Inflation Hedging

An Empirical Analysis on Inflation Nonlinearities, Infrastructure, and International Equities

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Vollständiger Abdruck der von der Fakultät für Wirtschaftswissenschaften der Technischen Universität München zur Erlangung des akademischen Grades eines

Doktors der Wirtschaftswissenschaften
(Dr. rer. pol.)

genehmigten Dissertation.

Vorsitzender: Univ.-Prof. Dr. Florian v. Wangenheim
Prüfer der Dissertation:
1. Univ.-Prof. Dr. Christoph Kaserer
2. Univ.-Prof. Dr. Marc Steffen Rapp, Philipps-Universität Marburg

Die Dissertation wurde am 17. Juli 2012 bei der Technischen Universität München eingereicht und durch die Fakultät für Wirtschaftswissenschaften am 15. November 2012 angenommen.

to Jia Yan

Abstract

The “great moderation” under Alan Greenspan has finally come to an end. The aftermath of the 2007/ 2008 financial crisis is once again dominated by asset price volatility and concerns about inflation. The causes and consequences of inflation are heavily disputed amongst academics and investors alike. The resulting forecast uncertainty has revived the desire to hedge inflation.

Inflation hedging is entangled even for the most basic asset classes. For example, investment professionals favor real assets and equities over bills and bonds. In contrast, academics largely uncover equities to perversely hedge inflation and recommend rolling bill investments.

This dissertation takes a broad perspective on inflation hedging. It focuses on the long-term relation between asset returns and inflation and covers a 60-year time period with long inflationary as well as deflationary periods, across a set of 50 countries with vastly different experiences, covering relatively low and stable inflation as well as several hyperinflations. The methodology extends the Fisher framework and applies a matrix transformation to account for overlapping data and spatial correlation-consistent standard errors to allow for cross and serial correlation.

The dissertation has three core findings. First, it bridges the gap between academia and practice with an inflation nonlinearity. Stocks hedge low inflation poorly which confirms previous empirical studies. However, they play out their real asset characteristics and become a robust hedge during high inflations, just as conventional wisdom suggests. The nonlinearity is repeated in fixed income. Bills and bonds cope relatively well with low inflation, as found in academic research, while losing at high inflation, which is consistent to the investors' opinion. Significant inflation inevitably resulted in a value transfer from creditors to debtors.

Returns to commodities and international diversification behave more linearly and hedge inflation well across different regimes. Gold prices move fairly volatile which is far away from gold's reputation to be a "safe harbor."

Second, the dissertation analyzes listed infrastructure based on a proprietary dataset that exceeds the existing research in depth and richness. This segment enjoys a reputation for asset intensity, stable cash flows, and inflation hedging. The empirical results tell a different story: infrastructure overall and by sector is not a superior hedge compared to equities. Only infrastructure with particularly high pricing power hedges inflation on a five-year horizon, thereby significantly exceeding stocks.

Lastly, the inflation hedging research lags behind the globalization in investment opportunities. The dissertation proposes international equity indices as a hedge against domestic inflation. These investments benefit from exchange rate moderation and diversification. However, two factors constrain their advantage over domestic equities: firstly, a high comovement of domestic and international inflation neutralizes the exchange rate moderation, and secondly, a strong home currency appreciates during global inflations, which decreases the value of foreign investments. Thus, the strategy does work best in countries with weak home currency and idiosyncratic inflation shocks.

Overall, hedging inflation proves to be more difficult in practice than conventional wisdom would suggest. No single asset hedges inflation perfectly and the risk of significant real shortfalls remains. Yet, several overarching themes have emerged: Inflation hedging becomes easier for long investment horizons. International investments generally outperform purely domestic ones. And lastly, a conditional approach becomes vital since the risk return characteristics depend on the inflation level.

Acknowledgment

I am indebted to my supervisor Professor Christoph Kaserer for his advice and support on my journey through my dissertation at the Technical University of Munich. Thank you very much for your encouragement and continuous support. I am very grateful to Professor Robert J. Hodrick for sponsoring my stay at Columbia University, challenging my research on international equities as inflation hedge, and giving me the opportunity to dive into the research on the other side of the pond. I enjoyed the fruitful joint research with Christoph Rothballer and very much appreciated his inputs during my dissertation. Finally, I would like to thank my colleagues at the Technical University of Munich and Columbia University as well as several students, whom I have supervised, for their curiosity and open questions which have inspired me during this research. Additional thanks goes to several conference participants and discussants in Europe and the US for their critical thinking. All errors are my own.

A slightly different kind of thank you goes towards the political and monetary leaders in the US and Europe for their determined response to the recent financial crisis that has helped to revive the relevance of this piece of research.

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List of abbreviations

ADF	Augmented Dickey-Fuller unit-root test with H_0 of unit-root
AEb	Advanced economies broad, the subset of advanced economies without fixed exchange rates
AEn	Advanced economies narrow, the subset of advanced economies without fixed exchange rates and with positive Chinn-Ito index value
BG	Breusch-Godfrey LM test for serial correlation at lag one with H_0 of no autocorrelation
Bil. I.	Portfolio of international bills from Germany, Japan, UK, and US
Bnd. I.	Portfolio of international bonds from Germany, Japan, UK, and US
BPCW	Breusch-Pagan/ Cook-Weisberg heteroskedasticity test with H_0 of homoscedasticity
CPI	Consumer price index, as index value
CPI_M	Consumer price index, in monetary units
DEM	German mark, a currency
DM	Developed markets equity, i.e. the MSCI World and its GFD extension before 1969
EEb	Emerging economies broad, the subset of the emerging economies without fixed exchange rates
EM	Emerging markets equity, i.e. the MSCI Emerging Markets and its GFD extension before 1987

EMU	European Monetary Union
EUR	Euro, a currency
FRF	French franc, a currency
GDP	Gross domestic product
GFD	Global Financial Data, a provider of long-term financial time series
GSCI	S&P Goldman Sachs Commodity Index
IIB	Inflation indexed bonds
KPSS	Kwiatkowski-Phillips-Schmidt-Shin stationarity test with H_0 of stationarity
MSCI	Morgan Stanley Capital International, an index provider
MSCI EM	MSCI Emerging Markets index
MSCI W	MSCI World index
OECD	Organisation for Economic Co-operation and Development
P25	25 percentile of a series, i.e. value of the lowest 25% of observations
PPP	Purchasing power parity
PRE	Private real estate
REIT	Real estate investment trust
RUB	Russian ruble, a currency
SCC-SE	Spatial correlation-consistent standard errors according to Driscoll and Kraay [1998]
UK	United Kingdom, a country
US	United States of America, a country
USD	US dollar, a currency
USD_{PPP}	Real exchange rate against the USD

VAR	Vector auto regression (model)
VEC	Vector error correction (model)
VIF	Maximum variance inflation factor of the independent variables

List of symbols

α	Constant real return in the Fisher framework, logarithmic
β	Inflation coefficient in the Fisher framework, regressed on nominal returns
β_r	Inflation coefficient in the Fisher framework, regressed on real returns
Δ	First difference of a variable, logarithmic
γ	Unexpected inflation coefficient in the Fama and Schwert [1977] framework
μ	Arithmetic mean
π	Realized inflation, logarithmic
σ	Standard deviation
θ	Measure of comovement between domestic and international inflation (regional or global), calculated in a variance decomposition of a dynamic latent factor model
CPI	Consumer price index
CPI_M	Consumer price index, in monetary units
$E(\pi)$	Consensus expectation for inflation, E(.) also used for other variables

$e_{Local,Foreign}$	Nominal exchange rate in direct quotation, i.e. local currency units per foreign currency unit
i	Interest rate, yield to maturity
Inf^{+}	High inflation, beyond 10% annually, logarithmic
Inf^{o}	Medium inflation, between 5% and 10% annually, logarithmic
Inf^{-}	Low inflation, below 5% annually, logarithmic
k	Investment horizon
N	Number of observations
r_n	Nominal return, logarithmic
r_r	Real return, logarithmic

Chapter 1

Introduction

"So when turbulence in US housing markets metastasized into the worst global financial crisis in more than 75 years, [Ben Bernanke] conjured up trillions of new dollars and blasted them into the economy; engineered massive public rescues of failing private companies; [...] blew up the Fed's balance sheet to three times its previous size; [...]. He didn't just reshape US monetary policy; he led an effort to save the world economy."

Michael Grunwald (2009)
TIME Magazine: Person of the Year 2009, Ben Bernanke.

This article marks the starting point of this dissertation in early 2010. Shortly afterwards, one of the major German magazines covered the same person with a slightly different notion: "Mr. Inflation - How US central bank chairman Ben Bernanke fuels global inflation".[1] Monetary policy is back on center stage. Its consequences on prices in general, and on assets specifically, remain ever more controversial, sparking the interest of academics and investors alike. It also fascinates me, and I devote my dissertation to this topic. This chapter details my motivation, and the objectives and structure of this work.

[1]Translated from Dönch, U., Johann, B., Körner, A., Matthes, N. (2010) Mr. Inflation - Wie US-Notenbank-Chef Ben Bernanke die weltweite Teuerung anheizt, Focus, 4, 96-105.

1.1 Motivation

Politicians and central bank officials saved us from the financial crisis that spread from the United States in 2007 and threatened to melt down the global financial system. The weapons of choice were loading on sovereign debt, money creation, and a strong commitment to low interest rates for the years to come.

Some say the worst is over for now; certainly the saviors do. Economic growth is stabilizing (at a low level), banks are slowly recovering. Others fear the unintended and looming consequences: inflation and sovereign debt issues that further incentivize price inflation policies. Financial reform lags behind expectations and loses momentum. The shadow banking system is expanding once more. Consumer prices are rising, with inflation standing at 3.0% and 4.2% in 2011 for the US and UK respectively.[2] The inflation outlook remains uncertain. Concerned investors look back to the 1970s, which are marked by debt monetization and high inflation, for example, more than 15% per year in the US or more than 20% in the UK. Prices more than doubled in the US and tripled in the UK over the period from 1973 to 1981. Investors suffered real losses of 30% and more in bonds and equities over the same time period.

How will this economic situation play out? Will inflation similar to the 1970s materialize or not? The outcome of the current financial crisis is difficult to predict. I leave this challenge to macro-economists and instead focus on the investor's playing field: What can an investor do to protect her assets against an inflationary scenario? Which assets react negatively to inflation, which ones stable, and, if any, which ones positively? The answers to these questions remain unclear. The gap between academic results, mainstream investment opinions, and the sales pitches for several financial products is wide. For example, most academic research concludes that equities fail to hedge inflation. Their nominal returns even decrease during high inflation. Even though the conceptual reasons are disputed, this result dominates the academic literature for all but the very long run investment horizons. In contrast, equities are embraced as inflation hedge by the financial press and many asset managers alike. Moreover, several financial products have been launched that advertise investments in basic consumer goods producer, mining, or infrastructure stocks as protection against inflation. The

[2] Source: International Financial Statistics of the International Monetary Fund as downloaded March 19, 2012.

advantage of these sectoral strategies in turn lacks statistical evidence in academic analysis. I want to look behind several mainstream conclusions and to develop some of my own thoughts in this dissertation.

1.2 Objective

This dissertation aims to extend the knowledge on inflation hedging, specifically the impact of high inflations and the effectiveness of listed infrastructure and international equities in protecting against inflation.

Most of the inflation hedging literature relies on a single country and a time period of about 30 years. While this extends much longer than the average time series in finance, it is fairly narrow for this type of question. Combining a slow-moving macro-economic time series with noisy asset returns can lead to patterns that are more spurious artifacts than economic causes and consequences. High level data is available for a much broader set of countries, and I aim to include this in order to review existing findings. This can serve as a basis for conditional asset class choice and can integrate the often contradictory views of academia and conventional wisdom.

Infrastructure investments supposedly hedge against inflation. This popular mantra of investors lacks a sound empirical foundation. Existing studies suffer from short or aggregated return data and relatively weak methodology. I aim to challenge this hypothesis based on a novel, proprietary dataset covering 46 countries and almost 40 years.

A common strategy against high inflation is to escape into foreign currencies, mainly the US dollar. At the same time, international diversification for inflation hedging has been largely neglected by academic research. I want to analyze international equity diversification and thereby initiate a broader discourse on this subject. Issues such as the importance of global cross-correlations or currency performance are likely to pop up in other international asset classes as well.

1.3 Scope

This dissertation is a finance work, written by a finance scholar, from the perspective of an investor, and aiming to provide investment guidance. It clearly separates itself from the large body of economic research in this field and does not touch issues such as the nature of inflation, how to forecast inflation, how to predict the impact of monetary policy on prices, or how to effectively apply monetary policy for the benefit of society. It partly touches these issues in a review of the related economic theories in order to help the reader understand money and inflation, but with inflation hedging as the ultimate goal in mind.

I study the inflation hedging of several asset classes across a broad range of countries and time. My priority is to understand the behavior of single asset classes and support conditional asset class choice, depending on an investor's inflation expectations. I do not study the implications of multiple assets in a portfolio context, nor do I analyze the impact of cross-correlation and risk/return trade-offs across assets.

1.4 Structure

Extending knowledge can only be successful after defining its current frontier. The work, thus, first reviews the necessary background on the economic theory of money and inflation. It details how the value of money is measured both at a given point in time and over time, which brings us to inflation. A literature review on inflation hedging by asset class follows. This explains inflation hedging theory, its measurement, and the relevant empirical findings. The synopsis of the empirical research serves as foundation for this dissertation's three main hypotheses. The next chapter presents the data in a consistent way in order to contrast the statistical nature of the economic and financial time series and to allow comparisons across asset classes. I then tackle the hypotheses one by one. The first chapter leverages a broad country and time dataset to study nonlinearities in inflation hedging. I will detail the methodology, present the empirical results, and discuss their implications in this chapter. The same structure is used in the two following chapters. The next chapter covers listed infrastructure as an inflation hedge, and the last one covers international equity investments. An overall conclusion brings the results together, fits them into the existing literature, and outlines directions for future research.

Chapter 2

A primer on money and inflation

This chapter provides the essential economic background for inflation hedging, mainly what drives the value of money and inflation and how this can be measured. The chapter does not intend to provide a detailed review of the economics literature, but rather a text-book style summary on the most established streams of research. It ultimately serves as a primer - without the intention of being complete.

The first part is about money, what it is and how it derives value at a point in time. The second part extends this view across time. The value of money over time represents the core time series in this work: inflation. This background will already point to some of the limitations of research on inflation.

2.1 Money and its value at a point in time

Money and prices are ubiquitous in our developed economies today. Virtually everyone uses money on a daily basis, in high finance and politics just as much as in the not-for-profit space. Despite its frequent use, there is little understanding on where money comes from, what drives its value, and how all this can be measured. These questions are important to understand before we can tackle inflation hedging. And this section tries to address them.

I first define what money is, highlight its main functions and inherent conflicts that arise from these. Then I explain where money comes from and what gives it value. The first part mainly bases on the accounts of [Mankiw, 2001, p. 647ff], [Mishkin, 2009, p. 54ff], and Tobin [2008]. I finally go into more detail on how the value of money is being measured.

2.1.1 Definition of money

"Money [...] is defined as anything that is generally accepted in payment for goods or services or in the repayment of debts."

Frederic Mishkin in his textbook in economics,
Mishkin [2009], p. 8.

"Money is an agreement within a community to use something as a medium of exchange."

Bernard Lietaer, contributor to the euro and thought leader on monetary systems, at a talk at Columbia University (2011) and in Lietaer [2002].

Most definitions of money in academia and practice share several features. First, it is something, tangible or intangible, that can be used as a medium of exchange. Money relieves us from barter. Therefore, it needs to be generally accepted from the market participants. This agreement can be made formally or informally, freely or by coercion, consciously or unconsciously.[1] In fact, most of us have never thought about it and simply continue the general agreement. The acceptance must not come from society as a whole but can be limited to any subgroup, be it an internet game community that uses digital tokens as currency, or a regional community that runs an alternative currency. This shows the boundary of money and difficulties when converting money from one form to another.

Both definitions deviate regarding the main function of money. Lietaer focuses solely on its function in transactions while Mishkin adds the role as store of value. While this is not a black and white distinction of functions as such, it shows the priorities for the design of money and the conduct of monetary policy. The next subsection explains these functions in more detail and highlights why these are inherently conflicting to each other.

[1] Compare Lietaer [2002].

2.1.2 Functions of money

Recent economics and finance textbooks share a wide consensus on the functions of money. The three main functions are medium of exchange, unit of account, and store of value.

Money as a medium for exchange

Money eliminates the double coincidence of wants problem in a barter. For example, you can sell something for money in the trust that the money you receive can later buy something again. You do not need to consider what object the seller later wants when dealing with the buyer in the first place. Money simply serves as a neutral medium. To be suitable as a medium for exchange, money must be conveniently transportable or transferable, verifiable and difficult to counterfeit, as well as fungible, meaning equivalent to one another. What is less obvious is that money must remain in circulation to maintain its value. If a large share of money is stored, there will simply not be enough money for everyone to complete the transactions and prices will adjust. This makes it a substitute for the less liquid assets.

Money as a unit of account

When money is used frequently as a medium for exchange it automatically becomes a unit of account or numéraire, i.e. a standard numerical unit for the market value of goods and services. Similar to how the gram highlights relative weight or the meter relative distance to a more or less arbitrary reference unit, money highlights relative economic worth. Money must be countable and divisible to serve as an effective numéraire.

Money as a store of value

Money will only be used as a medium for exchange and unit of account if its value is stable. A seller will only accept money if he can later use it in exchange to buy something again. This is less concerning if both transactions are close to each other, e.g. you sell your car today and buy a new one the day after. It becomes more important if the intertermporal consumption shift becomes larger, for example when you save money for your retirement. Then, money must be easily storable, nonperishable, and scarce in the long-run.

This function requires money to stay in one place rather than to circulate. You keep money for later instead of spending it now. This makes it a complement to illiquid assets such as stocks or real estate - its most liquid yet no interest paying one. This contradicts the function as medium for exchange and the switch between the two adds to the complexity in managing the money supply which brings us to the next section.

2.1.3 Types of money and its supply

In the early history of money, commodities such as rice, grains, copper, or gold served as money. So called commodity money provides intrinsic value, e.g. for food consumption, as production inputs, or jewelery which supported their acceptance and naturally stabilized their value. Despite its physical weight, commodity money is superior to barter as the objects are universally accepted for trade and become a standardized unit of account even though the objects do not carry any face value. The exchange of tokens on commodities rather than commodities themselves, so called representative money, eases the use of money. Scarcity is still ensured due to the limited natural supply. New explorations have sometimes significantly expanded the supply and distorted existing prices, e.g. during the Spanish gold discoveries. Moreover, in cases of declining demand, e.g. the Black Death in Europe, the existing supply remained too large which again distorted prices.

Fiat money overcomes the one for one link between the physical underlying and the stock of money and thereby eases the control of the money supply. It carries no (significant) intrinsic value but rather gains it by the government order to be legal tender, which makes it unlawful not to accept it for payment. Its supply is not naturally scarce but controlled by the government. The main supply channels are currency and bank money. Currency is the physical object accepted as a medium of exchange such as paper bills or coins. Its creation is under direct government control. However, this only represents around 10% of a developed nation's money supply. The remainder, bank money, is also liquid for transaction and generally also considered as money. It is created through the fractional-reserve banking system. It is not physical and the fractional reserve system adds some risk of non-fulfillment. The relatively low capital requirements for banks have given bank money a dominant share in the total money supply and leave only indirect control over the money supply with the central bank. The theoretically infinite supply and the lack of intrinsic value make the long-term value of fiat money subject to trust in the political and monetary system. And even short-term, the question arises what gives money value if it is intrinsically worthless.

2.1.4 The value of money: Purchasing power and its measurement

Fiat money in itself is worthless. Just imagine you would be stranded on an desert island with 10'000 EUR in cash. Your cash would be worth nothing while your knife could still be of use.[2] So, what gives it value if not the object itself? It is the agreement to use it as a medium for exchange. Money is worth whatever it can buy, the number of pencils, water bottles, and so on. The value of money will be high if it buys many goods, and it will be low if it buys few goods. Economists call this the purchasing power of money. This original meaning has been turned upside down from monetary authorities and the press. Purchasing power is today typically measured in the amount of money that has to be paid for a defined goods basket. Higher prices in general imply that goods became more expensive rather than that the value of money decreased. I stick to this view simply because it is so pervasive. However, in most cases when I talk about increasing prices it essentially relates to a decreasing value of money.

Purchasing power is what makes money valuable. It is defined as the number of goods and services that can be purchased with a unit of currency. It does not focus on a specific transaction but rather looks at a broad consumption basket, typically the consumption basket of an average consumer. This will be fine when analyzing inflation hedging in general. However, when applying inflation hedging to a specific investor we should bear in mind that his consumption basket might differ substantially from the average person. The potential mismatch limits the

[2] Example from Bernard Lietaer (2010) What is money?, http://www.lietaer.com/2010/09/what-is-money, accessed Dec 10, 2011.

validity of the inflation hedging results. It is not possible to correct this bias retrospectively without detailed, disaggregated price data.

