated, with peaks in the 1970's. Hong Kong has a wider variation of inflation from the 1980's to the early 2000's, but has recently had an inflation that is very correlated to the other small trade-dependent Asian counterparts.

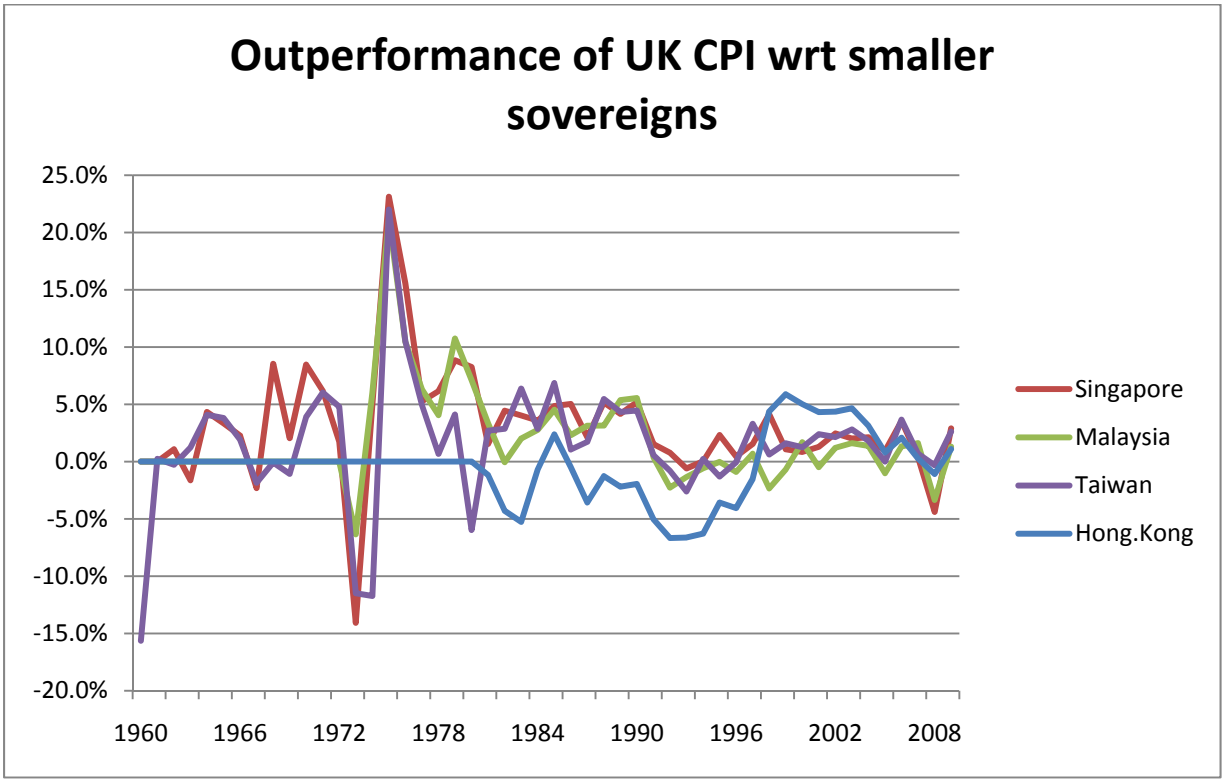



**Figure 5: Outperformance of UK CPI against smaller sovereigns' CPI (percentage change)**

We also observe in Figure 5 that the annual UK RPI has in general "outperformed" the CPI of the Asian trade-dependent sovereigns except for a brief period in the early 1970's and also in the 1980's to mid-1990's for Hong Kong.