Measuring purchasing power requires two ingredients: Weights and prices. Weights determine what goods and services the average person buys. They can be measured in units, such as the number of books, or as expenditure shares, which is sufficient for relative indices. Weights are based on surveys which typically exclude non-average persons like high net-worth individuals or pensioners and "non-typical" spending such as spending abroad or savings. Weights do not only relate to the goods and services as such but also to where they were bought, the sales channel (e.g. online or offline) and geography (e.g. urban or rural). Prices attach monetary value to each goods and service. They are averages across several sales outlets which match the geography and sales channel of the respective weight. Investment goods, such as owner-occupied real estate are proxied with the opportunity costs, rental equivalent, or alternative cost approach. The combination of prices and weights allows to calculate the purchasing power of money and analyze the spending pattern of the average consumer.

A look at some important baskets, namely the United States, Japan, and Europe/ Germany, highlights the complexity of this measurement and the composition of the baskets. In the United States, the Bureau of Labor Statistics is in charge for the consumer price index.[3] The consumer expenditure surveys base on a total of 28'000 weekly diaries and 60'000 quarterly interviews. The bureau tracks the prices of 200 item categories with 80'000 items behind it on a monthly basis. In Japan, the Statistics Bureau of the Ministry of Internal Affairs and Communications carries out the Family Income and Expenditure Survey.[4] It surveys about 9,000 households through a three-stage stratified sampling method. Each sample household records its daily income and expenditures on family account books over a six months period. This allows to compute the average expenditures or weights. Prices are then collected for 585 items represented in different qualities, standards, volumes, etc. from 28'000 stores across 167 locations. In Europe, Eurostat of the European Commission is responsible for the harmonized consumer

[3]Bureau of Labor Statistics (2012) Consumer price index, http://www.bls.gov, accessed March 2012.

[4]Statistics Bureau of the Ministry of Internal Affairs and Communications (2012) Consumer price index, *http : //www.stat.go.jp/english/data/cpi/index.htm*, accessed March 2012.

price index.[5] It defines a minimum standard for the member countries and aggregates the country-specific indices with purchasing power parity adjusted gross domestic product weights into the European consumer price index. Each of the countries define their specific representative baskets. Altogether, Eurostat tracks 700 products across several outlets and 1'600 different locations which results in a total of 1'800'000 monthly price observations.

The Organisation for Economic Co-operation and Development OECD provides a standardized comparison of the national expenditure surveys. The weights for Germany, Japan, and the United States in the years 1999 and 2009 are shown in Table 2.1. The services share has been rising across developed countries and is as high as 50% in Germany and Japan and 61% in the United States. Food and beverages captures as little as 9% in the United States. This pattern is representative for developed countries. Housing has been rising and now occupies roughly one third of the total expenditures.

This subsection shows the effort it takes to measure the purchasing power of money at a point in time. And still the statistics are subject to sampling errors or survey inaccuracies. International comparisons are further complicated by different basket compositions, methodologies, and potential conflict of interests in some countries. And most critically, a likely deviation of the investor's actual inflation exposure from the average inflation. Despite the potential weaknesses, it is difficult to find more powerful alternatives. The subject becomes even more entangled when leaving the static view and taking a dynamic view over time which leads us to inflation.

2.2 Inflation and the value of money over time

This section takes the static view on purchasing power and extends it across time. Purchasing power over time is the inverse of inflation. Inflation has been subject of intense discussion in the aftermath of the 2007/ 2008 financial crisis. The views on the drivers, timing, and magnitude of inflation between and within investment

[5] Eurostat (2012), Harmonised indices of consumer prices (HICP), *http : //epp.eurostat.ec.europa.eu/cache/ITY$_S$DDS/EN/prc$_h$icp$_e$sms.htm*, accessed March 2012; and European Central Bank (2012), Measuring inflation - Harmonised Index of Consumer Prices (HICP), *http : //www.ecb.int/stats/prices/hicp/html/index.en.html*, accessed March 2012.

Table 2.1: Composition of household expenditures in Germany, Japan, and the United States

Product category	**Germany**			**Japan**			**United States**		
	1999	2009	Δ	1999	2009	Δ	1999	2009	Δ
Food and beverages	13	10	-2.8	23	21	-1.5	11	9	-2.2
Clothing and footwear	7	5	-2.0	7	5	-2.2	5	4	-0.9
Housing incl. utilities	27	31	3.3	26	27	1.4	34	37	2.5
Furnishing	7	6	-1.5	4	4	-0.7	4	4	-0.1
Health	3	4	0.6	3	5	1.3	5	6	0.3
Transport	14	13	-0.7	9	9	0.0	15	14	-0.8
Communication	2	3	0.8	2	3	1.4	3	3	0.6
Recreation and culture	10	12	1.2	9	10	0.6	7	7	0.6
Education	1	1	0.1	4	4	-0.4	2	3	0.3
Restaurants and hotels	5	4	-0.2	8	7	-1.6	7	7	0.3
Miscellaneous	10	11	1.1	5	7	1.7	7	6	-0.5
Total	100	100	0.0	100	100	0.0	100	100	0.0
... Goods	56	50	-6.1	52	50	-2.3	41	39	-2.5
... Services	44	50	6.1	48	50	2.3	59	61	2.5
... Food and beverages	13	10	-2.8	20	19	-1.3	10	8	-1.8
... Energy	9	10	0.7	7	7	0.8	7	9	1.6
... Others	78	80	2.0	73	74	0.5	83	84	0.2

Abbreviations: Furnishing includes furnishing, household equipment and routine maintenance, Miscellaneous includes miscellaneous goods and services as well as alcoholic beverages, tobacco and narcotics.
Source: OECD (2012), Statistics, http://www.oecd-ilibrary.org, accessed March 2012.

community and academia differ wildly. This sections defines inflation, highlights the major schools of thoughts, potential real economic consequences, and looks into the technical measurement of inflation. I filter for usefulness for inflation hedging and the reader might want to keep in mind that inflation forecasting and monetary policy as such is not in the scope of this work.

2.2.1 Definition

"Inflation is a process of continuously rising prices, or equivalently, of a continuously falling value of money."

Michael Parkin in The New Palgrave Dictionary of Economics,
Parkin [2008].

Parkin's definition goes back to his first article in the dictionary in 1980 and captures the notion of the falling value of money. While inflation *is* a decrease in the value of money over time, it *manifests* itself in increasing prices for goods and services. Other recent definitions neglect this and focus on rising prices only (e.g. compare [Mankiw, 2001, p. 665] or [Barro, 1997, p. 237]). Inflation along this paper's definition is more precisely coined price inflation which distinguishes it against monetary inflation, a term of the Austrian school that relates to growth of the money supply. Hyperinflation typically refers to inflation with monthly rates beyond 50% as defined by Cagan [1956]. Deflation means a decreasing price level and disinflation defines inflation with a declining but still positive value. I define the following inflation ranges: low inflation below 5%, annually logarithmic, mid inflation from 5-10%, and high inflation above 10%.

2.2.2 Causes in the closed economy

The basic economic models on inflation assume a closed economy. All transactions in this economy are to be settled with money as medium for exchange. The aggregated value of these transactions is the demand for money. Currency and bank money represent the money supply. The price level works like a clearing price for the supply and demand. Inflation in the closed economy occurs either because of under-demand in real economic activity or over-supply of money. The prevailing schools of thought focus on different sides of this equation: Monetarism identifies the money supply as key cause of inflation whereas Keynesianism focuses on the aggregated demand.

Monetarism and the quantity theory of money

According to Cagan [2008], monetarism views the quantity of money as the major driver of the price level and proposes that the objectives of monetary policy are best achieved by targeting the rate of growth of the money supply. The quantity theory of money lies at the heart of monetarism and proposes an equality between the money supply, a product of money stock M and money velocity V, and economic activity, a product of transaction quantity Q and price level P:

$$M * V = Q * P.$$

Monetarism deducts two claims from this equation. First, changes in the money stock M have a positive impact on changes in the price level P which is founded in the persistence of V and Q. Second, given empirically comparatively small long-run changes in V, the price level P will in the long-run only be determined by the relative growth difference of money supply and real economic activity. For these claims to hold monetarism largely requires independence amongst the variables, especially M and Q, which is termed money neutrality. At the same time it does generally not assume super-neutrality which is the independence of the growth rate of M and Q. Money growth might indeed have short-term impact on the real economy, but, since the impact is unpredictable, a stable monetary policy remains superior.[6]

Keynesianism

Keynesianism in its broad sense believes in the use of macroeconomic policy to stabilize the economy and to maintain low levels of unemployment. Related to inflation, Keynesianism proposes that pressures in the real economy express themselves in prices. Shocks fall in one of three categories: aggregated demand beyond the potential output causes demand-pull inflation; supply shocks, for example as

[6]Compare Barro [1997].

consequence of a natural disaster, causes cost-push inflation; a spiral of wage push and rising prises causes built-in inflation. Inflation in all cases is mainly driven by economic and not monetary factors. Furthermore, the economic factors can be influenced by an active monetary and fiscal policy for the benefit of society.[7]

2.2.3 Consequences in the closed economy

While inflation and higher prices sound disadvantageous at first, the conceptual consequences are not that clear. Higher prices may be bad for the buyer, but at the same time are good for the seller. The aggregated benefits for society in a closed economy might be neutral as the higher costs for one side result in higher revenues for the other.[8] Moreover it is very difficult to prove causality and disentangle it from other business cycle variables. Even statistical tools like Granger causality have not yielded clear results.[9]

Economists often separate anticipated from unanticipated inflation when analyzing the consequences of inflation. The distinction became especially important for monetary policy with the rise of rational expectations theory after Robert Lucas 1976 paper on “Econometric policy evaluation: a critique’.

Anticipated inflation

Anticipated inflation is defined as the market consensus expectation of inflation. It is reflected in interest rates, financing, or investment decisions. Yet, different levels may lead to different economic outcomes. The Mundell-Tobin effect proposes that higher anticipated inflation increases the opportunity costs of holding money which in turn leads to higher investment in physical capital and higher output. Money and capital are viewed as substitutes. In stark contrast, the overlapping generations framework of Samuelson and Wallace as well as the cash-in-advance model of Stockman treat money and capital as complements. People save more in response to higher anticipated inflation which in turn decreases capital investments.[10]

[7] Compare Backhouse and Bateman [2008] and Parkin [2008].
[8] Compare [Mankiw, 2001, p. 676ff].
[9] See Parkin [2008] for more details.
[10] More on this in Parkin [2008].

While the impact on the investment level remains unclear, substantial levels of anticipated inflation induce real costs which are summarized in [Mankiw, 2001, p. 680]. People would like to minimize currency holdings and go to the bank more often, e.g. instead of withdrawing money on a monthly basis, you would go daily to avoid losing interest. The associated costs are termed shoe-leather costs. Menu costs relate to businesses and arise from frequently changing list prices. While this might be as simple as re-stickering for restaurants, it becomes more cumbersome for large supermarkets or travel catalogs. More general, dynamic pricing structures lead to miss-allocation of resources in an economy. This will be amplified by tax distortions as most tax laws ignore inflation. Low income labor migrates into the high income tax bracket (cold progression) and inflation induced capital or interest gains will lead to substantially higher real taxes during high inflation.

The gains and costs of inflation will likely be not distributed homogeneously. The government will benefit from seigniorage as it issues new money which can contribute substantially to the state budget in high or hyper inflations [Mankiw, 2001, p. 676]. Moreover it benefits from inflation tax distortions. Creditors are more likely to suffer than debtors as inflation rates accelerate fairly quickly and thus tend to be underestimated in cases of hyper inflations. This risk already creates the need for an inflation hedge against anticipated inflation. However, the wealth transfer will ultimately be decided by unanticipated inflation.

Unanticipated inflation

Unanticipated inflation is the difference between anticipated and realized inflation. As such, it is the surprise component which almost by definition leads to distortions and wealth transfers in society [Mankiw, 2001, p. 685]. The magnitude of the surprise depends on the market participants individual anticipation and, in case that differs from the market consensus, the degree to which they get rewarded for it. Even if you expect inflation to be above consensus, the market clearing interest rate will not reflect it and you may still suffer from unanticipated inflation. Positive unanticipated inflation will inevitably lead to a wealth transfer from creditors to debtors. Their real interest and principal burden will be less than expected which lowers the real return for the creditor. The risk of unanticipated inflation emphasizes the need for an inflation hedge for asset owners in the short- and long-run.

2.2.4 Implications for exchange rates

The above effects of inflation implicitly assume a closed economy. Most practical concerns today are in open economies. Understanding inflation in this context requires to master exchange rate behavior. I introduce purchasing power parity and the international Fisher relationship to provide some background on this topic. Both theories are closely linked to inflation hedging with international diversification.

Purchasing power parity

The modern form of purchasing power parity (PPP) goes back to Cassel [1918]. According to Cassel, "(t)he rate of exchange between two countries is primarily determined by the quotient between the internal purchasing power against goods of the money of each country', or in more formal terms

$$e_{Local,Foreign} = \frac{CPI_{M,Local}}{CPI_{M,Foreign}}$$

with $e_{Local,Foreign}$ denoting the exchange rate and CPI_M the monetary price of the CPI goods basket in the respective currency. It builds on the theory of one price which predicts the same price for every tradeable good across locations. Gold, for example, is a perfectly tradeable good and should be priced identically in Germany and the US. According to this absolute form of PPP, the exchange rate shall reflect current prices rather than future expectations, the real economy rather than the financial economy.

The consumer price indices of most countries are reported as pure index numbers rather than monetary units which constraints empirical tests to relative PPP. Relative PPP is defined as the first derivative of the above which is in logarithmic form

$$\Delta e_{Local,Foreign} = \Delta CPI_{Local} - \Delta CPI_{Foreign}.$$

Relative PPP predicts a synchronous movement between exchange rate changes and the differential in inflation ΔCPI. This provides a tool for assessing the current value of a currency (relative to a reference point in time) and forecasting long-term adjustments to it. However, there are severe draw-backs. First, PPP fails to explain the high short-term volatility in exchange rates with its slow-moving underlying inflation differential. Thus, its empirical short-term track record is poor and major deviations exist and persist over several years. While the theory of one price holds closely for gold, it becomes blurred in broad consumption baskets that underly the consumer price index. Non-tradeable goods, trade frictions, and relatively high transport costs distort the picture. Moreover, the consumption baskets differ which makes the inflation differential only a poor proxy for exchange rate adjustments. This casts doubt on the inflation hedging of international assets, at least in the short-run. A more detailed introduction to PPP can be found in Mankiw [2001], p. 704, and Sarno [2008].

International Fisher effect

In contrast to PPP, the international Fisher effect or Fisher's open hypothesis aims to provide a forward-looking picture of the exchange rate and focuses on the financial economy. Starting point for Fisher's open hypothesis is that all investors should get the same real interest rate. Under perfect PPP and the Fisher hypothesis, this will yield to the same expected return for local and foreign investments, i.e. in logarithmic notation:

$$E(i_{Local}) = E(i_{Foreign}) + E(\Delta e_{Local,Foreign}).$$

Thus, the expected exchange rate movement should perfectly mirror the differential in interest rate yields i. The equality will be maintained through arbitrage opportunities that arise from covered interest rate parity and the forward expectations parity. Tests on the Fisher equation cast doubt on the assumption of a constant and homogeneous real rate which distorts the theoretical prediction. Again, inflation hedging in an international context seems more complicated in practice than in theory. More background on the international Fisher effect can be found in Mishkin [2009], p. 448.

2.2.5 Measurement: Consumer Price Index

Empirical tests of inflation hedging require a proxy for inflation. The most common proxy is the consumer price index. It essentially extends the concept of purchasing power, as reviewed in the previous section, over time. Again, it is commonly measured and discussed as price increase rather than decrease in the value of money - which we should keep in mind when interpreting the results.

Measuring the purchasing power of money over time introduces additional complexity. First, the basket composition will naturally change over time, be it supply-driven through product innovation or changing product quality or demand-driven through changing preferences and substitution. Tracking the basket composition with consumer surveys is expensive and changes in its composition could affect the index even in case of stable prices. This could partially be mitigated by revising historic indices at the cost of increased computational complexity and changing historical figures. The solution requires a trade-off between accuracy, monetary costs, and transparency.

The most widely followed measurement strategy is a combination of periodic updates of the cost of living baskets, e.g. every fifth year, and in between a fixed-weight cost of goods index in the short-run. The following introduction bases on the accounts of Lebow and Rudd [2008] and the Consumer Price Index Manual of the International-Labor-Organization [2004]. The fixed weight indices are typically Laspeyres indices which base on the historic weights and avoid recalculations that would be necessary under a Paasche index. It leads to overstating inflation as consumers cannot substitute products with rising prices. More sophisticated methods like the Fisher or the Törnqvist ideal index try to overcome these by averaging but are hardly used in practice. In some instances, such as the US, constant price elasticities and substitution rates are assumed to correct the weights.

The consumption baskets are updated every five years in Japan and in Germany (and most European countries). The US increased the update frequency from once every ten years to every second year in 2002. All indices of these countries are conceptually Laspeyres indices between the revisions. Inflation is typically reported on a monthly basis with and without seasonal price adjustments. Notable exceptions are Australia and New Zealand which only report on a quarterly basis. I will rely on annual inflation data to avoid seasonality corrections and overlapping data.

Inflation reporting is subject of extensive academic and practical discourse. While methodological problems certainly exist, the consumer price index is still the best proxy available and reasonably representative. A relevant risk is not technical but rather political: systematic inflation understatement, e.g. as disputed for Argentina. Initiatives like “The Billion Prices Project @ MIT” from Professor Rigobon and Cavallo at the Massachussets Institute of Technology compute online shopping price indices on a daily basis. This allows to at least question the official reports and increase the transparency on pricing data.

Another severe shortcoming relevant for inflation hedging is a likely mismatch in consumption pattern. While the consumer price index might reflect the price increases of the average consumer or society as such, it must not be relevant to a specific investor’s price exposure. The index does not distinguish between rich and poor consumers and is unavailable for students or retirees. Unfortunately, there is no easy remedy. I assume that the general consumer price index is representative for an investor’s spending pattern and therefore relevant benchmark for inflation hedging.

2.3 Summary

This chapter introduced the basic economic concepts relevant for inflation hedging. Purchasing power represents the value of money and is measured against a broad goods basket. It essentially depends on the scarcity of and trust in fiat money. The inverse of purchasing power over time is called (price) inflation. It refers to a rise in the general price level over time and is captured in the consumer price index. While its measurement comes along with a range of technical and conceptual difficulties, such as political bias or consumption mismatch, it is very difficult to come up with a superior alternative. The inflation hedging literature unanimously relies on this consumer price index and has to live with their shortcomings.

Chapter 3

Inflation hedging in the literature

"There is nothing new except what has been forgotten."

Marie Antoinette, 1755-1793, France.

The essential first step of any dissertation is to learn from the existing literature. This chapter summarizes the main findings of this review. First, I provide a conceptual definition of inflation hedging. The theory on this topic is clear and I keep this short. Second, I introduce how inflation hedging has been defined empirically. The matter is more complicated to capture in empirical analyses than it first seems conceptually. Similarly, the empirical results which I present by asset class are also more entangled and, in some cases, seriously challenge the underlying theory. A synopsis summarizes and contrasts the empirical findings.

3.1 Theoretical foundation

The theoretical foundation of inflation hedging is dominated by broad propositions, general enough to abstract from the actual problems. Neither the real impact of money nor the subtleties of inflation measurement distort the picture. I provide a conceptual definition of inflation hedging before introducing the main theories on inflation hedging.

3.1.1 Definition of inflation hedging

Inflation hedging relates the financial return of an asset to inflation. The asset can be monetary or non-monetary, for example a 10 EUR bill or an apartment in downtown Munich. It can be tangible, e.g. a ton of steel, or intangible like a credit default swap on Italian government bonds. The aim is to protect existing wealth against inflation. The financial return to an asset is measured in monetary terms. If a stock price increases from 10 EUR to 11 EUR over one year, its financial return in nominal terms will be 10%. This view does not yet incorporate a potential loss in the value of money. If inflation over the same period stands at 5%, the investor's effective gain will decrease to approximately 5%[1]. This return, called the real return, is the nominal monetary return minus inflation in logarithmic notation, or in other words, the gain of an asset relative to other goods and services.

Definition: An asset hedges against inflation if its real return moves independent of inflation.

For example, let us consider a physical asset like a valuable commodity. It carries value but is assumed not to generate ongoing positive or negative cash flows such as storage costs or usable value. The financial return to this asset will be the difference between purchase and sales price. If its value moves along with inflation its real return will be constant and the asset will hedge inflation.

3.1.2 Classical dichotomy and the neutrality of money

Classical dichotomy was first termed by Patinkin [1956] and is a by-product of monetarism and the neutrality of money. It shapes the mainstream believe on inflation and real assets without people actually knowing the concept behind it. Classical dichotomy distinguishes nominal variables denominated in monetary terms from real economic variables denominated in units, time, etc. It proposes that both variable categories are independent in case of money neutrality which allows to separate them in economic analyses.