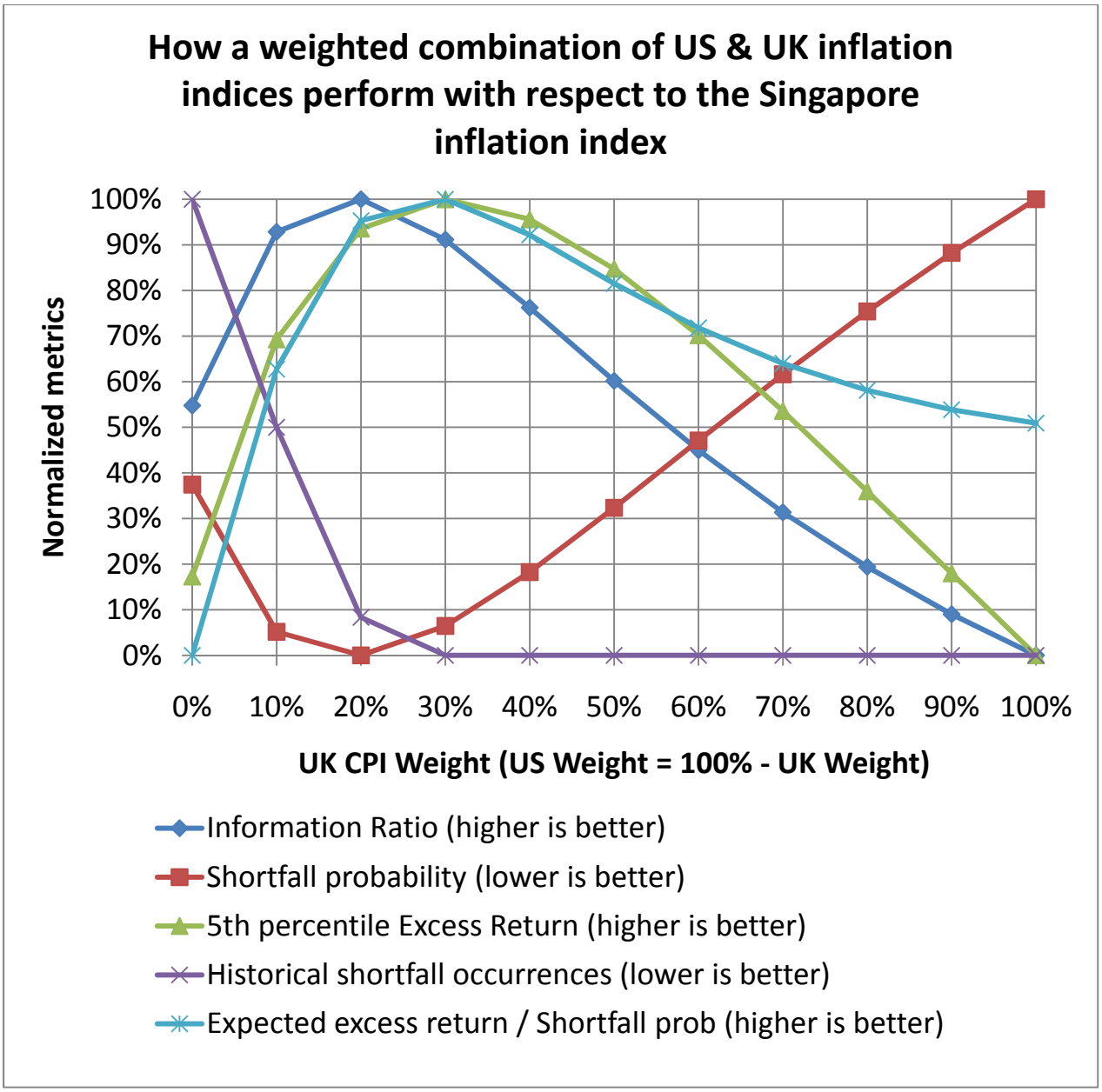



**Figure 6: Outperformance of various weighted combinations of US and UK CPI against Singapore CPI (percentage change)**

Figure 6 illustrates how various combinations of US and UK inflation-indexed bonds would have performed with respect to Singapore's inflation index. A portfolio consisting of between 20% and 30% UK inflation-indexed bonds, with the remainder in US inflation-indexed bonds, would have been optimal in terms of ex-post information ratio, shortfall probability, shortfall occurrences and excess return. This is in line with the proof in Appendix C that a weighted combination of major inflation indices is a sensible hedge for local inflation.

## 5. Conclusion

We have discussed three methods by which small countries such as Malaysia, Singapore, and Taiwan, can make use of financial tools to offer their aging populations the means to protect their retirement income against inflation. The first method is the direct issuance of inflation-indexed bonds. The second method is through the use of inflation swaps. The third is to invest in a basket of foreign inflation-indexed bonds with stable and sufficient correlation to the local inflation index, while hedging out currency and interest rate risks. The last 2 methods have the benefit of not requiring the governments to directly issue inflation-indexed bonds.

Our analysis indicates that a broad-based weighted-average CPI replication measure has merit in hedging inflation risk. Indeed, assuming Purchasing Power Parity holds and that there are free capital flows globally, there will be no difference in real risk-free rates across markets as differences in interest rates reflect differences in expected inflation. In reality however, PPP does not hold and capital flows globally are restricted. As a consequence, the methodology will only work if the deviations from PPP and free global capital flows are relatively small. Nevertheless, insurance against these deviations could potentially be provided by governments and/or sovereign wealth funds, where these national entities would insure any shortfall, while capturing any surplus from such deviations.

Using simple performance and risk metrics utilized in portfolio management, we find that in most cases, a combination of US, Japan and UK inflation-indexed bonds are sufficient to replicate and hedge the local inflations of Singapore, Malaysia, Hong Kong and Taiwan. This is not unexpected as the annual CPI percentage change of the G3 countries (US, Japan, and UK) are highly correlated, while inflation in the smaller trade-dependent Asian countries, such as Singapore, Malaysia, and Taiwan, similarly, are highly correlated.

With this ability to provide inflation-adjusted returns, governments, pension funds, and other institutions can begin to offer a broad suite of inflation-indexed products, ranging from retirement annuities to inflation-linked insurance policies. This will improve the functioning of national pension systems, and hence the welfare of retirees. The added benefit of such structures is that they allow governments to broadly replicate their local Consumer Price Index (CPI) returns without disrupting their traditional financing structures.

Finally, given the potential of reinsuring national default risks across borders via currency and credit default swap facilities at the federal level, there is also a unique role for the government during this process to serve as the reinsurer of last resort.

**References**

"Experiences in Japan: Inflation Indexed Bond Markets", Yukinobu Kitamura, Hitotsubashi University Working Paper, 30 January 2009.

Inflation-Indexed Securities, Mark Deacon and Andrew Derry, New York: Prentice Hall, Table 1.1, page 6, 1998.

"Inflation Derivatives: An Intuitive Approach", Barclay's Capital (former Lehman Brothers), Fixed Income Research Department's Interest Rate Strategy article, June 23, 2008.

"A TIPS Scorecard: Are TIPS Accomplishing What They Were Supposed to Accomplish? Can They Be Improved?" Michelle L. Barnes, Zvi Bodie, Robert K. Triest, and J. Christina Wang, Federal Reserve Bank Public Policy Discussion Paper No 09-8.

"Think global: How to hedge Asian inflation", Nomura Fixed Income Research Department's Inflation Strategy article, April 19, 2011.

# APPENDICES A - C

## A. Countries Issuing Inflation-Indexed Bonds

(The tables in this appendix are reproduced from "Experiences in Japan: Inflation Indexed Bond Markets", Yukinobu Kitamura, Hitotsubashi University Working Paper, 30 January 2009.)