This separation implies that all real assets, i.e. real variables, ought to be independent of money and inflation and, thus, protect against inflation. Com-

[1] 4.76% when including the base effect.

modities, gold, and real estate clearly fall into this category. But even equities represent real assets. Their value is backed by product sales, i.e. a flow of real assets, which relative to other broad goods basket, e.g. the consumer price index, represents a real variable. The neutrality of money proposes that the value of all real variables should be independent of the stock of money and, in case of super neutrality, the growth rate of money. Consequently, their monetary value should move along with inflation which makes them a good inflation hedge. Historic accounts support this colorfully for high inflations, e.g. during Austria's high inflation in 1919: "the value of [...] industrial investments is rising [in parallel to inflation] to an extent which seems to be incomprehensible' ([Fergusson, 2010, P. 25]).

Classical dichotomy primarily relates to realized inflation. In a weaker form it should also hold for anticipated inflation. Only in case of unanticipated inflation, when a wealth transfer between creditors and debtors becomes real, should the value of equities show risk on inflation. Any test of inflation hedging on real assets will also be a test of the predictions of classical dichotomy and the super neutrality of money. When controlled for unanticipated inflation, the test is on its weaker form.

3.1.3 The Fisher hypothesis

Fisher [1930] follows the idea of money neutrality and the separation of the monetary and the real economy. His main hypothesis for inflation hedging, known as the Fisher hypothesis, proposes that expected nominal interest rates in fixed income equal expected inflation plus a constant real rate. Therefore, nominal interest rates should move one for one with expected inflation.

This has direct and testable implications for inflation hedging in fixed income. Absent of changes in liquidity and other risks, which might be correlated to inflation, the yield to maturity of any fixed income instrument should mirror the inflation expectations. Moreover, if the forecasting error in expected inflation is unsystematic, the expected returns will also move one for one with the realized inflation over this period, which is easier to observe.

The Fisher hypothesis became the most widely tested prediction and standard framework in inflation hedging since this information is observable in the markets.

We will see in the following how it has been modified in empirical studies to reach beyond fixed income.

3.2 Empirical definition

The empirical inflation hedging definitions can be separated into single-asset and multi-asset frameworks. The single-asset frameworks can be further grouped into Fisher and its derivatives as well as other simpler measures. I will provide an overview of the main methodologies in these three categories. Spierdijk and Umar [2010] also summarize the main methodologies and provide a quantitative translation between them.

3.2.1 Single-asset frameworks based on the Fisher hypothesis

Fisher's main hypothesis marks the core of inflation hedging research and has been applied in several derivatives, depending on the inflation proxy, control variables, and investment horizons.

The original Fisher hypothesis

The Fisher hypothesis of Fisher [1930] predicts a one for one ex ante relation between returns and inflation

$$E(r_n) = \alpha + \beta E(\pi) + \epsilon \tag{3.1}$$

with r_n denoting the nominal return of an asset, α a constant real return, and β the asset's correlation coefficient with expected inflation $E(\pi)$ which is expected to equal one. This framework is very powerful since expected nominal returns are directly observable as yields to maturity for bills and bonds (absent of default risk) and short-term expected inflation can be inferred from surveys or forecasting models at reasonable accuracy. It is less suitable for long-term predictions as expected inflation is difficult to acquire then, and for other asset classes such as commodities or equities which do not have clearly observable expected returns.

The ex-post version of Fisher

An ex-post version of Fisher has been used for long-term analysis and a wider range of asset classes. Given unsystematic forecasting errors between expected and realized inflation and unbiased return expectations it proposes a one for one relation between realized nominal returns r_n and realized inflation π:

$$r_n = \alpha + \beta\pi + \epsilon. \tag{3.2}$$

The ex-post version has conceptually been used in some of the older long-run cross-country equity analysis such as Cagan [1974] to more recent studies such as Bekaert and Wang [2010] which include a broad range of assets, countries, and investment horizons.

The Fama and Schwert [1977] framework

The theory chapter has hypothesized different dynamics for expected and unexpected inflation. The Fisher frameworks so far have only incorporated expected or realized inflation. Fama and Schwert [1977] have extended this framework to account for unexpected inflation as:

$$r_n = \alpha + \beta E(\pi) + \gamma(\pi - E(\pi)) + \epsilon.$$

$(\pi - E(\pi))$ is coined unexpected inflation with expected inflation $E(\pi)$ proxied with last period's inflation. An asset is defined a complete hedge against expected inflation if $\beta = 1$ and a complete hedge against unexpected inflation if $\gamma = 1$. $0 < \beta < 1$ and $0 < \gamma < 1$ imply partial hedging while negative values imply a perverse hedge. This framework has been adopted widely and filled with different proxies for expected inflation in short-term analysis up to one year. Long-term analysis have relied on realized inflations since anticipated long-term inflation relies on survey data, which is only available for a limited country and time coverage.

Cointegration and VEC models

The Fisher regressions estimate the inflation hedging coefficients for one specific investment horizon. The empirical results are generally sensitive to the investment horizon which requires to test the coefficients for several intervals independently. While this is possible with the Fisher framework, the inflation time series tends to become persistent at multi-year horizons which introduces the risk of spurious regression. A more elegant way to deal with this problem are cointegration analysis and vector error correction (VEC) models, which have been first applied to inflation hedging by Ely and Robinson [1997].

Cointegration analysis tests the stationarity of real returns, i.e. nominal returns minus inflation. If these are stationary, the real returns of the asset are independent of inflation and it provides a long-term hedge. I will perform similar tests for each asset and country in the data section. Vector error correction models analyze multiple time series simultaneously. They build the prerequisite for impulse response functions which allow insights on the hedging characteristics over the time horizon, e.g. three months rolling bill returns might react neutral to an inflation shock in the first weeks but then gradually increase and hedge inflation for example at a one-year horizon effectively.

The drawback of this analysis are often wide confidence bands for the hedging coefficients and the de-facto restriction to single countries. The application to unbalanced panel data becomes complex with panel test statistics undifferentiated and, to the best of my knowledge, has not yet been done convincingly.

3.2.2 Single-asset frameworks beyond the Fisher hypothesis

Several studies from investors and some academics directly compute correlation coefficients of returns with inflation as well as short-fall risks. Since these measures are less wide-spread in the literature I will only summarize them briefly.

Pearson correlation coefficient

The Pearson correlation coefficient is a common measure in science for the degree of linear dependence between two variables. For the nominal return r_n and inflation π it calculates as

$$\rho_{r_n,\pi} = \frac{cov(r_n, \pi)}{\sigma_{r_n}\sigma_{\pi}}. \tag{3.3}$$

The higher the correlation, the better an asset's inflation hedging. A coefficient of (minus) one indicates perfect positive (negative) linear correlation.

The correlation coefficient is a scaled version of the inflation hedging coefficient estimated based on the Fisher equation. In the ex-post Fisher equation (3.2) and an ordinary least squares estimator this calculates as

$$\beta = \rho_{r_n,\pi}\frac{\sigma_{r_n}}{\sigma_{\pi}}. \tag{3.4}$$

The β adjusts the correlation coefficient upwards in case of high asset return volatility relative to inflation volatility. This difference becomes especially relevant when analyzing volatile equity returns in advanced economies which typically enjoyed low inflation volatility.

Short-fall risk and real return variance

The measures introduced before focus on synchronous movements of returns and inflation and pay relatively little attention to total risk. From an inflation hedging perspective, total risk relates to real returns. If an asset's real returns are volatile it is an inferior inflation hedge. Viewed in isolation, this measure strongly disadvantages volatile assets. However, it becomes more meaningful in a portfolio context as explained in the next section on Bodie's hedge ratio.

Short-fall risk is defined as the likelihood p of an asset to yield real returns r_r below a certain benchmark z, e.g. the real returns to be below zero or a certain minimum required return:

$$p = P(r_r < z).$$

It is part of the early analysis of Reilly *et al.* [1970] and Cagan [1974]. Short-fall risk captures total risks and aims to trade off volatility against differences in absolute return levels. Derivatives of this short-fall risk also account for the magnitude of the losses. The risk metric is often used in the context of value-at-risk but less frequently in inflation hedging. I refer to Maurer and Sebastian [2002] for more background on this measure and Amenc *et al.* [2009] for a recent application.

3.2.3 Multi-asset frameworks

Single-asset frameworks are powerful for conditional asset class choice. An investor interested in the inflation exposure of his overall portfolio could apply these same techniques based on his portfolio's return history. Multi-asset frameworks go beyond this point and analyze the value add of a marginal investment for portfolio inflation risk (hedge ratio) or aim to find the optimal portfolio weights to track inflation (inflation tracking portfolios). I will briefly introduce the two concepts that represent only a niche in the inflation hedging research and are less relevant for this paper's single-asset focus.

Hedge ratios

Bodie [1976]'s starting point is a nominally risk-free rolling government bill. The only real risk of this investment stems from inflation. Adding a second asset allows to build a portfolio that has less variance in real return. The delta between the minimum variance portfolio and the bill variance is the inflation hedging potential (its upper bound). The delta between the returns, which can be positive or negative, represent the associated costs of inflation hedging (its lower bound).

This hedging concept was revived by Schotman and Schweitzer [2000], who explicitly coined the name hedge ratio, and Amenc *et al.* [2009]. Besides this, the relatively little attention might be driven by the sole focus on realized inflation and the bias towards low-risk asset classes. Another disadvantage is the inability to assess the hedging potential of bills themselves.

Inflation tracking portfolios

The inflation tracking portfolio extends the idea of the hedge ratio into a multi-asset context. It optimizes the portfolio weights of all available assets so to minimize the tracking error of inflation. Bekaert and Wang [2010] have recently applied it including a broad menu of assets covering bills, bonds, stocks, real estate, gold, and foreign bonds.

The weights w of the inflation tracking portfolio are computed with a regression of the returns of all assets a

$$\pi = \alpha + \sum_a w_a r_{n,a} + \epsilon.$$

This represents the reverse regression to Equation (3.1). A higher portfolio weight indicates stronger inflation hedging of an asset. The weights w_a are the higher, the higher the covariance of asset a and inflation (ceteris paribus) which becomes apparent when combining Equations (3.3) and (3.4). A negative weight implies negative hedging and thus would require short-selling.

The next section will summarize the empirical results along these definitions for each asset.

3.3 Empirical findings by asset

Empirical research on inflation hedging gained momentum during the time of elevated inflation in the 1970s. The excitement has not faded away entirely and a wide range of academic analyses have been performed since then. This section summarizes the most important empirical contributions that are relevant for this work. Covering the research in its entirety certainly is beyond the scope of this literature review. It rather aims to summarize the status quo of knowledge which allows to identify gaps or uncover new hypothesis based on the existing patterns.

The literature review is organized by asset. They are a natural object of study and fit into this work's focus on conditional asset class choice and single-asset frameworks. The assets are ordered from purely domestic assets to international assets which have a global demand and are localized using exchange rates, from purely monetary assets such as bills to real assets like gold. Within the asset classes I will highlight the impact of different horizons, inflation levels, inflation types, and methodology. Differences in these partly lead to very different inflation hedging characteristics and seemingly inconsistent results. The inflation hedging coefficients will relate to nominal returns if not stated otherwise.

3.3.1 Fixed income

Fixed income instruments are purely monetary instruments without intrinsic value. I cover bills, bonds, and inflation indexed bonds (IIB) - all of which are issued by the respective national government. Their value depends on the trust into the domestic monetary and social institutions as payment depends on the willingness rather than the ability of governments to pay.

Bills

Bills represent the nominally least risky, domestic sovereign debt. The maturity ranges between one and three months with predictable nominal cash flows. The return time series are constructed by rolling over the shortest maturities.

The original Fisher framework of Equation (3.1) dominates the inflation hedging research on bills. Yields to maturity are easily observable in the market and proxies for short-term inflation expectations seem fairly robust with only limited distortions from inflationary surprises.

Fisher [1930] proposes a perfect inflation hedge with $\beta = 1$ for bills. The empirical track record is not that clear with most observations for advanced economies in the range of $0.5 - 1$ which indicates a partial hedge. Overall, the Fisher hypothesis is accepted in its essence as a cornerstone of interest rate theory. Several studies aim to explain systematic deviations from Fisher.

One research stream argues for partial inflation hedging. Mundell [1963] and Tobin [1965] find a negative correlation of real bill returns with inflation. They propose a ''wealth effect': Inflation reduces real wealth, which in turn leads to more savings and puts pressure on real interest rates. This justifies a β below one. Modigliani and Cohn [1979] argue that investors fail to correctly account for inflation due to "inflation illusion'. In response nominal rates do not fully integrate inflation rates. Carmichael and Stebbing [1983] even propose an "inverse Fisher' for real rates to money assuming a high degree of substitutability between money and financial assets and nonpayment of interest on money balances.

A second research stream conceptually demands an inflation hedging coefficient above unity. The "tax effect' of Darby [1975] postulates a β above one to compensate for the investor's tax burden - a "detail' that has been ignored in the previous theories and tests along Fisher. Taylor [1993] argues for an over proportional relation to inflation based on two case studies in the 1990s. Monetary authorities will adjust their policy pro-actively based on anticipated inflationary pressures. Nominal rates then move with expected inflation but tend to overshoot materialized inflation regularly.

While the idea of a pro-active and successful monetary authority sounds enticing, its results are rather the exception than the rule: Most recent studies for single asset classes such as Bekaert and Wang [2010] confirm a sub-optimal hedging relation of below unity. This study covers a broad set of 45 countries between 1970 and 2005. Bills in advanced economies tend to hedge better at longer horizons compared to short horizons with expected inflation betas increasing from 0.5 at the one-year horizon to 0.9 at the five-year horizon and unexpected inflation betas from -0.1 to 0.4, respectively. The hedging coefficients seem worse in emerging economies that suffered high inflation shocks although the study is not very precise on the inflation rates included in the respective geographical footprints. Recent studies applying vector auto regressions (e.g. Brière and Signori [2009]) or vector error correction models (e.g. Attie and Roache [2009]) confirm this picture while showing a much longer adjustment process. Their coefficients for realized inflation start at close to zero and only surpass 0.5 at the five to six year mark. Bill rates seem to adjust only gradual and lag behind inflation. This makes them an incomplete inflation hedge in practice thereby confirming Irving Fisher's own doubts.

Nominal bonds

Nominal bonds represent long-term sovereign debt with maturities of seven to ten years. Absent of default risk, the nominal cash flows and yield to maturity are again determined at the purchase date. Once purchased, bond investments have no inherent flexibility to move with inflation when held until maturity. The long investment horizons complicate the empirical analysis. First, price changes by other risk factors, such as changing liquidity preferences or perceived solvency risk, are likely to distort the performance series. These price movements are also likely to be at least weakly correlated with inflation and bias the coefficients or the proxies for expected long-term inflation. Second, survey based inflation proxies are scarce and unavailable for a wide set of countries - and even if available, the expectations are very persistent and indicate only little variation.

Most empirical studies investigate below maturity horizons and resorts to performance rather than yield data. The performance data is constructed with a rolling investment strategy into a portfolio of (partially synthetic) bonds with seven to ten years to maturity. The original Fisher framework still dominates bond analyses at shorter horizons while horizons of or beyond one year often motivate a shift to the ex-post version of Fisher based on Equation (3.2).

Empirical tests highlight inferior inflation hedging of bonds compared to bills with especially bad hedging characteristics in the short-term and for unexpected inflation. The one year coefficients for expected and unexpected inflation in advanced economies are around 0.3 and and -0.5 respectively [Bekaert and Wang, 2010]. They further find that inflation targeting can only partially improve the hedging properties of bonds. The long maturities make bonds more rigid and less adaptable to inflation than bills. This inferiority is confirmed across the horizon for realized inflation in the vector regression models of Attie and Roache [2009] and Brière and Signori [2009] based on a US sample. At best, bonds reach a positive coefficient at an eight-year horizon. Fabozzi [2005] provides a more comprehensive overview.

Inflation indexed bonds

In contrast to nominal bills and bonds, the principal or coupon payment of inflation indexed bonds (IIB) is directly linked to realized inflation. Shouldn't this provide an ideal hedge against inflation? A closer look at IIB reveals that inflation indexing is not the only difference: The volume and liquidity of IIB is still small and investor experience limited compared to their nominal counterparts. Lehnert *et al.* [2009] and McGrath and Windle [2006] show that these effects add permanent rather than transitory pricing inefficiencies in the US and the UK. Moreover, although the cash flows depend on realized inflation, IIB essentially trade based on inflation and real return expectations. A pro-active monetary policy could again distort the inflation hedging similar to the case of bills as Dudley [1996] argues. For example, an IIB pays a real coupon of 1% plus realized inflation. If a successful proactive monetary policy with high interest rates to fight future expected inflation increases the real return of a nominal bond to 2%, this will decrease the value of an IIB. This interplay of expected and realized inflation and real returns makes the empirical inflation protection more complicated than the name of this asset class suggests.

IIB are a relatively recent phenomena in developed countries which naturally constraints the empirical research. The UK has issued IIB in 1981 and still remains one of the most established and largest issuer until today. Other countries joined much later, e.g. the USA and Germany in 1997 and 2006, respectively. The empirical studies for advanced economies rely on periods with very low inflation or on synthetic data. Several emerging economies have issued IIB earlier and typically after high inflation levels and volatility as it was their only means to regain trust: Chile (1956), Brazil (1964), Colombia (1967), Argentina (1973), Italy (1983), Mexico (1985). Still, overall volumes have been comparatively low. The maturities mostly extend well beyond 10 years. The performance data thus is not "until maturity' but incorporates pricing fluctuations as in the case of bonds. A more comprehensive overview can be found in Garcia and Van Rixtel [2007].

The empirical research on IIB is much smaller and more recent than for nominal bills and bonds. At the same time, the applied inflation hedging methodologies are more diverse. Most evidence indicates disappointing inflation hedging of IIB. Kothari and Shanken [2004] note their lower volatility of real returns and particularly low correlation with other asset classes. That makes a case for IIB in a portfolio setting rather than as stand-alone inflation protection. Brière and Signori [2009] document very poor inflation hedging properties of IIB in the US for short (negative inflation β) and long horizons (β of only 0.2 to 0.4) using a vector auto regression and a synthetic reconstruction of IIB returns for the period before 1997. In a portfolio setting with the only goal to maintain purchasing power, IIB receive more weight than nominal bonds, real estate and equities combined. However, IIB weights reduce to zero as soon as positive real return targets are introduced. To the best of my knowledge, no dedicated inflation hedging study for UK IIB exists. A simple regression analysis along the ex-post Fisher framework stated in Equation (3.2) reveals very poor inflation characteristics with a β

of 0.1 (0.3) for a one- (five-) year horizon. The analysis builds on logarithmic UK retail price inflation which is the underlying inflation index and the UK IIB index provided by Global Financial Data for the period 1981 to 2009.

3.3.2 Equities

Conventional wisdom classifies equities as real assets. On the one hand, equities are backed up by a company's asset such as buildings, plants, equipment, and stock. On the other hand, when facing inflationary pressure, a company should be able to adjust its prices and thus provide its owners with a real cash flow - if not for a specific company then at least the economy on an aggregated level. Consequently, equities are mostly studied on an aggregated level and on a total return basis. They represent an important building block of this paper and will be presented in more detail.

In contrast to fixed income, expected returns of equities are not directly observable and the bulk of research relates to ex-post returns and studies them in the context of the ex-post Fisher or Fama and Schwert [1977] framework. A more diverse set of methodology is used when linking the inflation hedging to other macro-economic drivers.

During the high noon of American inflation in the 1970s, the equity inflation relationship became one of the hot topics in finance. A hot topic revealing a great surprise: Bodie [1976], Jaffe and Mandelker [1976], Fama and Schwert [1977], and others all find equities to be a perverse inflation hedge.[2] Or as Zvi Bodie concludes on page 469: "to use common stocks as a hedge against inflation one must sell them short.'' Interesting enough, the analyses have focused on the same narrow dataset covering the USA between 195x - 197x and including distinct shocks like the Vietnam war or the oil price shocks.[3] This surprise has seized the researchers for decades, finding various explanations for the perverse hedge based again on

[2]Shortly before, Cagan [1974] noted that broadly selected stocks provide inflation hedging in the long-run. His analysis was based on 24 countries and spans from World War I to 1969 and compares means across ten to 30-year horizons. He notes further that this relation sometimes is obscured by other influences especially when inflation is low. He was neither cited by Jaffe and Mandelker [1976] nor by Fama and Schwert [1977] and his findings became soon overlooked.

[3]Jaffe and Mandelker [1976] have extended the analysis with a sample from 1875 to 1970 yielding positive inflation hedging of equities.

similar datasets - either from the USA or the highly correlated UK market.

Fama [1981] establishes the proxy hypothesis: A decrease in real growth leads to monetary counter policies causing inflation and a more cloudy economic outlook followed by decreasing stock prices. Therefore, inflation merely proxies real economic activity. Shortly afterwards, Geske and Roll [1983] argue that rational stock investors anticipate decreasing real growth, their impact on the state budget and a monetization by the Federal Reserve. Thus, declining stock prices signal increasing inflation - essentially reversing Fama's causality. Malkiel [1979] and Pindyck [1984] argue that increased inflation comes along with increased economic uncertainty. Higher uncertainty about future outlooks will lead to a risk premium for stocks - the inflation/ uncertainty premium. Modigliani and Cohn [1979] strongly oppose this idealized, rational investor. They argue that investors suffer from inflation illusion and falsely discount real cash flows with nominal discount rates. This shall explain the undervaluation in periods of high inflation. Most of these hypotheses have been supported, discussed, and discredited several times thereafter.

Boudoukh and Richardson [1993] use an instrumental-variables approach, based on almost 200 years of data in the US and UK, to show that equities at least hedge inflation in the long-run. Ely and Robinson [1997] reach a similar conclusion based on a vector error correction model applied to 17 countries individually. In general, it does not depend on whether the inflation source is from the real or monetary sector. In contrast, Hess and Lee [1999] argue that it depended on the source of inflation at least in the US, UK, Germany and Japan - with a negative (positive) correlation for real output (monetary) shocks. Barnes [1999] continues along these lines and analyzes 25 countries. He finds a negative correlation in (only) 40% of his countries with most of the series being unrelated. The two high inflation countries Chile and Israel exhibited a statistically significant positive relation. Lothian and McCarthy [2001] find a positive relation across 14 developed countries but are puzzled by the very long lags. The recent study of Bekaert and Wang [2010] analyses 45 countries for the last forty years. Despite presenting some strong inflation hedging panel results for equities in emerging markets, they overall conclude on page 795 that "equities are very poor hedges of inflation risk, both in the short and in the long run."

Some researches disaggregate the data and analyze effects by industry or clusters. Boudoukh *et al.* [1994] find non-cyclical industries like food and beverage, tobacco, or utilities to better hedge inflation than cyclical industries like machinery or transport, at least directionally for horizons up to one year. The results suffer from very low statistical significance though. The reasoning builds on the proxy hypothesis and the higher robustness of non-cyclical industries against real output shocks. Their analysis has recently been reconstructed by van Antwerpen [2010]. He does not find significant results for any of the industries at a 5% level - neither on expected, unexpected, or realized inflation. The only exception being Oil which reacts positively to unexpected inflation. Luintel and Paudyal [2006] use a cointegration framework to study long-term effects on industry level in the UK. He finds a strong positive relation above unity for the majority of industries. Services and financial institutions slightly outperform the other industry groups. Ang *et al.* [2012] study the inflation hedging heterogeneity of individual stocks. Good inflation hedges are often in the Oil and Gas and Technology sectors. They also form portfolios based on historical inflation hedging characteristics of individual stocks. The resulting inflation protection is not superior to overall equities due to a high time variation in the underlying coefficients.

One of the few departures from Fisher is the empirically inspired '‘Fed Model’. While its name has been shaped somewhat accidentally by Yardeni [1999], its roots go back to a simplified Gordon growth model in which growth and equity premium offset each other (originally proposed by Gordon [1959]). Deducted from the idea that asset classes compete for portfolio share, it postulates that the dividend or earnings yield on stocks should move along with the yield on nominal Treasury bonds, or at least that the two should be highly correlated.

$$\begin{aligned} \frac{Dividends}{Price} &\approx Yield\ to\ Maturity\ of\ Long\ Term\ Bond \\ &\approx \alpha + E(\pi) \qquad\qquad applying\ Eq.\ (3.1)\ with\ \beta = 1. \end{aligned}$$

Indeed, several researchers confirmed this correlation for the US.[4] As dividends are rather slow moving, this implies decreasing equity prices in increasing inflation environments - a sharp contrast to the predictions of Fisher. Bekaert and Engstrom [2010] argue that the “Fed Model’ can explain the perverse hedge with the inflation uncertainty risk premium proposed in earlier research.

[4]See for example Asness [2003].

In summary, stocks cannot live up to their expectations and appear a disappointing hedge against inflation. Statistically significant and favorable inflation hedging is limited to long-horizons and to observations outside the main markets, which often included higher inflations. Return volatility is high and the results are relatively unstable cross-sectionally and cross-serially.

3.3.3 Infrastructure

This chapter follows the literature review of Rödel and Rothballer [2012]. Several authors argue that infrastructure assets offer inflation protection, among them RREEF [2005], Colonial First State [2006], Orr [2007], Williams [2007], Rickards [2008], UBS [2009], and Goldman Sachs [2010]. First, the replacement costs of infrastructure assets increase during inflations, hence protecting the value of past investments (RREEF [2007]). Second, many infrastructure firms operate in (quasi-)monopolies allowing to pass higher costs onto consumers. As their typical services constitute essential goods, consumer price sensitivity is low, effectively linking revenues to inflation (RREEF [2005]). Third, regulatory regimes such as incentive regulation permit inflation-linked rent escalations (often through application of an RPI-X formula), and therefore embed a natural inflationary hedge (Rickards [2008]). Fourth, infrastructure firms have a low share of operating costs after initial construction. Hence, they are little affected by inflationary commodity and other input prices (Martin [2010]).

While infrastructure in general comprises social (e.g. schools, prisons, hospitals) and economic infrastructure, most studies focus on the latter which has more privatized entities and is easier to track. Economic infrastructure is subdivided into transport, utilities, and telecommunication. It only includes firms that own or have a concession for a physical infrastructure asset and derive the majority of revenues from core infrastructure businesses. The investment performance is measured as total returns in case of listed infrastructure and based on the underlying cash flows in case of non-listed infrastructure. Most studies are from investment professionals and focus on direct correlation coefficients rather than the Fisher framework.

Empirical evidence to confirm the positive inflation hedging is limited. Peng and Newell [2007] find negative, yet insignificant, correlations for nominal listed and unlisted infrastructure returns with Australian inflation, but their analyzed time series is short (1995-2006) and their study is limited to a single country. Sawant [2010] investigates three international infrastructure indices and finds a higher correlation between their nominal returns and the US inflation (ranging between 0.09 and 0.11) than for the S&P 500 (standing at 0.05). In addition to the difference being insignificant, this finding is questionable as it compares domestic equities with a mix of domestic and international infrastructure assets without accounting for exchange rate effects. Similarly, Bitsch *et al.* [2010] find a positive relationship between the nominal internal rate of return of unlisted infrastructure investments and inflation, and a negative one for non-infrastructure, though neither coefficient is statistically significant. Armann and Weisdorf [2008] revert to annual cash flows (proxied by EBITDA) of US infrastructure assets and concessions. They find a correlation coefficient of 0.35 between the nominal growth of infrastructure cash flows and inflation, indicating a comparatively strong inflation hedge, although significance tests are not performed.

As noted in the previous section on equities, several publications investigate equities by industries. Some of their industry classification match infrastructure sectors. Boudoukh *et al.* [1994] for example find that annual nominal stock returns of utilities covary positively with expected inflation with a (statistically insignificant) coefficient of 0.5. van Antwerpen [2010] replicates this approach for 1928 to 2008 and finds utilities among the best performing industries at an annual horizon. Pilotte [2003] uses US data from 1953 to 1997 to confirm the relative advantage of utilities as first reported by Boudoukh *et al.* [1994]. Luintel and Paudyal [2006] perform cointegration based tests for U.K. data from 1955 to 2002 and find that utilities, but also most other sectors are good inflation hedges. In contrast, Martin [2010] finds that nominal utility returns from 1930 till 2008 are essentially uncorrelated with changes in US inflation across most time periods. Similar evidence for telecom or transport infrastructure is not available.

In summary, the papers on infrastructure rely solely on bivariate correlations and lack sophisticated statistical methods to test inflation hedging. Moreover, the infrastructure return history is limited. The most widely used index, the UBS Global Infrastructure index, only reaches back to 1995 - a period dominated by low inflation levels. Other indices have even shorter histories, e.g. MSCI World Infrastructure (1998), Macquarie Global Infrastructure (2000), S&P Global Infrastructure (2001), Dow Jones Brookfield Global Infrastructure (2002). The history of publicly available country level indices, which are required to preclude exchange rate effects, is even shorter and has so far constrained the empirical analyses in this domain.

3.3.4 Real estate

Real estate investments enjoy the reputation to hedge inflation. Measuring real estate performance is difficult and the research can be separated by the underlying data, which is public or private real estate data. Research using public real estate data focuses on real estate investment trusts (REITs) or, in earlier times, on listed companies whose main activity is driven by real estate. For the price of management and regulatory bias, return data becomes readily available. Their history goes back to the 1970s for the US, but much later for most other countries, e.g. in the 2000s for Germany. Consequently, most empirical research has focused on the US. Listed real estate shows a high correlation with equity, or as Gyourko and Linneman [1988] put it: "Concerning inflation hedging, [REITs] look more like traditional stocks and bonds than any other type of real estate." Most inflation hedging results of public real estate directionally resembles the perverse hedge findings on equity in the short-run and a moderate inflation hedging in the long-run, e.g. in the multi-factor models of Hoevenaars *et al.* [2008], Brière and Signori [2009], Amenc *et al.* [2009]. Bekaert and Wang [2010] find real estate to consistently underperform stocks in hedging expected and unexpected inflation annual and multi-year comparisons. The results might fundamentally differ to an investor's actual exposure to physical real estate.

Research using private real estate PRE return data relies on appraisal- and survey-based portfolio indices, which might be distorted by appraisal behavior and appraisal smoothing. Geltner *et al.* [2003] provide more background on this. In one of the earlier studies, Fama and Schwert [1977] find very strong hedging characteristics for expected and unexpected inflation using the residential house price component of the CPI in the US. Rubens *et al.* [1989] separate residential, business real estate and farmland. Their results support residential real estate (driven by unexpected inflation), but are inconclusive on farmland and business, which shows some hedging for expected inflation only. Hoesli *et al.* [2007] find only slightly better hedging properties of private real estate compared to common stock in the US and the UK. Ganesan and Chiang [1998] find good inflation hedge properties for commercial and residential property in Hong Kong, but not for other private real estate and even worse for property stock.

Overall, real estate results are less clear than conventional wisdom would suggest. Unlisted real estate, especially the residential segment, performs strongly. Listed real estate tends to fall short of unlisted real estate but still exceeds equities. Hoesli *et al.* [2007] provide a more comprehensive literature overview for real estate and inflation.

3.3.5 Gold

The history of money and gold is tightly interwoven. It is a reserve medium of central banks and in public opinion probably still the ultimate protection against inflation. The transaction and storage costs of physical gold is very low so that investors can actually invest in the physical commodity rather than in rolling gold futures. The inflation hedging research has concordantly focused on gold price indices. Gold prices show very different dynamics than the preceding assets. While demand for real estates or even equities is largely driven by domestic supply and demand, the market dynamics of gold are global in nature. The law of one price predicts that identical goods should have one price in an efficient market. Given its low transaction and transportation costs and its highly fungible nature, gold is one of the prime examples for the law of one price to hold, as exemplified in Rogoff [1996]. Can gold then be an inflation hedge for all countries simultaneously? Or put the other way, who's inflation hedge is it? The inflation hedging characteristic of gold depends on (a) the global price development and as such on global cross-correlations and (b) the exchange rate development of the domestic currency. Unfortunately, the majority of research does not disentangle these two factors and focuses on the US with ''domestic' gold.

The inflation hedging methodology for gold lacks observable expected returns and follows the one of equities. Ex-post Fisher and the Fama and Schwert [1977] framework dominate the specific inflation hedging research. A broader set of variables is often used in conjunction with inflation to explain gold returns in a wider context.

Lawrence [2003] from the World Gold Council applies bivariate correlation coefficients and a vector error correction model on the gold price, US producer price inflation, a range of other macro-economic variables, and mainstream asset returns between 1975 and 2001. First, he finds no correlation between nominal gold returns and inflation which implies poor hedging. He characterizes gold as a zero beta asset due to its consistent low correlation to the macro-economic factors and other asset classes. Blose [2010] analyzes the reaction of gold prices to changes in US inflation expectations, measured as the difference between survey and realized inflation changes. The monthly analysis spans from 1988 to 2008 and shows no statistically significant relationship. He argues that the cost of carrying gold increases along with the expected return which leaves the spot price unchanged. He dismisses the alternative hypothesis of speculative inflation hedging demand for gold. The study also provides a broad literature review which uncovers only three out of eleven studies with a statistically positive relationship. The VAR model of Brière and Signori [2009] extends this perspective over the horizon. It finds an increasing pattern with coefficients of 0.25 to 0.5 for the one month and five-year horizon respectively for the period 1973 to 1990. Gold then is the best inflation hedge. Worthington and Pahlavani [2007] confirm this picture for the long-run. The second sample after 1990 of Brière and Signori [2009], however, uncovers gold to be the worst inflation hedge of all. It exhibits a declining pattern down to -0.8 at the 20-year horizon. This highlights the volatile behavior of gold and the instability of the results in a single country, 20 year setting.

The preceding evidence reflects a purely US perspective. Levin and Wright [2006] from the World Gold Council reject the independence and accept a one for one long-run relationship between the gold price and realized US inflation using an error correction model from several start years up to 2005. They acknowledge significant short-term deviations that require five years to revert to the long term trend. Other important factors are inflation volatility, measured over the preceding 12 months, credit risk, US trade weighted exchange rate, and the gold lease rate. World inflation (volatility) as additional variable is not significant in their analysis. Bekaert and Wang [2010] study gold and gold futures in an international setting of 45 countries and localize the US dollar gold returns using spot exchange rates. Gold shows strong inflation hedging coefficients in the sample, with coefficients at the annual horizon of 0.9 to 1.4 for expected and 1.1 to 2.4 for unexpected inflation. The hedge remains strong for longer horizons as well. Pukthuanthong and Roll [2011] analyze the relation of gold and currencies. They confirm that gold price in US dollar is related to a depreciation in the US dollar for 1971 to 2009. He further shows that the US dollar is no different to other currencies and the same is also true for example for the Euro, Pound, or Yen. They do not bridge from currency movements to inflation, though.

In summary, gold shows weak inflation hedging in the short-run. This improves somewhat over the horizon but is overshadowed by gold's high volatility. The cross-country evidence looks more promising and exchange rate moderation seems to strengthen inflation hedging.

3.3.6 Commodities

The physical market for commodities is characterized by local preferences, less standardization, and higher transportation costs compared to gold, which lead to temporary deviations of the law of one price. The financial market and financial instruments on commodities however, are closely tight to the main US indices. Thus, commodity investments essentially share the global nature with gold. This exposes the investor to a combination of global commodity supply and demand as well as to exchange rate dynamics.

Most studies relate to the S&P Goldman Sachs Commodity Index (GSCI), with 70-80% exposure to energy commodities, or the Thomson Reuters/ Jefferies CRB Index with an energy exposure of approximately 40%. High storage and transaction costs make a buy and hold strategy of the physical underlying as in the case of gold unattractive. Most financial instruments and, thus the exposure of a typical investor, are based on a rolling commodity future basis with treasuries as underlying. Gorton and Rouwenhorst [2006] shows that the resulting returns are highly correlated with spot prices but yielded significantly higher returns.

Commodities have been assessed as inflation hedge in a similar manner as gold was. More than with any other asset class, the problem of endogeneity or reverse causality comes up. Does higher inflation drive up commodity prices or do higher commodity prices drive up inflation? How long needs the transmission through the value chain and is there a vicious circle through expectations? The question is further complicated as monetary authorities monitor commodity spot and future prices to estimate future inflation and adjust their monetary policy. Granger causality tests do not give definitive answers and the "solution' was either ignoring the question or applying synchronous methodologies like vector auto regressions.

Gorton and Rouwenhorst [2006] constructed an equally weighted index of monthly returns to commodity futures from 1959 to 2004. They find comparable risk return characteristics to US equities and with a negative correlation to common equity and bonds which is driven by the different order in the business cycle. Commodities are positively correlated with realized inflation at the one- and five-year horizon (correlation coefficient of 0.3 and 0.5 respectively), and quarterly with coefficients on expected and unexpected inflation of 0.2 and 0.3 respectively. Kat and Oomen [2006a] confirm the comparable return pattern between commodities and equities on a disaggregated level. In Kat and Oomen [2006b], they report positive correlation coefficients of around 0.25 on annual frequencies with large variations by individual commodity (-0.3 to 0.6; against unexpected inflation proxied with inflation changes). Similar to equities, the high volatility of the disaggregated underlying leads to unstable coefficients. Lastrapes [2006] analyzes disaggregated commodity prices in the US using a VAR model. He splits inflation in monetary and productivity shocks and finds that both show positive impact on commodity prices. Belke *et al.* [2010] apply a similar VAR model and put it in a global perspective. Based on aggregated data from the major OECD countries post 1970 weighted by purchasing power parity adjusted GDP they primarily analyze inflation forecasting and transmission. However, they also note that monetary aggregates positively relate to commodity prices. The work of Attie and Roache [2009] highlights the horizon dependency using a VEC model for US data after 1956. Commodities react quickly and positively indicated by a coefficient of 0.7 at the one-year horizon, the highest in the sample. Yet the positive impact fades away as the horizon increases and the long-term impact remains zero. This casts doubt on the otherwise strong hedging characteristics in the long-run. Commodities perform slightly, but not fundamentally better in Amenc *et al.* [2009]'s vector auto regression model spanning quarterly US data from 1973 to 2007. In contrast, Hoevenaars *et al.* [2008] find very stable and positive hedging characteristics for commodities spanning quarterly US data from 1952 to 2005 - indirectly highlighting the immense sensitivity of these regression approaches.

Overall, commodities show partial inflation hedging characteristics. While the evidence is mostly positive and superior to other asset classes, coefficients remain mostly below unity.

3.3.7 International diversification

People that face high inflation often substitute their domestic currency with a stable international currency such as the US dollar. US Dollars are then used as a store of value and also medium for exchange. This is a simple form of international currency diversification with the aim to hedge inflation. I define international diversification as investments in (predominantly) foreign assets that requires exchange rate conversion. Pre-dominantly as I consider an investments in a global stock index international even though domestic shares might constitute a (minor) share of the index. Gold and commodities also fall in that category but have been reviewed separately as the existing literature considers them as domestic.

The exchange rate conversion exposes the investor to exchange rate movements. Most short-term investors would associate this with risk and explicitly hedge against exchange rate changes. A long-term investor aiming to hedge inflation, however, might take this exposure as exchange rates should moderate inflation differentials in the long-run along purchasing power parity. For example, a higher domestic inflation decreases the value of money which should, ceteris paribus, lead to a higher price for the foreign currency. The value of foreign investments in local currency will therefore increase and mitigate domestic inflation. Even if PPP works perfectly in the long-run, the exchange rate moderation will be impacted by cross-correlation in inflations. Neely and Rapach [2008] and others find a global component in inflation, especially amongst advanced economies, which certainly reduces the inflation hedging effectiveness of international diversification.

The empirical research can be subsumed into two streams. The first one is macro-economic and tests absolute and relative PPP applying stationarity or trend analysis on real exchange rates. This stream does not primarily focus on inflation hedging but the outcome is relevant under the assumption that the investment abroad can be protected against inflation or that inflation abroad is simply negligible relative to domestic inflation. It also reveals more about exchange rate risk and volatility.

The second stream has its origin in domestic inflation hedging and simply includes an international asset. The methodology follows the Fisher framework or plain correlation coefficients and neglects specific issues of cross-correlation and other exchange rate determinants. I will only briefly review the first stream as it is mostly related to economics rather than finance. The second stream is very thin and I aim to be fairly comprehensive on it. I will not review the works on international portfolio diversification and international asset pricing using inflation comovements as these do not allow direct conclusions on inflation hedging.

The introduction of floating exchange rates after the fall of Bretton Woods has enabled academia to test PPP on a broad basis. The empirical track record of PPP was fairly poor in the 1970s, a time with a series of real shocks, e.g. the oil price shocks. Dornbusch [1988] concluded that ''PPP had failed altogether in the 1970s' and that it lacked empirical support.'' Since then, the consensus has shifted. Longer samples, relatively calmer trade relations, and cross country panels in general provide strong support for PPP. For example, Lothian and Simaan [1998] support for a 1:1 movement of exchange rates and inflation differentials for one- to seven-year horizons. More recently, Alba and Papell [2007] introduced country characteristics in the panel set to show that the correlation is the better, the more open to trade and geographically closer the countries are. They also provide a comprehensive summary and overview of the research in the area of PPP. Overall this suggests that foreign currencies are a strong hedge when domestic inflation is high compared to foreign one.