| Country | Issue Date | Index Used |
|---|---|---|
| Argentina | 1972-89 | Non-agricultural wholesale price |
| Australia | 1983- | Consumer prices |
| | 1991 | Average weekly earnings |
| Austria | 1953 | Electricity prices |
| Brazil | 1964-90 | Wholesale prices |
| | 1991- | General prices |
| Canada | 1991- | Consumer prices |
| Chile | 1966- | Consumer prices |
| Colombia | 1967 | Wholesale prices |
| | 1995- | Consumer prices |
| Czech Republic | 1997- | Consumer prices |
| Denmark | 1982- | Consumer prices |
| Finland | 1945-67 | Wholesale prices |
| France | 1952, 1973 | Gold price |
| | 1956 | Level of industrial production |
| | 1956 | Average value of French securities |
| | 1957 | Price of equities |
| Greece | 1997- | Consumer prices |
| Hungary | 1995- | Consumer prices |
| Iceland | 1955- | Consumer prices |
| | 1964-80 | Cost of building index |
| | 1980-94 | Credit Terms Index |
| | 1995- | Consumer prices |
| Ireland | 1983- | Consumer prices |
| Israel | 1955- | Consumer prices |

**Countries Issuing Inflation-Indexed Bonds (Cont'd)**

| Country | Issue Date | Index Used |
|---|---|---|
| Italy | 1983 | Deflator of GDP at factor cost |
| Mexico | 1989- | Consumer prices |
| New Zealand | 1977-84 | Consumer prices |
| | 1995- | Consumer prices |
| Norway | 1982 | Consumer prices |
| Poland | 1992- | Consumer prices |
| Sweden | 1952 | Consumer prices |
| | 1994- | Consumer prices |
| Turkey | 1994-97 | Wholesale prices |
| | 1997- | Consumer prices |
| United Kingdom | 1975- | Consumer prices |
| | 1981- | Consumer prices |
| United States | 1742, 1780 | Commodity prices |
| | 1997- | Consumer prices |

Note: In addition to government bonds, this table includes issues by public corporations, semi-government authorities, and those that carry a government guarantee.

Source: Mark Deacon and Andrew Derry, (1998) Inflation-Indexed Securities, New York: Prentice Hall. Table 1.1, page 6. (Reproduced from Table 1, page 8 in "Experiences in Japan: Inflation Indexed Bond Markets", Yukinobu Kitamura, Hitotsubashi University Working Paper, 30 January 2009.)

**Size of Issuance:**

US - $536.2 billion as of October 2008

UK - £157 billion as of September 2008

France - Euro 151.3 billion as of September 2008

Italy - Euro 83.7 billion as of October 2008

Canada - CA$31.5 billion as of November 2008

Japan - ¥1010 billion as of December 2008

Source: Treasury Department of the United States, Debt Management Office of United Kingdom, the Department of Treasury of Italy, Bank of Canada, Ministry of Finance of Japan and the Bank of Japan (Mizuho Securities). Reproduced from Table 2, page 9 in "Experiences in Japan: Inflation Indexed Bond Markets", Yukinobu Kitamura, Hitotsubashi University Working Paper, 30 January 2009.

**B. Using Derivatives to Hedge Inflation Risk**

Types of Contracts – Reproduced from Barclay's Capital (former Lehman Brothers) Fixed Income Research Department's Interest Rate Strategy article, "Inflation Derivatives: An Intuitive Approach", June 23, 2008. Products and definitions are excerpted directly from the Lehman article.

1. **Zero-Coupon Inflation Swaps**
   In a zero-coupon swap, the buyer receives the cumulative inflation payment at expiry of the contract and does not receive any income over and above the inflation rate. The contract, therefore, directly trades inflation, not real yields. More specifically, a zero-coupon inflation swap is a bilateral contract in which at termination the inflation buyer (receiver) pays a predetermined fixed rate (a.k.a. the "inflation breakeven rate") and receives the cumulative change in the CPI index from the inflation payer (seller). There is no exchange of cash flows at inception or during the life of the contract (other than collateral postings).

2. **Price Index Swaps**
   A price index swap, or a "revenue swap," is similar to a zero-coupon inflation swap; with the difference being that it has periodic (typically annual) cash flows. At each payment date the inflation receiver pays the pre-agreed fixed inflation breakeven rate in exchange for the overall change in CPI since inception.

3. **OTC Inflation Bond / Real Yield Swap**
   An OTC inflation bond, or a real yield swap, is a contract in which a party receives a real interest rate, i.e., a "real" coupon that accretes at the rate of realized inflation in exchange for Libor floating rate payments. To mimic TIPS cash flows, the real rate in the United States is typically quoted semi-annually versus quarterly Libor payments. And as with TIPS, at maturity the real rate receiver pays par and receives an inflation-adjusted principal (or simply receives the inflation uplift). The real coupon rate is determined by the implied expected nominal cash flows on the inflation leg being projected using the inflation curve against the floating Libor payments, both discounted at Libor flat. The real coupon is then solved for such that the NPV of the floating leg matches that of the real rate leg (so that the swap has zero value at onset).

4. **Inflation Asset Swaps**
   An inflation asset swap involves purchasing an inflation bond (e.g., a TIPS) and then passing on all its cash flows to the asset swap seller in exchange for Libor ± spread. At maturity, the buyer pays the inflation-adjusted principal it receives from the TIPS, in return for par or the market price. Note, unlike the earlier instruments discussed, the buyer of the inflation asset swap does not have any inflation or real rate exposure. The asset swap buyer simply passes on the cash

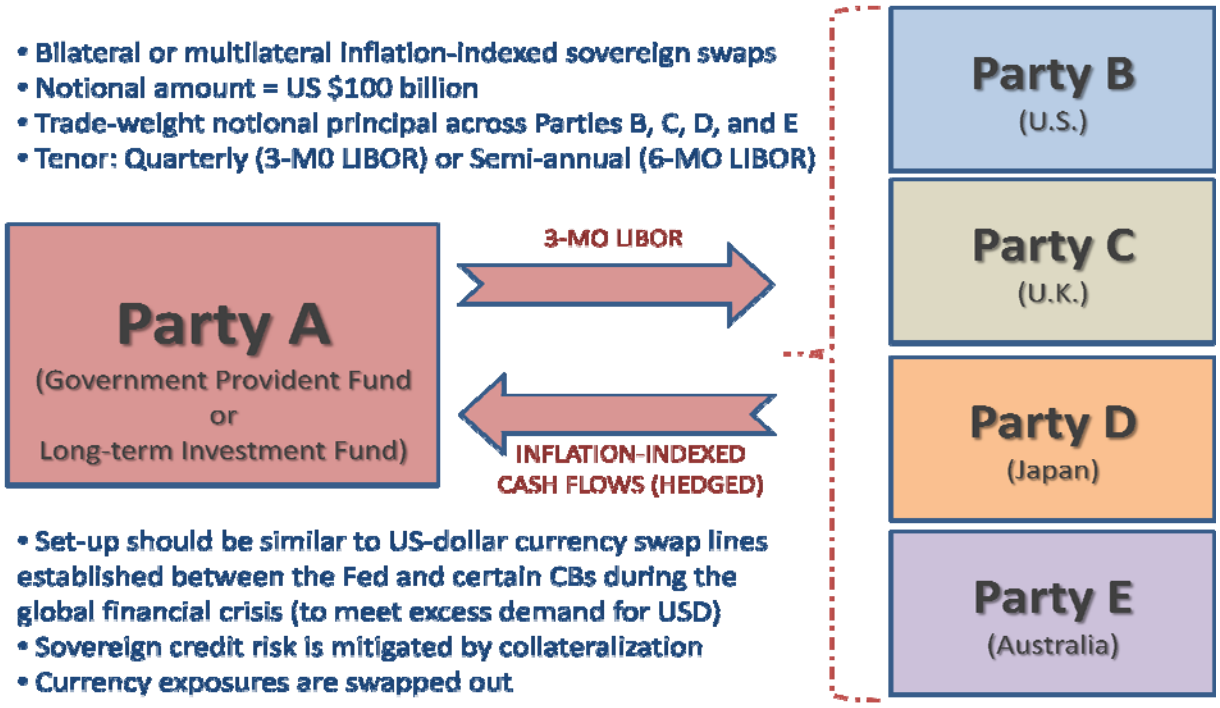
flows it receives from the TIPS held on the balance sheet to the asset swap seller in exchange of Libor ± spread. The only exposure the asset swap buyer has is to the spread to Libor, which is commonly referred to as the "asset swap spread" (ASW).