The exchange rate dynamics underly the inflation hedging characteristics of other international assets. While a large body of literature exists for domestic equities, to the best of my knowledge, research on international equities and inflation hedging is limited to a master thesis. van Antwerpen [2011] analyses two broad international indices against US inflation and finds slightly superior yet not significantly different hedging of foreign equities. He does neither account for exchange rate behavior nor comovement. Bekaert and Wang [2010] include foreign bond (not equity) portfolios, but cover the US investor perspective only and focus on domestic asset classes. They find that foreign bonds are useful to hedge expected and unexpected inflation, especially on a multi-year horizon with coefficients between one and two. Strongin and Petsch [1997] work is somewhat related and correlates several international asset returns to global inflation which does not directly tackle the topic of inflation hedging for local investors. Several studies on listed infrastructure include globally diversified infrastructure indices such as the UBS Global Infrastructure & Utilities index in their (domestic) analyses without even mentioning exchange rate effects. They find superior hedging coefficients of international over domestic indices. I have raised this issue in Rödel and Rothballer [2012] and shown that domestic infrastructure is hardly superior to domestic equities. The positive attributes found for the international indices was due to exchange rate moderation.

In summary, international diversification exhibits some promising results for inflation hedging but remains largely uncharted territory. Issues around cross-correlation, investment restrictions, and exchange rate risks have not been analyzed so far.

3.4 Synopsis

Table 3.1 summarizes the literature review and allows a comparison across assets. Bills are the best hedge for the relatively moderate inflation periods in the advanced economies. But, they only partially hedge inflation yet with relatively low volatility (and returns). The main remaining risk is a large unexpected inflation shock that has occurred during high inflations and wiped out monetary assets. Commodities also show consistently positive inflation coefficients. While their inflation protection is inferior to bills, especially in the long-run, they protect better against unexpected inflation.

Contrary to common believes, equities show largely negative inflation coefficients even on nominal returns and fail to protect against inflation in all but the very long run and at high inflation. Inflation indexed bonds (with little empirical evidence) and gold have also largely disappointed and do not fulfill the expectations of a ''real asset'.

The table highlights three areas with very little empirical research. First, the empirical work on infrastructure lacks behind its popularity amongst investors. The existing studies are limited by short and insufficiently granular data (and simple methodology). Second, international diversification has received very few attention from academia although the investment universe has opened up considerably in the last decades. International equities, for example, remain uncharted territory. Lastly, most research has focused on the advanced economies which were dominated by low to moderate inflation. No study has taken a broad ap-

Table 3.1: Inflation hedging in the literature

Asset Class	Consensus View	Expected vs. unexpected Inflation	Short vs. long horizon	Low vs. high inflation
Bills	Partial hedge, coeff. between 0.5 and 1.0	No hedge against unexpected inflation, coeff. between -0.1 and 0.4	Hedging increases quickly until 1a and plateaus at the 5a horizon	Indication for bad hedging at high inflation (limited evidence)
Bonds	Partial hedge, coeff. approx. 0.2 less than bills	Negative hedge at unexpected inflation with coeff. around -0.5	Comparable to bills, but with negative offset	Indication for bad hedging at high inflation (limited evidence)
Inflation-indexed Bonds	Indication for poor and partial hedge (limited evidence)	N/A	Increasing pattern, negative coeff. at first and then up to 0.4	N/A
Equities	Poor hedge, coeff. between -0.4 and 0.3; disaggregated results unstable	Negative hedge against unexpected inflation with coeff. around -0.4	Increasing pattern, negative coeff. at first and then neutral, some cases up to 0.6	Indication for strong hedging at high inflation (limited evidence)
Infra-structure	Mixed results, lack of robust methodology and data	N/A	N/A	N/A
Real Estate	PRE with strong hedging, REITs with hedging comparable to other equities	PRE mostly strong hedge against unexpected inflation, REITs negative hedge	Increasing pattern, remaining at low 0.2 for REITs	N/A
Gold	Mixed results, mostly unsignificant relation	Mixed results, often strong for unexpected inflation	Mixed results	Indication for strong hedging at high inflation (limited evidence)
Commo-dities	Partial hedge, coeff. below unity; disaggregated results with large variations	Mixed results, often strong for unexpected inflation	Hump-shaped with peak at 1-2a and neutral behavior at long horizons	N/A
Interna-tional diversifi-cation	PPP: Significant deviations in the short-run Bonds: Indication for partial hedge (limited evidence) Equities: N/A	Bonds: Indication for partial hedge (limited evidence) Equities: N/A	PPP: Valid in the long-run Bonds: Increasing pattern (limited evidence) Equities: N/A	N/A

Note: All coefficients relate to nominal returns and inflation up to 20%. The consensus view relates to realized or expected inflation.

proach and integrated the findings of low and high inflation environments. These three gaps in the literature form the basis of this work.

Chapter 4

Hypotheses

The literature review provides a good starting point for future research. It has highlighted the following three areas of interest for me.

4.1 Inflation hedging exhibits nonlinearities

The first hypothesis grounds in the gap between conventional wisdom and empirical evidence. Conventional wisdom predicts monetary assets to perform poorly during high inflations since they do not have intrinsic value. Equities or commodities supposedly maintain their value as they are backed by real assets. To a great surprise, the empirical literature uncovers the opposite for advanced economies. Rolling investments in government bills hedge inflation. The value of equities deteriorates with higher inflation levels.

This seemingly contradictory result could be an artifact of narrow framing. While fixed income could hedge the relatively low inflation in advanced economies, at one point, the hedge should deteriorate. Similarly, while equities might perform worse at (low) inflation, their real asset characteristics should play out in high inflations. First indication for this is provided by Barnes [1999] and Bekaert and Wang [2010]. Equities hedge inflation better in countries with high inflation incidents than in countries with relatively low inflation only. Yet, the authors stick to the overly strong linearity assumption in each country and do not allow nonlinearities to integrate the evidence across countries.

I would expect nonlinearities to show up when including a wide range of inflation observations. My hypothesis is:

Hypothesis 1. *Inflation hedging exhibits nonlinearities for low versus high inflation environments.*

4.2 Infrastructure as superior inflation hedge to equities

The second hypothesis originates from the investment community. CalPers, the Canadian Pension Plan, and other major investors subsume infrastructure under their inflation protection asset categories. This reflects the investment community's firm belief in infrastructure as an inflation hedge. Unfortunately, the lack of data has not yet allowed to research this on a statistically sound basis. For example, the existing indices with a long data history mix international and domestic infrastructure investments which blends infrastructure and exchange rate performance effects.

I have access to the proprietary infrastructure performance dataset of Rothballer and Kaserer [2011]. It is exceeding the established indices by length and breadth and allows to analyze this asset class on a very granular level. My hypothesis for the analysis is:

Hypothesis 2. *Infrastructure is a superior inflation hedge compared to equities.*

4.3 International equities as superior inflation hedge to domestic equities

The third hypothesis is inspired by evidence from high inflation countries. Once inflation picks up and people lose trust in their home currency, they substitute it with foreign currencies, mostly the US dollar. The use of substitute currency is often ruled illegal by the government and, thus, becomes difficult to replicate on a larger scale during high inflation. I will apply a similar strategy to advanced economies instead.

The last decades were characterized by moderate inflation and flexible exchange rates in advanced economies. The accompanying financial openness allows international equity diversification at low cost. The value of foreign equity investments is more independent of local inflation and the exchange rate further moderates inflation differentials. Both effects will make international equity investments a better inflation hedge than domestic equities.

The inflation hedging research has, to the best of my knowledge, solely focused on domestic investments and not analyzed these effects yet. My hypothesis is:

Hypothesis 3. *International equities are a superior inflation hedge than domestic equities.*

Chapter 5

Data

This chapter introduces the data behind the analysis, starting with the panel dataset as a whole, then covering the macro-economic variables (the explanatory variables) and the asset returns (the explained variables). Each series will be presented in a consistent way, including a general description of the concept and source, range of values over time, and summary statistics by country. While this risks reading repetitively, it allows a comparison of the series and highlights their distinct statistical nature.

5.1 Country and time coverage

One goal of this research is to broaden the existing view on inflation hedging with explicit consideration of high inflation experience. The first lever is to go back in time to the last incidence of globally elevated inflation rates in the 1970s. I also incorporate the inflationary time before that to avoid a bias on the disflationary period thereafter. The time spans the 61 years from December 1949 until December 2010. While it excludes the major disruptions shortly after World War Two, it includes the turmoil caused by the recent financial crisis starting in 2007/ 2008. The second lever to learn from higher inflation is broadening the country scope. The country set includes the 24 countries as part of the MSCI World and 21 countries as part of the MSCI Emerging Markets in 2010. In addition I have added other countries of relative economic importance with data available, namely Argentina, Iran, Pakistan, Saudi Arabia, and Venezuela. The number of countries reaches a total of 50. The detailed list of countries including their income clustering, which will be used when analyzing inflation nonlinearities, and their index membership, which will be used when analyzing international diversification, is provided in Table 5.1. The countries range from relatively poor India or Pakistan with per capita GDP of below 3'000 USD to some of the richest countries like Norway or Singapore with per capita GDP above 44'000 USD.[1] It includes well established and independent monetary systems like in Switzerland as well as emerging and in times severely troubled ones like in Turkey.

The diversity of the panel and length of data history naturally limits the choice of indicators to the most widely available economic time series and asset classes. For example, survey data on inflation expectations or real estate performance data is unfortunately not available for most parts of my panel set and had to be excluded from the analysis. Most of the data was downloaded in February 2011 from Global Financial Data (GFD), a provider of long-term global returns and macro-economic data. One data source increases the data comparability and consistency across countries, e.g. arising from different reporting times and even regional scope (e.g. German reunification). At the same time it exposes to unsystematic database errors. I have cross-checked the data with other sources such as some countries' national account statistics, International Financial Statistics from the International Monetary Fund, country equity return data from MSCI Barra and documented the adjustments in the following sections. Potentially remaining data errors are likely to cancel out as all my analyses build on a sufficiently large number of observations.

5.2 Economic time series

Macro economic time series are the independent variables in my regressions. The central variable is inflation. The effect of real economic growth partially overlaps with inflation as first identified in the proxy hypothesis of Fama [1981]. Economic growth will be included as a control variable and presented in a similar way. Lastly, the analysis of international diversification presumes financial openness so that international diversification was actually possible for the investor. This

[1] Purchasing power parity corrected at 2005 USD.

Table 5.1: List of countries, index membership, and income cluster

Country	**TLD**	**MSCI Index**		**GDP / Capita**			**Income Cluster**			
		W	EM	1949	1979	2009	1949	1979	2009	Total
Argentina	ar			6	10	13	HI	LI	LI	LI
Australia	au	Yes		10	19	34	HI	HI	HI	HI
Austria	at	Yes		5	20	36	HI	HI	HI	HI
Belgium	be	Yes		8	20	33	HI	HI	HI	HI
Brazil	br		Yes	2	7	9	LI	LI	LI	LI
Canada	ca	Yes		10	23	36	HI	HI	HI	HI
Chile	cl		Yes	4	5	13	HI	LI	LI	LI
China	cn		Yes	0	1	6	LI	LI	LI	LI
Colombia	co		Yes	2	4	7	LI	LI	LI	LI
Czech Republic	cz		Yes	6	15	23	HI	HI	LI	HI
Denmark	dk	Yes		8	20	35	HI	HI	HI	HI
Egypt	eg		Yes	0	3	5	LI	LI	LI	LI
Finland	fi	Yes		6	16	33	HI	HI	HI	HI
France	fr	Yes		7	20	31	HI	HI	HI	HI
Germany	de	Yes		5	21	32	HI	HI	HI	HI
Greece	gr	Yes		3	14	28	LI	HI	HI	HI
Hong Kong	hk	Yes		0	12	40	LI	HI	HI	HI
Hungary	hu		Yes	4	12	18	HI	LI	LI	LI
India	in		Yes	1	1	2	LI	LI	LI	LI
Indonesia	id		Yes	1	1	4	LI	LI	LI	LI
Iran	ir			3	10	12	LI	LI	LI	LI
Ireland	ie	Yes		5	12	41	HI	LI	HI	HI
Israel	il	Yes		0	14	25	LI	HI	HI	HI
Italy	it	Yes		4	15	28	HI	HI	HI	HI
Japan	jp	Yes		2	17	32	LI	HI	HI	HI
Korea, Republic Of	kr		Yes	1	4	23	LI	LI	HI	LI
Malaysia	my		Yes	2	4	12	LI	LI	LI	LI
Mexico	mx		Yes	3	8	12	LI	LI	LI	LI
Morocco	ma		Yes	0	2	4	LI	LI	LI	LI
Netherlands	nl	Yes		7	20	37	HI	HI	HI	HI
New Zealand	nz	Yes		10	16	25	HI	HI	HI	HI
Norway	no	Yes		8	23	49	HI	HI	HI	HI
Pakistan	pk			1	1	3	LI	LI	LI	LI
Peru	pe		Yes	3	6	7	HI	LI	LI	LI
Philippines	ph		Yes	1	2	3	LI	LI	LI	LI
Poland	pl		Yes	4	10	15	HI	LI	LI	LI
Portugal	pt	Yes		3	10	21	LI	LI	LI	LI
Russian Federation	ru		Yes	0	0	14	LI	LI	LI	LI
Saudi Arabia	sa			0	34	21	LI	HI	LI	LI
Singapore	sg	Yes		0	12	45	LI	HI	HI	HI
South Africa	za		Yes	5	8	9	HI	LI	LI	LI
Spain	es	Yes		3	14	28	LI	HI	HI	HI
Sweden	se	Yes		9	20	34	HI	HI	HI	HI
Switzerland	ch	Yes		13	27	38	HI	HI	HI	HI
Taiwan	tw		Yes	1	7	29	LI	LI	HI	LI
Thailand	th		Yes	0	2	8	LI	LI	LI	LI
Turkey	tr		Yes	2	5	9	LI	LI	LI	LI
United Kingdom	uk	Yes		10	18	33	HI	HI	HI	HI
United States	us	Yes		15	28	43	HI	HI	HI	HI
Venezuela	ve			8	13	11	HI	HI	LI	HI

This table reports the countries, index memberships (as of Dec 2010), and per capita income in 2005 PPP USD from GFD.
Abbreviations: TLD top level internet domain, W MSCI World, EM MSCI Emerging Markets, HI High income, LI Low income.

requires a country and time filter for financial openness which I will explain here as well.

5.2.1 Inflation

Hedging against inflation means to hedge against an increase in the general level of prices. The most widely reported measure for this is the consumer price index. It reflects the price increase in local currency for an average consumption basket. While this might differ significantly from a specific investor's liability pattern I resort to this measure for practical reasons. The inflation time-series reflects changes in the consumer price index CPI and is abbreviated ΔCPI or π. The data is obtained from GFD, a database for long-term global time-series.

Figure 5.1 shows the inflation rates in the dataset. The dashed line indicates that the inflation data is fairly complete. The sample starts with 46 countries in 1950 and covers all 50 countries by mid 1990. The changing shading highlights a switch from a largely low inflation environment with annual rates below 5% in about 70% of the countries to a time with rates above 5% in about 90% of the countries in the 1973.[2] 1973 to the mid 1980s was characterized by elevated inflation around the world. Even relatively stable economies like the UK or US suffered from inflation of up to 22% (in 1975) and up to 12% (1972, 1979, 1980), respectively. While most developed economies have stabilized by mid 1980 it needed a further 15 years for inflation around the world to go back to the pre 1970s level. Any research on inflation hedging that aims to draw valid conclusions for inflation beyond 10% must include the experience of elevated inflation of the 1970s or corresponding observations from emerging markets. This macro pattern also indicates a high level of comovement in inflation rates, a fact that we will observe more closely shortly. Deflationary periods remained the exception throughout the time period covered.

Table 5.2 presents the summary statistics for inflation for each country separately. The country spectrum reflects very diverse inflation environments. On the one hand, Germany, Malaysia, Singapore, and Switzerland have all enjoyed an average annual inflation below 3% with inflation volatility standing at a mere

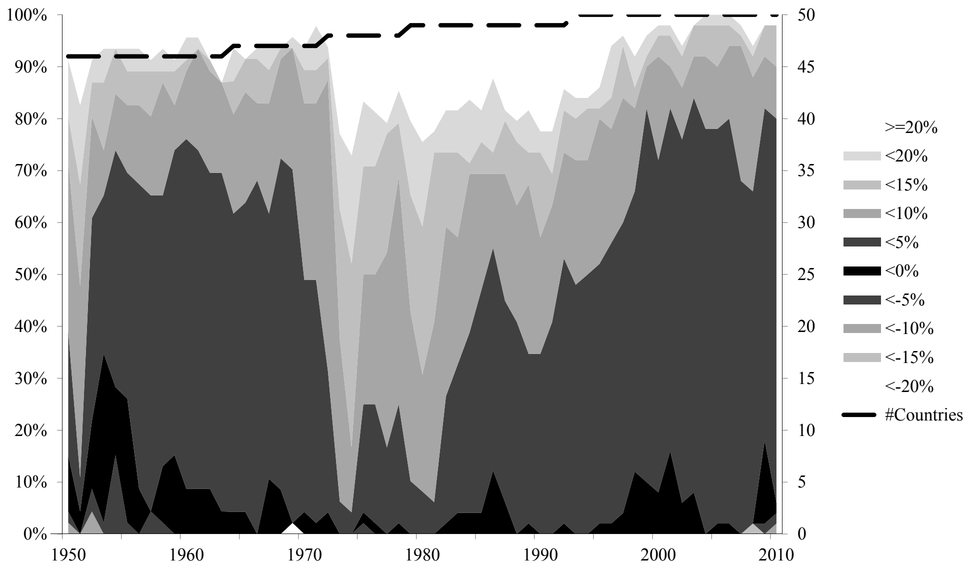
[2] The shading intervals will be the same for all data series to increase comparability of the graphs. For inflation and also economic growth the intervals are relatively wide, especially in the negative scale.

Table 5.2: Summary statistics of inflation (ΔCPI)

Country	**N**	**Distribution**				**Time series properties**			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	61	51.6	72.8	2.5	10.2	3	0	4	0.6
Australia	61	5.2	4.3	1.4	5.5	0	0	1	0.4
Austria	61	3.6	3.7	4.5	29.0	0	29	0	0.1
Belgium	61	3.4	2.8	1.5	6.1	2	0	1	0.6
Brazil	61	57.6	80.5	2.0	6.1	0	0	25	0.6
Canada	61	3.7	3.1	1.0	3.2	4	0	3	0.7
Chile	61	28.2	36.5	2.7	10.3	2	0	24	0.4
China	32	5.1	6.4	1.7	5.5	14	2	1	0.2
Colombia	61	13.6	11.5	-0.8	8.6	7	46	0	0.4
Czech Republic	47	3.8	6.6	4.1	22.4	10	0	0	0.3
Denmark	61	4.7	3.6	0.9	2.8	0	0	0	0.6
Egypt	61	7.4	7.1	0.4	3.3	42	0	0	0.5
Finland	61	5.2	4.7	1.0	3.7	0	0	0	0.4
France	61	4.7	4.1	1.3	4.8	0	0	1	0.5
Germany	61	2.6	2.3	0.9	6.9	0	17	0	0.2
Greece	61	8.3	7.4	0.6	2.5	100	0	7	0.9
Hong Kong	61	4.1	5.2	0.0	2.9	37	0	0	0.7
Hungary	61	7.1	8.2	1.4	4.5	35	0	3	0.4
India	61	6.2	5.8	0.1	3.9	9	20	0	0.2
Indonesia	61	25.1	44.2	4.4	26.1	0	0	0	0.2
Iran	61	11.8	9.3	0.3	4.1	54	0	0	0.3
Ireland	61	5.5	5.1	1.2	4.3	33	0	7	0.7
Israel	61	20.9	32.3	2.6	10.1	52	0	14	0.7
Italy	61	5.7	5.2	1.5	4.7	32	0	14	0.9
Japan	61	3.3	4.1	1.7	6.4	0	0	0	0.4
Korea, Republic Of	61	13.9	23.1	4.7	29.1	0	0	0	0.3
Malaysia	61	2.7	4.7	0.9	6.9	0	0	0	0.2
Mexico	61	16.1	19.6	2.1	7.3	9	0	5	0.7
Morocco	61	4.5	4.2	1.3	5.6	0	0	0	0.4
Netherlands	61	3.6	2.7	0.5	2.6	0	0	0	0.4
New Zealand	61	5.7	4.7	0.9	2.6	53	0	6	0.8
Norway	61	4.8	3.4	0.8	2.8	0	0	0	0.5
Pakistan	61	6.9	6.1	1.0	7.2	14	6	0	0.2
Peru	61	36.8	77.8	3.8	17.3	0	0	4	0.4
Philippines	61	7.4	8.0	1.8	7.6	48	1	0	0.5
Poland	61	15.3	32.9	4.3	23.4	1	0	1	0.3
Portugal	61	7.3	7.6	1.2	3.5	80	0	12	1.1
Russian Federation	18	37.6	55.2	2.5	8.4	0	11	0	0.2
Saudi Arabia	39	3.8	7.8	2.2	7.2	0	0	21	0.4
Singapore	61	2.5	5.1	2.2	9.4	0	0	0	0.1
South Africa	61	7.3	4.6	0.3	1.9	15	0	12	0.9
Spain	61	6.8	5.1	1.0	3.6	2	0	9	0.7
Sweden	61	4.7	3.7	1.0	4.1	2	0	0	0.6
Switzerland	61	2.5	2.4	0.8	4.6	11	0	1	0.5
Taiwan	61	6.3	12.8	4.6	29.0	0	3	0	0.1
Thailand	61	4.3	5.5	-0.2	5.3	24	5	0	0.2
Turkey	61	25.3	21.2	0.7	2.3	0	0	15	0.7
United Kingdom	61	5.2	4.5	1.8	6.2	10	0	9	0.7
United States	61	3.7	2.8	1.4	5.0	15	0	4	0.7
Venezuela	61	14.5	15.7	1.5	5.2	0	0	11	0.3
Median	61	5.7	5.6	1.4	5.5	2.1	0.0	0.6	0.4

This table bases on annual logarithmic observations. μ, σ, and p-values are in [%]. Abbreviations: BPCW Breusch-Pagan/ Cook-Weisberg heteroskedasticity test with H_0 of homoscedasticity; BG Breusch-Godfrey LM test for serial correlation at lag one with H_0 of no autocorrelation; ADF Augmented Dickey-Fuller unit-root test with H_0 of unit-root; KPSS Kwiatkowski-Phillips-Schmidt-Shin stationarity test with H_0 of stationarity with critical t-values of 0.21 (0.146) for the 1% (5%) significance level).

Figure 5.1: Inflation in the dataset (ΔCPI)



The dashed line shows the number of countries available in the dataset. The shaded area shows the return range covered in the analysis. The white areas indicate absolute real returns greater than 20% whereas the black areas indicate only minor deviations around zero.
Note: Figures as annual logarithmic returns. The left (right) axis shows the share (number) of total countries covered.
Compare to Kaserer and Rödel [2011].

2-5%. Malaysia is clearly the exception amongst low income countries. On the other hand, Argentina, Brazil, Chile, Indonesia, Peru, and Turkey experienced an 61 year average annual inflation beyond 25%, including very high inflation on the way. The time series are more peaked than the normal distribution with a median Kurtosis of 5.5 and skewed to the right with a medium skewness of 1.4, implying relatively frequent high inflation outliers. The Breusch-Pagan/ Cook-Weisberg test rejects homoscedasticity for most time series at a 5% confidence level. This matches the above observation of periods with relatively high inflation variation such as in the 1970s and calmer periods such as in the late 1990s and early 2000s. The Breusch-Godfrey LM test rejects the null hypothesis of no autocorrelation for all but six countries at a 5% confidence level. Inflation seems to change gradually. This also explains why inflation expectations are often linked to recent inflation experience. Simple AR(1) processes even proved to be very efficient forecasts of inflation as shown in Ang *et al.* [2007]. The Augmented Dickey-Fuller unit-root test rejects unit roots for most time series at 5% confidence level. The Kwiatkowski-Phillips-Schmidt-Shin stationarity test contradicts this by also rejecting stationarity for most series. In cases with shorter data history, e.g. when regressing equity or bill returns, non-stationary behavior becomes more frequent. The results of the Augmented Dickey-Fuller and Kwiatkowski-Phillips-Schmidt-Shin test often remain contradicting. Inflation of single countries is likely to be fractionally integrated which might bias coefficient estimates slightly towards zero. At the same time, non-stationarity can still be strongly rejected for the panel as a whole. The Im-Pesaran-Shin test of Im *et al.* [2003], which tests unit-roots under the presence of auto- and cross-correlation in heterogenous panels, rejects unit-roots at 0.1% significance level for shorter and longer data history. By and large this accepts the stationarity assumption underlying the regression framework.

Fama and Schwert [1977] have included inflation changes, i.e. the first derivative of inflation, in their standard inflation hedging regression to proxy unexpected inflation. I follow their approach to account for increasing or decreasing inflationary environments and label this variable $\Delta\pi$. Inflation changes exhibit a median of 0.00 %, a very high Kurtosis of 137 and a Skewness of -4 implying very sudden disinflations which typically occured after hyperinflations with the introduction of a new currency. More importantly, the correlation with inflation stands at fairly low 0.27 which limits issues of variance inflation when regressed against both variables in combination.

The comovement of inflation across countries will be relevant when analyzing the inflation hedging of international equities. The interchange of largely black and white areas in Figure 5.1 already indicated comovement. More formally, the tests for panel cross-correlation according to Pesaran, Frees, and Friedman as reviewed in De Hoyos and Sarafidis [2006] are all highly significant. Each test rejects the H_0 of cross-sectional independence for the panel at a $<$1% confidence level. The comovement of inflation can more formally be tested in dynamic latent factor models using variance decomposition. Neely and Rapach [2008] analyze 64 national inflation rates between 1951 and 2009 and decomposes their movement into a world, a regional, and a idiosyncratic country factor. The country factor accounts for 49% of the movement in inflation on average, and only 34%, 33% and 26% in Australasia, Europe and North America respectively. The developed economies seem to broadly move alongside each other. I will replicate this analysis separating advanced and emerging economies rather than applying a pure geographic clustering. This grouping can separate more clearly by institutional similarities and openness, factors Neely found to drive the comovement.

Overall, inflation is a slow-moving time series with inherent auto-correlation, fractional integration, and high international comovement. This will require a special methodology and in parts even limit the interpretation of the results.

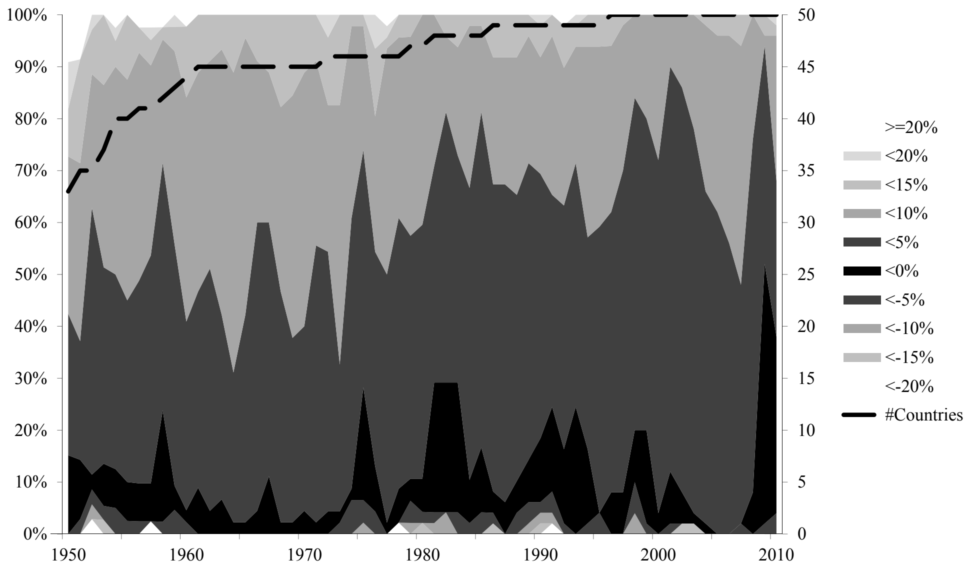
5.2.2 Economic growth

The proxy hypothesis of Fama [1981] spotted a potential overlap of inflation and contracting economic development. While the direction of causality is not clear as discussed in section 3.3.2, the overlap might bias the inflation hedging conclusion if not properly separated. I proxy economic growth with real growth of a country's gross domestic product denominated in local currency. This time series is widely followed and available for most countries and times. I abbreviate it with ΔGDP. The data is from GFD and cross-checked with national account data, data from the world bank, and IHS Global Insight, a database covering economic, financial, and political time series. I have corrected two deviations from the GFD data, namely for Egypt in 2006 and 2007 and Poland before 1994. I have extended the time series to 2010 using the CIA World Factbook[3] for China, Iran, Pakistan, Russia, and Saudi Arabia as their values were not yet available from GFD during my download.

Figure 5.2 shows the real economic growth in the dataset. The dashed line indicates that data for 33 countries is already available from the start in 1950. The coverage gradually extends to 45 by the mid 1960s. The macro pattern shows that half the countries grew at a staggering rate beyond 5% annually until the early 1970s. Coinciding with the global inflationary period in the early 1970s and 1980s up to as much as 30% of the countries experienced real economic decline. Afterwards the vast majority of countries grew inbetween 0 and 5% a year. The

[3] Central Intelligence Agency of the United States of America (2012), The World Factbook, *https://www.cia.gov/library/publications/the-world-factbook*, accessed Feb 20, 2011.

Figure 5.2: Real economic growth in the dataset (ΔGDP)



Notes of Figure 5.1 apply.

most recent financial crisis starting in 2008 has left its mark with 50% of the countries exhibiting real economic decline. The degree of global comovement seems lower than with inflation. The shaded areas move fairly parallel for most of the time.

Table 5.3 presents the summary statistics of real economic growth for each country separately. The dataset covers a broad range of economic track records. The Asian economies lead the table of real economic growth. China grew an average of 9.4% over the three decades on record, Taiwan a staggering 7.5% average over the full 61 years. The UK occupy the red light with a mere 2.3% for the full 61 year timespan. The full sample averages should be taken with care as they very much depend on the absolute levels at the start in 1950, as apparent for example in the case of Japan. The economically most volatile countries are the Czech Republic with a history of only 25 years and Chile with a standard deviation of 16.3% and 8.8% respectively. Norway enjoyed the most stable economic growth

Table 5.3: Summary statistics of real economic growth (ΔGDP)

Country	N	Distribution				Time series properties			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	61	2.8	5.5	-1.0	4.9	3	21	0	0.1
Australia	61	4.0	2.4	0.2	3.5	92	4	0	0.2
Austria	61	4.0	4.8	2.2	9.2	0	0	0	0.3
Belgium	61	2.6	3.2	-0.4	5.4	1	28	0	0.1
Brazil	61	4.8	4.4	-0.3	2.5	35	85	0	0.1
Canada	61	3.7	2.7	-0.2	3.2	56	66	0	0.1
Chile	61	3.7	8.8	0.0	8.3	0	0	0	0.0
China	32	9.4	2.6	-0.2	2.9	10	0	2	0.1
Colombia	61	4.2	2.2	-0.6	5.1	16	2	0	0.1
Czech Republic	25	1.3	16.3	-2.0	11.4	0	64	0	0.0
Denmark	61	2.4	2.8	-0.1	2.8	0	3	0	0.1
Egypt	58	4.9	5.0	0.2	3.8	45	43	0	0.1
Finland	61	4.1	6.1	2.6	13.4	0	0	0	0.1
France	61	3.2	2.1	0.1	2.4	34	0	3	0.2
Germany	61	3.6	3.4	0.9	4.1	8	0	0	0.3
Greece	61	4.1	4.4	0.6	4.4	0	30	0	0.2
Hong Kong	50	6.3	4.5	-0.3	2.8	60	34	0	0.1
Hungary	61	4.6	8.0	1.7	13.7	0	57	0	0.1
India	61	4.5	3.2	-0.9	3.8	12	11	0	0.0
Indonesia	52	4.8	3.8	-2.4	12.9	47	1	0	0.3
Iran	51	4.1	7.9	-1.3	5.4	10	0	0	0.2
Ireland	61	3.9	3.3	-0.3	3.8	0	0	0	0.2
Israel	60	6.0	6.6	-0.3	4.5	0	80	0	0.2
Italy	61	3.2	2.6	-0.1	2.5	95	46	1	0.1
Japan	61	5.0	4.2	0.3	2.1	1	5	3	0.1
Korea, Republic Of	57	6.2	3.7	-1.1	5.0	49	69	0	0.2
Malaysia	55	6.0	4.8	-0.2	4.7	1	38	0	0.1
Mexico	61	4.6	5.1	2.2	15.9	94	60	0	0.1
Morocco	58	3.8	4.9	-0.1	2.4	88	0	0	0.0
Netherlands	61	3.2	2.6	0.0	2.8	1	10	0	0.1
New Zealand	61	3.1	3.2	0.3	6.8	0	48	0	0.0
Norway	61	3.4	1.9	-0.3	2.8	57	41	0	0.1
Pakistan	57	4.3	2.9	-0.4	4.4	1	70	0	0.1
Peru	61	3.9	4.9	-1.4	6.2	9	0	0	0.2
Philippines	61	4.3	3.4	-1.0	7.1	58	9	0	0.2
Poland	30	2.4	4.8	-1.8	5.5	0	1	0	0.1
Portugal	57	2.8	3.2	-0.8	5.7	12	9	0	0.1
Russian Federation	15	4.0	4.5	-0.9	2.7	52	61	10	0.2
Saudi Arabia	39	3.7	5.4	0.2	4.2	0	8	0	0.2
Singapore	53	7.1	4.4	-0.4	3.4	90	3	0	0.2
South Africa	61	3.3	2.5	-0.7	3.5	10	1	0	0.2
Spain	61	3.9	3.1	0.4	3.0	1	1	0	0.1
Sweden	61	2.5	2.1	-0.8	3.4	42	0	0	0.1
Switzerland	61	2.6	3.0	-0.7	4.5	5	2	0	0.1
Taiwan	61	7.5	3.4	-0.4	3.8	99	23	0	0.2
Thailand	61	5.8	4.0	-1.6	7.4	49	2	0	0.2
Turkey	60	4.1	5.0	-0.4	2.8	4	52	0	0.0
United Kingdom	61	2.3	1.9	-1.0	4.4	27	0	0	0.1
United States	61	3.2	2.8	-0.4	3.4	2	59	0	0.0
Venezuela	61	3.9	5.0	-1.2	5.2	0	9	0	0.1
Median	61	3.9	3.7	-0.3	4.3	9.0	9.0	0.0	0.1

Notes of Table 5.2 apply.

with a volatility of only 1.9%. The time series is on average skewed slightly to the left with a Skewness of -0.3 and peaked slightly more than a normal distribution with a Kurtosis of 4.3.

The Breusch-Pagan/ Cook-Weisberg and Breusch-Godfrey LM test reject homoscedasticity and no serial correlation for 18 and 14 countries at a 1% significance level respectively. The Augmented Dickey-Fuller test rejects unit-roots for all but four countries (China, France, Japan, Russia). The Kwiatkowski-Phillips-Schmidt-Shin test broadly confirms this result and accepts stationarity for all but 9 countries at a 1% significance level. The correlation of economic growth to inflation is slightly negative -0.16 which is conceptually consistent to Fama's proxy hypothesis but less than in his US-only setting.

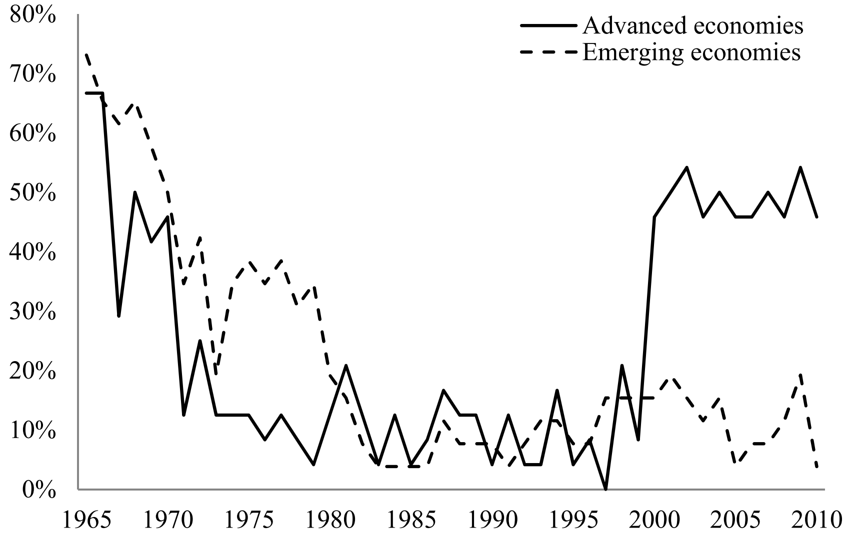
In summary, the real economic growth differed vastly amongst the countries in the sample and is relatively easy to account for as an additional factor due to favorable statistical properties and low correlation to inflation.

5.2.3 Financial openness

Financial openness is a prerequisite for international diversification. It is not an independent variable but a filter for the countries and times during which an investor could have invested abroad. This differs in nature from the other economic series and will, thus, also follow a different structure.

The empirical analysis on international diversification requires a trade-off between financial openness and inflation richness. The implications are only actionable and valid if the investor was able to invest abroad. This was typically the case in non-fixed exchange rate regimes with high capital mobility, a fairly recent development starting in the 1970s for advanced economies. Generally speaking, the later in time we start, the higher the capital mobility. At the same time, the conclusions are only valid within the inflation range covered. For example, if we rely on advanced economies after 1983 the upper bound for inflation will only be about 10%. The earlier in time we start, the wider the inflation coverage. I define a scope Advanced Economies broad or AEb focusing on inflation richness at reasonable capital mobility and Advanced Economies narrow or AEn focusing on investability at the expense of inflation diversity. Evidence from Emerging Economies EEb will only be used for robustness tests as capital mobility was

Figure 5.3: Share of de-facto fixed exchange rate regimes over time



The lines show the share of countries in the sample that did not have nominal exchange rate movements against the major anchor currencies USD, DEM/EUR, GBP, JPY, and CHF in a given year. Advanced (emerging) economies represent the 24 (21) countries currently in the MSCI World (Emerging Markets).
Source: Rödel [2012].

largely restricted.

AEb starts with the break-up of Bretton Woods in 1971 and comprises all advanced economies as part of the MSCI World today. Table 5.4 shows the list of advanced economies and summary statistics of their macro-economic variables. It includes annual inflation up to 25%. Nonlinearities in inflation hedging as mentioned in Kaserer and Rödel [2011] should thus be of limited concern. AEb is confined to non-fixed exchange rates and regional coverage by MSCI as proxies for capital mobility. Figure 5.3 plots the share of countries in the sample that show no de-facto movements against the important currencies USD, GBP, DEM, FRF, and RUB.[4]

[4]Minimum deviation of $|0.1\%|$ required to indicate movement due to roundings.

Table 5.4: Summary statistics by country for the advanced economies

Country	**Start**		**Inflation**			**ΔGDP$_r$**		**ΔLCU/USD$_n$**	
	AEb	AEn	μ	σ	$kpss_t$	μ	σ	μ	σ
Australia	1971	1984	5.65	4.04	0.33	3.56	2.27	0.39	11.89
Austria	1971	1978	3.38	2.15	0.21	2.65	2.50	-2.14	11.99
Belgium	1971	1978	3.87	3.02	0.38	2.10	2.86	-1.02	12.47
Canada	1971	1978	4.37	3.26	0.43	2.98	2.60	-0.01	7.20
Denmark	1971	1988	4.74	3.81	0.08	1.60	2.20	-0.61	11.84
Finland	1971	1978	5.06	4.50	0.43	2.55	3.10	0.17	11.56
France	1971	1990	4.62	4.00	0.14	2.02	1.51	-0.16	12.13
Germany	1971	1978	2.75	1.87	0.18	2.10	2.33	-2.06	12.15
Greece	1976	1996	10.09	7.54	0.13	2.17	2.38	5.67	12.85
Hong Kong	1971	1978	5.47	5.19	0.21	5.80	4.47	0.80	4.76
Ireland	1988	1992	2.56	2.29	0.17	5.08	4.38	-0.55	10.43
Israel	1992	1999	4.23	4.45	0.04	5.04	3.61	1.35	7.04
Italy	1971	1989	7.09	5.88	0.25	1.98	2.17	2.29	12.52
Japan	1971	1978	2.67	4.44	0.18	2.56	2.50	-3.48	12.34
Netherlands	1971	1978	3.30	2.57	0.24	2.29	2.01	-1.74	12.03
New Zealand	1986	1986	2.90	2.02	0.30	2.74	2.32	1.60	13.47
Norway	1971	1993	4.87	3.36	0.09	3.06	2.03	-0.36	11.40
Portugal	1989	1994	4.27	3.30	0.17	2.06	2.14	-0.22	11.03
Singapore	1971	1978	3.01	4.57	0.19	7.05	3.96	-2.07	5.67
Spain	1971	1993	7.34	5.51	0.08	2.89	2.20	1.63	13.10
Sweden	1971	1978	4.90	3.84	0.28	1.96	2.11	0.83	12.78
Switzerland	1971	1996	2.47	2.66	0.15	1.49	2.57	-3.68	12.80
United Kingdom	1971	1979	5.73	5.20	0.30	2.14	2.10	1.26	12.64
United States	1971	1978	4.29	2.98	0.27	2.82	2.44		
Min	1971	1978	2.47	1.87	0.04	1.49	1.51	-3.68	4.76
Mean	1974	1985	4.57	3.85	0.22	2.95	2.61	-0.09	11.14
Median	1971	1982	4.33	3.82	0.20	2.56	2.35	-0.16	12.03
Max	1992	1999	10.09	7.54	0.43	7.05	4.47	5.67	13.47

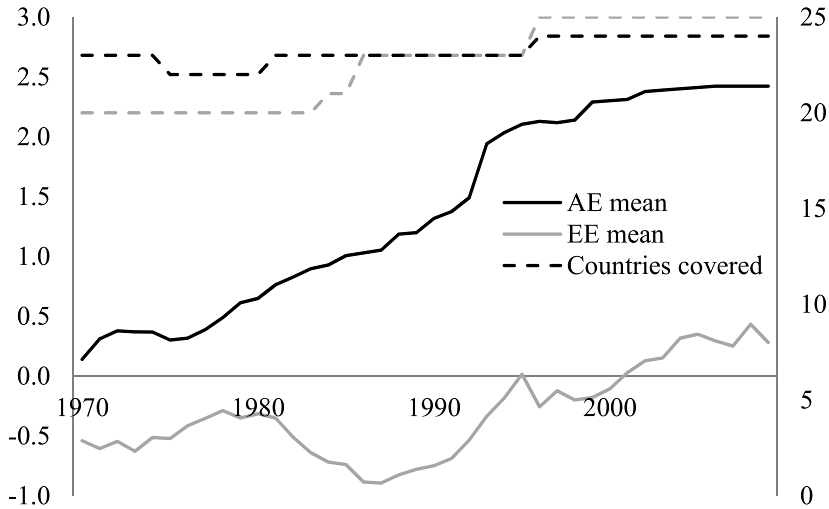
The statistics summarize the advanced economy broad (AEb) scoping, i.e. between the start year as mentioned in the second column and 2010. The KPSS test indicates fractional integration in inflation for 50% of the countries which may bias the regression coefficient estimates towards zero. The relative comparison between different time series should not be affected.
Notes: ΔLCU/USD$_n$ exchange rate movement against USD in direct quotation; μ average of annual logarithmic returns; σ standard deviation of annual logarithmic returns; $kpss_t$ stationarity test of Kwiatkowski *et al.* [1992] with 1% at 0.21.