5. Finally, **Inflation Futures (CME)** and **Inflation Options (OTC)** also exist.

Challenges

- There is currently a low level of liquidity and issuance in both the global inflation-indexed bond markets as well as the inflation-indexed derivative markets.
- Basis risk.

**Inflation-linked Sovereign Swaps: How it would work**




**C. Proof of the weighted-average CPI methodology starting from the PPP relationship**

We show here that the asset price change in local terms is the same as the asset price change in foreign terms if there is either:
1. No change in exchange rates, or
2. Exchange rates are fully hedged using forwards or futures.

Let A be the price of a particular basket of goods/assets in local currency terms and B be the price of the exact same basket in foreign currency terms. Let subscripts denote the discrete times at which we are observing the asset prices. Let S be currency exchange rate in amount of local currency per unit of foreign currency.

Assuming purchasing power parity (PPP), we have

$$A_t = B_t S_t$$

It follows that

$$\frac{A_{t+1}}{A_t} = \frac{B_{t+1} S_{t+1}}{B_t S_t}$$

and clearly

$$\frac{A_{t+1}}{A_t} = \frac{B_{t+1}}{B_t}$$

if S stays the same at 2 time instants. If we take the basket to be a reference basket of goods, this shows that under the PPP assumption the fractional CPI change in one country should be the same as the fractional CPI change in another if exchange rates do not fluctuate.

Now of course, in the real world, exchange rates do not stay constant. In fact they fluctuate wildly. Let's examine what happens when we hedge out the fluctuations in exchange rates using a forward exchange contract. Let $F_t$ denote the forward exchange rate at time t.

At the initial time t, our foreign basket of goods would be worth in local terms

$$A_t = B_t S_t$$

At the next time instant t+1, our currency-hedged basket of goods would be worth in local terms

$$A_{t+1} = B_{t+1} S_{t+1} + (F_t - S_{t+1}) B_t$$

where the 2nd term is the profit or loss due to the forward contract hedge on the starting foreign currency amount. Hence our return in local asset terms is

$$\frac{A_{t+1}}{A_t} = \frac{B_{t+1} S_{t+1} + (F_t - S_{t+1}) B_t}{B_t S_t}$$

Factoring out $\frac{B_{t+1}}{B_t}$ from the RHS, we obtain

$$\frac{A_{t+1}}{A_t} = \frac{B_{t+1}}{B_t}\left[\frac{S_{t+1}}{S_t} + \left(\frac{F_t}{S_t} - \frac{S_{t+1}}{S_t}\right)\frac{B_t}{B_{t+1}}\right]$$

If the time interval is short, $\frac{F_t}{S_t} \approx 1$ as forward prices will not be far from spot and $\frac{B_t}{B_{t+1}} \approx 1$ if we have a reasonable rate of inflation in foreign terms. Hence

$$\frac{A_{t+1}}{A_t} \approx \frac{B_{t+1}}{B_t}\left[\frac{S_{t+1}}{S_t} + \left(1 - \frac{S_{t+1}}{S_t}\right)\right] = \frac{B_{t+1}}{B_t}$$

or

$$\frac{A_{t+1}}{A_t} \approx \frac{B_{t+1}}{B_t}$$

regardless of how much the spot price ratio $\frac{S_{t+1}}{S_t}$ has changed.

Now let's have more foreign countries $B_i$. Let $\Delta CPI_{country} \equiv \log \frac{country_{t+1}}{country_t}$ denote the continuously compounded change in CPI levels for a country. Then we have:

$$\Delta CPI_{local} = \Delta CPI_{foreign,i}$$

$$w_i \, \Delta CPI_{local} = w_i \, \Delta CPI_{foreign,i}$$

$$\Delta CPI_{local} = \sum_i w_i \, \Delta CPI_{foreign,i}$$

where $w_i$ are the weights which sum to 1.