The break-up of Bretton Woods in 1971 marks the regime shift from largely fixed to predominantly flexible exchange rates amongst advanced economies. As little as 10% of the counties show no movements thereafter. The uptick at the turn of the century marks the harmonization of exchange rates within the European Monetary Union (EMU), a chapter of regional fixed exchange rates yet with high capital mobility. The emerging economies principally follow this move away from fixed exchange rates, yet with a delay. They reach a level of below 10% in 1983. Levy-Yeyati and Sturzenegger [2005] and Reinhart and Rogoff [2004] have constructed broader, more sophisticated measures for capital mobility also including observed exchange rate volatility, central bank interventions, and the existence of multiple rates. Their conclusions show a consistent opening up for advanced economies and a more gradual increase towards the EMU. For the emerging economies, Levy-Yeyati and Sturzenegger [2005] for example show a slower opening up reaching 20% of the sample as late as 1989. The existence of regional MSCI equity indices, a proxy for investability at relatively low costs, tell a similar story. The MSCI W is calculated from 1969 and covers the advanced economies. The MSCI EM covers the emerging countries and reaches back until 1987. Both proxies highlight severe capital constraints in the emerging economies until around 1987. We furthermore constrain EEb to inflation observations up to 25% for comparability reasons.

AEn focuses on financial openness. It excludes the observations from AEb that have a negative value of the Chinn-Ito Financial Openness index (Chinn-Ito index). A minimum of ten target countries, i.e. two per quintile portfolio defines its start at 1978. The Chinn-Ito index tracks financial openness and covers 1970-2009 for the whole sample except Taiwan. It captures the de-jure existence of multiple exchange rates and restrictions on transactions as reported in the IMF's Annual Report on Exchange Arrangements and Exchange (details in Chinn and Ito [2008][5]). Figure 5.4 provides the average values for advanced and emerging economies over time. Advanced economies start with a positive value in 1970 and increase continuously. Emerging economies only reach this level of openness in the early 2000s, a time of little inflation variability. Consequently, I do not analyze a "narrow' scope for emerging economies.

[5] It is normalized to an average value of zero across all observations.

Figure 5.4: Mean Chinn-Ito Financial Openness index over time



The solid lines show the cross-sectional average of the Chinn-Ito index over time for advanced (AE) and emerging economies (EE). The dashed lines indicate the number of countries in these groups and refer to the right axis.
Note: The data was downloaded in Jan 2012 from Chinn and Ito's website http://web.pdx.edu/~ito/Chinn-Ito_website.htm.
Source: Rödel [2012].

5.3 Asset returns

Each investable asset is represented by one time series per country. All series reflect total gross returns for a local investor, i.e. in domestic currency and gross of fees and tax. The returns are reported net of inflation as real returns. This increases comparability and reliefs from the complexities of the local tax systems. The investment universe includes the purely domestic assets bills, bonds, equities, and listed infrastructure. I explicitly label these domestic assets as their performance is mostly driven by local, national factors and there exists one distinct time series for each country. In contrast to the domestic assets, the investor can also invest in the international assets commodities, gold, international equities, and international listed infrastructure. Their performance decomposes into a global return, e.g. the US dollar denominated gold, commodity or MSCI World return, and an exchange rate gain or loss. Since the investors enjoy the same global return, the inflation hedging effectiveness depends on the exchange rate and the comovement of local inflation and global returns. I will highlight this dynamic in detail for equities. This dynamic has been ignored in other research on inflation hedging.

In the following, I will introduce the returns to domestic assets, pure US dollar exchange rate effects which are proxied with holdings of US dollar cash, and returns to international assets. The structure will resemble the one of inflation and economic growth for comparability reasons. I exclude real estate due to a lack of comparable data for the long timespan and diverse country set under investigation.

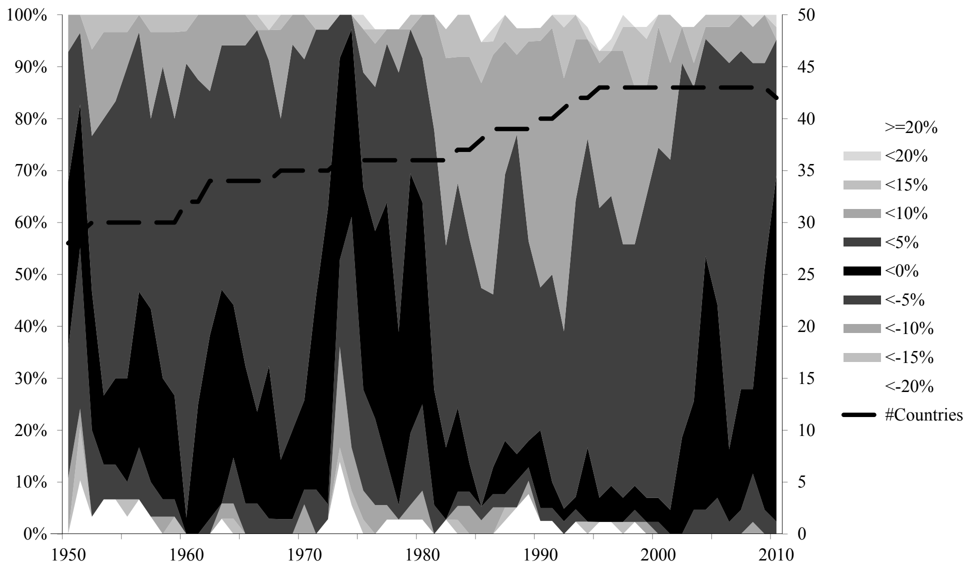
5.3.1 Bills

Bill performance reflect the total return of domestic bills which is the least risky nominal investment in local currency. The duration ranges between one and three months. The short contracts are simply rolled-over to estimate annual performances. The data is obtained from GFD. GFD follows potential disruptions such as partial sovereign defaults or currency changes from an investor's point of view. This is necessary to maximize the time span of countries with historically high inflation, for example Argentina.

Figure 5.5 shows the real bill returns in the dataset. The dashed line indicates that data for 28 countries is already available from the start in 1950. The coverage gradually extends to 43 in the mid 1990s. The shaded areas show the presence of different return ranges by year. As expected from a low risk investment, most of the area is black or dark gray which indicates neutral real returns. Coinciding with the global inflationary period in the early 1970s, bills yielded relatively low returns. This is indicated by the upswing in the black area. This trend reversed during the global disflationary period thereafter which can be seen by the gray area cutting in from above. Outliers, extreme returns beyond 20%, have mostly occured on the downside during the 1970s and 1990s.

Table 5.5 presents the summary statistics of real bill returns for each country

Figure 5.5: Real bill returns in the dataset



Notes of Figure 5.2 apply.

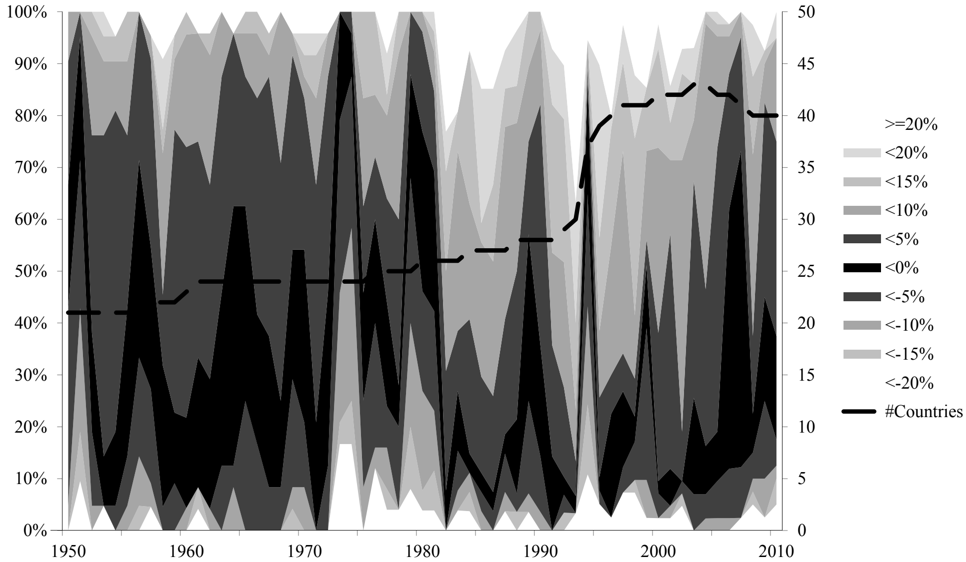
separately. Denmark shows the highest average annual real return for the full 61 years covered with 3.2%, Chile the lowest with -6.5%. The median return was 1.3% with a median standard deviation of 4.5%. Bills indeed carried relatively small real return volatility in most countries. This is manifested in a median kurtosis of 5. However, high inflation and sovereign default occassionally hit the investor which is reflected in the negative skewness. Bills are not as riskfree as their reputation suggests, best examplified with the -0.4% annual real return in Portugal over 60 years. The time series properties are fairly mixed by country, some strongly rejecting homoscedasticity and no serial correlation (typically the more stable countries such as Germany), some with positive indication for both (typically countries with a more stochastic risk profile such as South Africa). I can reject unit-roots for most countries while also having to reject stationarity for many. This partial non-stationarity might bias the coefficient estimates towards zero and I will come back to it when interpreting the results. Moreover it indicates doubt on the long-run inflation hedging characteristics of bills - at least in this

Table 5.5: Summary statistics of real bill returns

Country	N	Distribution				Time series properties			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	25	-5.8	28.8	-2.8	9.4	0	1	16	0.1
Australia	61	1.0	5.0	-1.8	8.7	0	0	2	0.3
Austria	61	1.7	4.0	-4.4	29.5	0	11	0	0.2
Belgium	61	2.7	2.6	-0.7	4.0	95	0	2	0.4
Brazil	16	13.0	6.5	0.9	3.3	3	75	9	0.1
Canada	61	1.9	3.0	-0.8	4.8	36	0	0	0.4
Chile	61	-6.5	28.2	-2.5	11.3	2	0	4	0.1
China									
Colombia									
Czech Republic									
Denmark	61	3.2	4.3	0.2	2.6	80	0	2	0.6
Egypt	59	0.1	5.6	-0.3	2.9	73	0	0	0.4
Finland	61	2.2	4.5	-0.7	4.4	2	0	0	0.3
France	61	1.4	3.7	-1.8	10.9	1	0	0	0.4
Germany	61	1.6	2.3	-1.2	7.5	0	17	0	0.2
Greece	61	1.5	5.6	-0.9	6.0	44	0	0	0.4
Hong Kong	43	-0.5	4.2	0.4	3.6	83	0	6	0.2
Hungary									
India	61	0.9	5.6	-0.1	3.9	13	24	0	0.1
Indonesia	21	4.6	5.8	0.7	4.6	67	9	0	0.0
Iran									
Ireland	61	1.3	4.1	0.0	2.8	64	0	2	0.3
Israel	26	5.8	16.5	4.3	21.2	0	92	0	0.1
Italy	61	1.6	3.6	-0.5	3.8	51	0	1	0.4
Japan	61	1.2	3.8	-0.8	6.1	0	0	0	0.3
Korea, Republic Of	60	-1.8	24.3	-4.7	28.7	0	0	0	0.4
Malaysia	51	1.5	3.7	-0.7	8.4	39	1	0	0.2
Mexico	49	2.5	8.1	0.0	6.0	71	0	0	0.3
Morocco									
Netherlands	61	0.7	3.3	-0.3	2.8	45	0	0	0.4
New Zealand	61	2.2	4.7	-0.5	2.9	13	0	1	0.3
Norway	61	1.0	4.1	-0.7	4.0	53	0	0	0.4
Pakistan	61	0.2	5.7	-1.6	8.4	26	27	0	0.1
Peru									
Philippines	61	2.0	6.9	-0.6	4.7	55	9	0	0.2
Poland	28	-1.7	38.7	-1.0	12.3	0	12	0	0.0
Portugal	60	-0.4	5.1	-1.7	6.9	32	0	0	0.4
Russian Federation	18	-23.6	121.6	-3.3	13.5	2	92	0	0.1
Saudi Arabia	19	2.4	3.9	-0.5	2.4	60	1	79	0.3
Singapore	51	1.1	4.3	-2.6	14.0	0	1	0	0.1
South Africa	61	0.7	4.4	-0.1	3.2	45	0	1	0.3
Spain	61	0.3	4.3	-0.4	2.4	21	0	1	0.3
Sweden	61	1.3	3.7	-1.2	7.8	13	0	0	0.3
Switzerland	61	0.4	2.0	-1.2	5.8	19	0	0	0.2
Taiwan	49	1.2	5.1	-2.2	9.4	0	1	0	0.1
Thailand	61	2.5	5.2	0.3	3.6	68	25	0	0.1
Turkey	38	2.5	19.0	-1.3	4.9	6	0	11	0.3
United Kingdom	61	1.5	3.8	-1.2	5.0	50	0	4	0.3
United States	61	1.0	2.2	-0.2	3.6	99	0	0	0.3
Venezuela	61	-2.6	9.9	-1.8	7.4	0	0	0	0.1
Median	61	1.3	4.5	-0.7	5.0	21.0	0.0	0.1	0.3

Notes of Table 5.2 apply.

Figure 5.6: Real bond returns in the dataset



Notes of Figure 5.2 apply.

broad country scope.

5.3.2 Bonds

Bond performance reflect the total return of domestic sovereign bonds with seven to ten year maturity. The annual performance is composed by coupon payments as well as price differences. The data is obtained from GFD. Sovereign defaults or '‘changes in payments' are followed from an retail investor's point of view.

Figure 5.6 shows the real bond returns in the dataset. The dashed line indicates that data for 21 countries is available in 1950 and remains below 30 until 1994. The maximum of 44 countries is reached in 2004. The series for Argentina, Egypt, and Morocco are suspended until 2010. The shaded areas paint a much more volatile picture also including more negative values compared to the one of bills. The white area from below indicates weaker returns in the 1970s and early 1980s during the global inflation. Long-term bonds lost considerably during the increasing inflation. This trend reversed during the disflationary mid to late 1980s. The large number of emerging economies added in 1995 drive the higher returns thereafter indicated by the area in light gray.

Table 5.6 presents the summary statistics of real bond returns for each country separately. Amongst the countries with full data history, German bonds rank first with a real return of 4.0% and Indian bonds rank last with a -0.4% return. Several countries that have experienced elevated inflation, amongst them Brazil or Russia rank poorly as well. The bonds longer maturity leaves its traits on median volatility which is 9.9%, more than twice the one of bills. Switzerland has the historically most stable bonds with a standard deviation of only 4.4% for the full time span.

The higher noise of bond returns also shows up in the time series properties. Homoscedasticity and no autocorrelation must only be rejected at the 5% significance for a minority of 12 and 2 countries, respectively. Bond returns are also less persistent with unit-roots being accepted for only four countries (Argentina, Greece, Poland, Turkey; with an average of only 14 observations) using the Augmented Dickey-Fuller test and stationarity being rejected in 8 countries at the 5% significance level with the Kwiatkowski-Phillips-Schmidt-Shin test.

5.3.3 Equities

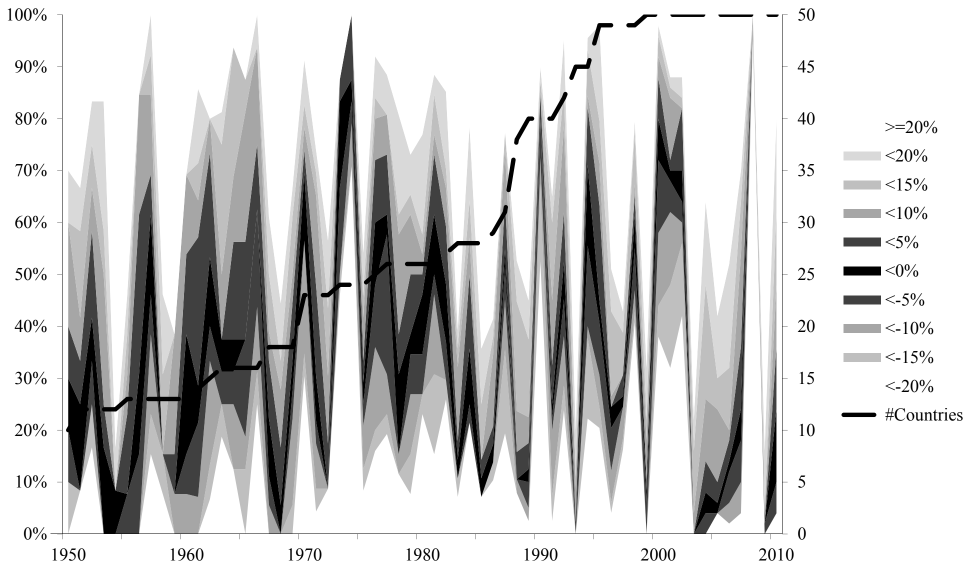
Equities aim to reflect the total return of a well diversified domestic stock investment before taxes or fees. The data is obtained from GFD. GFD bases its returns on established stock indices such as the MSCI country indices or popular all equity indices, e.g. the CDAX, an index of all equities of Prime and General Standard in Germany. These indices develop and change over time. Consequently, GFD splices indices to increase historical coverage and reflect the most prominent index over time. The time series of Egypt was not yet available for the year 2010 when I have acquired the data. I have spliced in the EGX100, a broad stock index in Egypt that covers the 100 most liquid and actively traded companies for 2010. The data was obtained from The Egyptian Exchange [2011]. The time series of Norway was split between the Oslo SE Total Return Index (Symbol _NTOTD), which is available from 1969 to 2001, and the narrower Oslo SE OBX-25 Total

Table 5.6: Summary statistics of real bond returns

Country	**N**	**Distribution**				**Time series properties**			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	13	-2.4	24.1	-2.6	8.7	3	100	9	0.1
Australia	61	1.9	9.9	-0.3	3.3	28	24	0	0.1
Austria	61	3.2	7.3	-0.8	4.5	14	72	0	0.1
Belgium	61	3.5	7.6	0.1	2.7	43	17	0	0.1
Brazil	17	-8.0	61.5	-3.4	13.3	0	93	0	0.1
Canada	61	3.2	8.3	0.4	3.1	43	63	0	0.1
Chile									
China									
Colombia	17	2.3	3.7	0.5	2.7	21	23	3	0.2
Czech Republic									
Denmark	61	3.9	10.8	1.3	6.2	19	53	0	0.2
Egypt	5	0.2	7.4	0.6	2.3				
Finland	51	3.7	10.1	0.8	4.1	18	50	0	0.1
France	61	2.8	9.0	-0.1	2.8	40	25	0	0.1
Germany	61	4.0	7.2	0.0	2.7	77	74	0	0.0
Greece	18	7.6	14.4	-0.8	4.1	4	33	97	0.1
Hong Kong	17	4.1	9.8	-0.3	3.1	3	82	0	0.2
Hungary									
India	61	-0.4	9.3	0.0	3.8	5	100	0	0.1
Indonesia									
Iran									
Ireland	61	1.5	13.5	0.0	2.9	56	70	0	0.1
Israel	17	5.1	6.4	0.0	3.8	50	10	0	0.1
Italy	61	2.7	13.1	-0.2	5.7	34	28	0	0.1
Japan	61	3.1	13.0	-0.5	5.4	0	1	0	0.0
Korea, Republic Of	54	12.6	20.1	1.3	4.2	0	34	0	0.1
Malaysia	50	3.8	7.3	0.3	4.3	19	60	0	0.0
Mexico	16	8.5	6.4	0.5	3.6	77	69	2	0.1
Morocco	13	6.1	10.7	0.2	3.5	2	76	0	0.1
Netherlands	61	2.5	7.5	1.0	5.6	35	40	0	0.1
New Zealand	61	1.4	11.2	-0.4	5.0	7	86	0	0.2
Norway	61	1.3	7.3	0.1	3.3	68	1	0	0.2
Pakistan	61	-0.4	12.3	0.4	9.7	0	94	0	0.1
Peru	17	7.6	16.6	-0.4	3.6	5	52	0	0.1
Philippines	14	10.9	17.1	-0.4	2.3	5	53	0	0.1
Poland	11	6.9	11.4	1.1	2.9	4	43	7	0.1
Portugal	35	2.2	16.5	0.0	3.8	13	6	0	0.3
Russian Federation	17	-16.1	76.3	-1.9	5.8	2	58	0	0.1
Saudi Arabia									
Singapore	23	2.0	3.6	0.1	2.4	96	8	0	0.1
South Africa	61	1.5	10.1	0.2	3.2	1	31	0	0.1
Spain	61	0.9	9.6	0.0	3.7	86	20	0	0.2
Sweden	61	1.8	6.9	0.4	2.8	5	82	0	0.1
Switzerland	61	1.7	4.4	-0.1	2.8	26	10	0	0.1
Taiwan	16	5.5	6.5	0.1	1.8	96	63	1	0.1
Thailand	31	7.3	15.4	1.3	6.1	35	34	0	0.0
Turkey	15	-25.5	22.1	-0.6	2.0	52	25	72	0.2
United Kingdom	61	2.5	7.5	0.0	4.0	87	75	0	0.1
United States	61	2.2	9.1	0.6	3.2	5	45	0	0.1
Venezuela	27	-3.8	27.9	0.5	4.0	90	34	0	0.1
Median	54	2.5	9.9	0.0	3.6	19.0	47.6	0.0	0.1

Notes of Table 5.2 apply.

Figure 5.7: Real equity returns in the dataset



Notes of Figure 5.2 apply.
Compare to Kaserer and Rödel [2011].

Return Index (Symbol _OBXD), which is available from 2000 to 2010. I have combined both indices to cover Norway from 1969 to 2010. The time series for Venezuela was only available until 2008 and I have extended it to 2010 using the Caracas Stock Exchange Stock Market Index from Bloomberg L.P. [2011], an index of the 15 most liquid and largest stocks traded at the Caracas Stock Exchange (Bolsa de Valores de Caracas).

Figure 5.7 shows the real equity returns in the dataset. The dashed line indicates that data for ten countries is already available from the start in 1950. Until the late 1980s the coverage gradually extends to thirty and then becomes complete in late 1990s. All additions after 1987 are for the emerging markets. The shaded areas show the presence of different return ranges by year. Dark areas signal small annual returns, i.e. calm times, light areas signal extreme returns of beyond 20%. The relatively narrow black shading indicates extreme events. Besides the mid 1960s and late 1970s the time series is dominated by extreme positive and negative returns. The up- and downward swings of the black shading signal extreme swings between largely positive and largely negative returns, in other words, between greed and fear. The movements across countries are highly cross-correlated.

Table 5.7 presents the summary statistics of real equity returns for each country separately. Ten country series are available for the full time period from 1950 to 2010. Sweden shows the highest average annual real return for the full 61 years covered with 8.4%, Italy the lowest with 3.5%. The median standard deviation is above 30% which highlights the high volatility in equities. Equities is a very fast moving time series compared to the macro-economic indicators discussed before. It leads to relatively low coefficients of determination in the regressions and also show up for the remaining assets. I will come back to this when interpreting the results. The slightly negative median skewness indicates higher likelihood of extreme negative movements compared to a normal distribution. The median peakedness also slightly exceeds the one of a normal distribution. The time series are fairly suitable for statistical analysis with hardly any heteroscedasticity and autocorrelation. The Augmented Dickey-Fuller test strongly rejects unit-roots and the Kwiatkowski-Phillips-Schmidt-Shin test only rejects stationarity in the case of Greece at the 5% level (none at the 1% level). The indicates equities to be a long-run inflation hedge.

5.3.4 Infrastructure

Infrastructure gained in popularity amongst investors and often is considered as an asset class in itself. The return series aims to reflect the performance of equity investments in economic infrastructure.

The analysis of infrastructure faces two data challenges: First, the data available is de-facto limited to listed infrastructure. Information on non-listed infrastructure returns is dotted at best and not sufficient to construct meaningful investment indices. I assume that listed infrastructure essentially shares the return characteristics of non-listed infrastructure investments - at least at and beyond the one-year horizon which is the focus of my study. Second, indices of listed infrastructure returns either have a very short data history or are blended international indices with a history of less than 20 years as can be seen in Table

Table 5.7: Summary statistics of real equity returns

Country	N	Distribution				Time series properties			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	44	2.2	59.9	0.4	4.9	34	0	0	0.0
Australia	61	6.4	21.2	-0.8	3.3	71	31	0	0.0
Austria	41	4.3	26.5	-0.4	7.1	0	93	0	0.0
Belgium	60	5.6	19.6	-1.0	5.0	0	76	0	0.1
Brazil	56	7.5	51.7	-0.2	4.1	27	7	0	0.0
Canada	61	6.2	16.3	-0.8	3.7	50	37	0	0.0
Chile	28	15.4	27.8	0.2	2.6	22	94	0	0.1
China	18	-4.3	43.2	-0.2	2.1	66	20	0	0.0
Colombia	23	4.4	67.5	-2.4	10.6	0	65	0	0.1
Czech Republic	16	6.9	27.9	-0.5	2.6	34	95	0	0.1
Denmark	41	7.1	27.9	-0.2	3.1	96	22	0	0.0
Egypt	16	13.0	50.1	-0.1	2.2	52	97	1	0.1
Finland	49	9.1	30.4	0.0	4.0	1	9	0	0.1
France	61	6.1	23.6	-0.4	2.7	36	65	0	0.1
Germany	61	6.8	24.5	-0.3	3.1	78	88	0	0.1
Greece	34	4.7	39.6	-0.3	3.3	23	16	0	0.2
Hong Kong	41	10.6	40.5	-0.7	3.5	2	67	0	0.0
Hungary	19	7.4	37.7	-0.2	3.1	90	41	0	0.0
India	23	11.3	35.2	-1.0	4.3	5	23	0	0.1
Indonesia	23	9.5	52.6	0.0	2.5	37	89	0	0.1
Iran	12	17.5	28.0	0.0	2.3	37	26	40	0.1
Ireland	22	3.5	33.4	-1.7	6.2	7	80	0	0.1
Israel	18	4.4	29.0	-0.3	2.0	84	9	0	0.0
Italy	61	3.5	26.0	-0.2	3.2	23	10	0	0.1
Japan	61	7.1	26.2	0.3	3.8	57	97	0	0.0
Korea, Republic Of	48	10.7	33.3	-0.4	2.9	89	69	0	0.1
Malaysia	38	5.1	32.6	-0.5	2.9	43	68	0	0.1
Mexico	23	14.6	29.6	-0.2	2.2	62	68	0	0.1
Morocco	16	10.3	20.4	-0.2	1.8	87	9	18	0.1
Netherlands	60	6.9	21.6	-0.7	3.7	17	56	0	0.1
New Zealand	24	0.7	25.9	-1.4	4.9	4	75	0	0.1
Norway	41	5.8	35.1	0.0	3.3	66	22	0	0.0
Pakistan	23	6.3	51.6	-0.6	3.8	35	5	0	0.0
Peru	18	16.5	33.7	-0.7	2.8	17	17	0	0.1
Philippines	29	7.2	45.9	0.2	3.1	11	79	0	0.1
Poland	19	10.5	60.7	1.9	8.2	0	8	0	0.0
Portugal	22	1.9	28.7	-0.8	3.2	68	86	0	0.1
Russian Federation	16	-5.3	89.7	-1.3	4.0	15	6	0	0.0
Saudi Arabia	25	7.5	35.8	-0.6	3.5	2	63	0	0.1
Singapore	41	6.4	37.5	-0.1	3.7	5	27	0	0.0
South Africa	50	7.8	19.7	0.0	2.4	91	81	0	0.0
Spain	61	5.1	23.8	-0.3	2.7	17	1	0	0.1
Sweden	61	8.4	23.9	-0.4	2.8	2	76	0	0.0
Switzerland	44	5.3	22.1	-0.5	2.9	95	92	0	0.1
Taiwan	23	6.4	41.5	-0.4	2.4	17	9	0	0.0
Thailand	35	7.9	40.6	-0.3	2.7	81	57	0	0.1
Turkey	24	10.5	71.0	0.4	2.3	12	0	0	0.0
United Kingdom	61	6.6	22.8	-1.2	7.7	49	48	0	0.0
United States	61	6.8	17.6	-0.8	3.8	49	86	0	0.1
Venezuela	23	0.0	55.5	0.8	4.2	7	31	0	0.0
Median	35	6.8	31.5	-0.3	3.2	34	52	0	0.1

Notes of Table 5.2 apply.

Table 5.8: Coverage of established infrastructure indices

Index	Start date	Firms
UBS Global Infrastructure & Utilities	1995, September	243
MSCI World Infrastructure	1998, December	153
NMX30 Infrastructure Global	1998, December	30
Macquarie Global Infrastructure	2000, July	243
INFRAX	2000, September	50
S&P Global Infrastructure	2001, November	75
Dow Jones Brookfield Global Infrastructure	2002, December	85

5.8. This might seem long for finance research, but is still too short for macroeconomic analysis and does not cover the period of elevated global inflation. As already highlighted in Section 3.3.3, this has restricted existing research to low inflation environments and a blend of domestic infrastructure and exchange rate effects that has not been properly disentangled. The observed positive inflation hedging characteristic might be driven by exchange rate effects and international diversification rather than the asset class characteristics of infrastructure.

I construct country-specific infrastructure indices as proposed by Amenc *et al.* [2009] to overcome the difficulties of previous studies. I use a cross-section of 1,458 listed infrastructure firms collected by Rothballer and Kaserer [2011]. The time series is labeled Infra. This sample includes all active and inactive publicly listed companies globally that carry a SIC or GICS code related to infrastructure as recorded in Thomson Worldscope. It includes all sectors of economic infrastructure, namely transport (ports, airports, pipelines, railways, highways), utilities (generation, transmission and distribution of electricity, gas and water), and telecommunication (fixed-line, mobile, satellite, cable), but excludes social infrastructure (e.g. hospitals, schools, prisons). It only includes firms that own or have a concession for a physical infrastructure asset and derive less than 50% of their revenues from non-core infrastructure businesses such as network services (e.g. shipping), capacity reselling (e.g. mobile virtual network operations), construction and equipment supply (e.g. power plant construction), related services (e.g. airport freight handling), or any other diversified businesses. The sample contains mostly fully privatized infrastructure assets, and just few firms that operate under public private partnership arrangements. Moreover, it excludes non-equity type securities as ADRs, funds and trusts.

The index construction follows the methodology of my equity benchmark, the MSCI country indices, with respect to return type, index weighting and rebalancing, country scope, trading liquidity, and survivorship bias. We use total returns from Thomson Datastream and apply the screens advocated in Ince and Porter [2006] to eliminate biases that arise from data errors such as data unavailability, rounding errors, and unrealistic returns. The indices are market value weighted with annual rebalancing at the end of the year. Similar to MSCI equity indices, I exclude illiquid shares from the constituent list. Specifically, I exclude firms with a relative trading volume $<0.4\%$ or a bid-ask-spread $>20\%$ based on five-year averages of monthly data or trade discontinuities (i.e. zero returns) in $>20\%$ of the observations in its respective return time series. We mimic the survivorship bias by excluding stocks with a market capitalization less than $50 million. In addition, I only include firms if a full year of data is available, hence excluding firm months after an initial public offering. Firms only enter the infrastructure index at the next annual rebalancing as it is the case for MSCI indices.

The infrastructure indices are calculated for each country individually using the local currency returns of all firms with headquarters in the respective country and listed on the local stock exchange.[6] The indices are subdivided into sector indices for transport, utilities, and telecommunication.

The above criteria reduce the cross-section from 1,458 to 824[7] infrastructure firms which is still three times as broad as the UBS Global Infrastructure index, the broadest publicly available infrastructure index.[8] My index times series starts in January 1973 and ends in December 2009, which is 2.5 times as long as the UBS index. Table 5.9 provides an overview of the number of infrastructure firms underlying the index calculations over time.

The main domestic index covers all listed infrastructure in a respective coun-

[6] The minimum number of companies per index is one to maximize index history. The resulting index volatility is still comparable to equities and not biasing the results as robustness tests using a minimum of three and five companies show.

[7] The sample contains 824 different firms, though not for all of them data is available in each year. Hence, the reported number of firms in table 5.9 is strictly lower across all years.

[8] The UBS index is more restricted in its geographic (firms are mostly from developed countries; none from South America and Africa; few from emerging Asia), sector (no integrated telecom, cable, or satellite), and size scope (only large-caps).

Table 5.9: Infrastructure firms over time

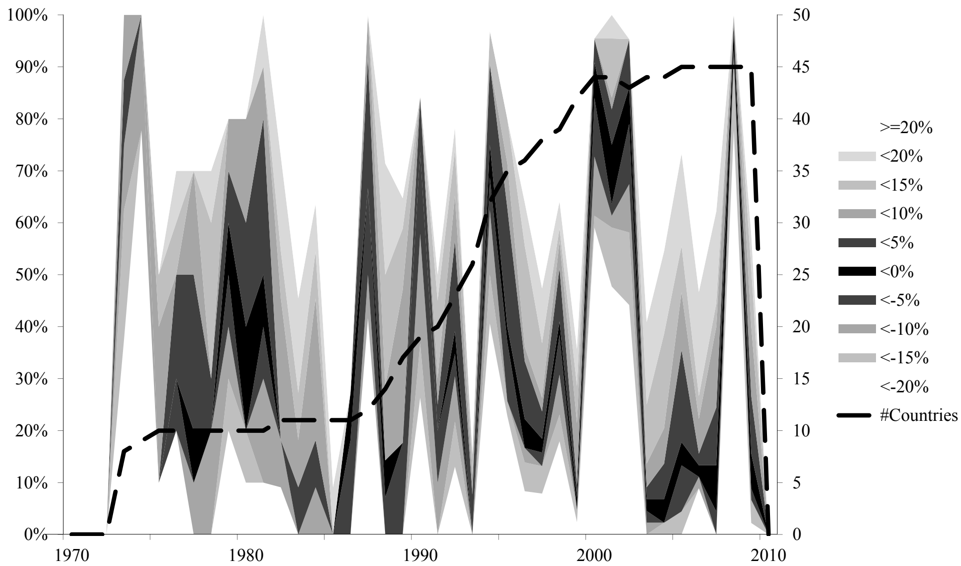
	1973	1975	1985	1995	2005	2009
Infrastructure	**34**	**113**	**173**	**380**	**638**	**749**
Telecom	**6**	**11**	**26**	**81**	**187**	**203**
Fixed-line	5	8	17	38	75	79
Wireless	1	2	5	26	79	78
Satellite				4	14	18
Cable		1	4	13	19	28
Transport	**6**	**9**	**14**	**41**	**111**	**135**
Airports				5	14	20
Ports	1	1	1	9	24	31
Highways				4	32	34
Rail	4	6	10	16	24	29
Pipelines	1	2	3	7	17	21
Utilities	**22**	**93**	**133**	**258**	**340**	**411**
Electricity	18	49	55	129	178	240
Water		1	6	23	39	46
Gas	3	15	31	52	58	52
Multi	1	28	41	54	65	73

Source: Rödel and Rothballer [2012].

try. The analysis will also draw on subsets based on infrastructure sector (Telecom, Transport, Utilities), pricing power (High, Low), and international diversification (Advanced economies, Emerging economies). For simplicity this section focuses on the main domestic index. I will highlight other relevant data differences during the analysis. Figure 5.8 shows its real returns in the dataset. Data for eight developed countries is available from 1973 (Australia, Belgium, Canada, France, Germany, Hong Kong, Italy, Japan). The first developing country, Malaysia, is added in 1986, followed by the Philippines in 1987, the Republic of Korea in 1988, and India in 1989. The maximum of 45 is reached in 2005. The series ends in 2009, the last year of index computation. The patter of the shaded area closely resembles the pattern of equity in Figure 5.7. The oscillating narrow dark band signals that high positive returns are followed by low negative returns and vice versa. The movements across countries again seem highly cross-correlated.

Table 5.10 presents the summary statistics of real equity returns for each

Figure 5.8: Real infrastructure returns in the dataset



Notes of Figure 5.2 apply.

country separately. The median country history is only 18 years, the shortest of all asset classes in this work. The median annual real return for infrastructure is 6.5% with a variance of 32.0%, both are close to equity with 5.9% and 30.8%, respectively. The time series characteristics generally resemble the ones of equity with a slightly negative skewness, limited concern for heteroscedasticity and autocorrelation. The distribution is less peaked than equity. The tests strongly reject unit-roots and accept stationarity for all countries except Chile at a 5% level. This makes infrastructure a good candidate for inflation hedging.

5.3.5 Exchange rates

The following assets are international performance series. They have one price which is commonly denominated in US Dollars, e.g. the commodity index, the gold price, or performance of a global equity index. The US dollar performance is

Table 5.10: Summary statistics of real infrastructure returns

Country	N	Distribution				Time series properties			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	17	3.5	47.9	-0.3	3.8	12	17	0	0.0
Australia	37	6.5	29.1	0.4	2.5	2	22	0	0.1
Austria	21	7.2	23.1	-0.4	4.3	36	59	0	0.1
Belgium	37	6.9	19.0	0.4	3.6	53	77	0	0.1
Brazil	16	4.5	37.6	-0.2	3.1	28	5	0	0.0
Canada	37	8.7	15.3	-0.3	2.5	40	69	0	0.1
Chile	20	13.3	30.0	1.1	5.2	10	91	0	0.2
China	16	5.7	47.5	-0.2	2.5	73	40	0	0.0
Colombia									
Czech Republic	16	6.5	32.8	0.0	2.3	22	42	7	0.1
Denmark	16	10.0	31.4	-0.7	2.8	85	57	3	0.1
Egypt	11	21.1	96.0	0.5	2.3	8	83	0	0.1
Finland	15	15.2	57.9	-0.6	3.3	63	94	1	0.1
France	37	7.5	37.1	-0.3	2.7	93	91	0	0.1
Germany	37	5.9	19.2	-1.7	8.8	1	47	0	0.1
Greece	13	0.1	36.1	-1.4	3.9	25	43	0	0.1
Hong Kong	37	9.8	38.1	-0.5	3.2	24	69	0	0.1
Hungary	12	-3.5	27.0	-0.3	2.1	86	75	4	0.1
India	20	8.9	46.6	-0.1	2.6	60	70	0	0.1
Indonesia									
Iran									
Ireland	2	-15.9	47.4						
Israel	17	7.5	32.6	-0.3	2.0	69	15	0	0.0
Italy	37	5.6	30.7	-0.2	2.8	85	70	0	0.1
Japan	37	1.9	29.0	0.5	4.0	63	91	0	0.1
Korea, Republic Of	21	16.9	50.9	1.9	7.2	59	71	0	0.0
Malaysia	23	4.6	26.2	-0.3	2.6	39	33	0	0.1
Mexico	18	11.0	28.3	0.2	2.2	81	22	0	0.0
Morocco	5	12.9	13.1	0.0	2.0				
Netherlands	15	3.7	54.6	-1.3	4.5	25	40	6	0.1
New Zealand	18	7.7	22.8	0.1	4.5	36	9	0	0.0
Norway	10	-4.3	62.7	-0.8	2.3	67	73	0	0.1
Pakistan	17	-2.4	44.2	-0.5	3.0	43	41	0	0.1
Peru	15	-3.8	53.8	0.4	3.0	19	4	0	0.0
Philippines	22	10.5	48.4	0.4	2.3	67	32	0	0.1
Poland	11	-2.0	29.5	-1.3	4.8	6	46	12	0.1
Portugal	14	8.1	30.1	-0.1	2.7	86	73	4	0.1
Russian Federation	11	7.1	66.1	-1.3	4.2	19	10	0	0.0
Saudi Arabia	7	3.4	50.5	0.2	2.4	78	39	8	0.1
Singapore	16	1.2	28.9	-0.1	1.6	55	73	0	0.1
South Africa	13	18.9	46.2	0.2	3.1	23	84	4	0.1
Spain	22	10.7	25.4	-0.6	2.5	49	60	0	0.1
Sweden	21	6.4	24.9	-0.4	2.0	50	70	0	0.1
Switzerland	35	5.4	21.0	0.4	3.3	43	54	0	0.1
Taiwan	18	-6.9	22.6	-0.2	2.1	93	69	3	0.1
Thailand	19	9.7	56.0	0.7	3.2	6	85	0	0.1
Turkey	16	-1.4	87.5	0.1	3.7	5	27	0	0.1
United Kingdom	28	10.5	23.9	-0.5	2.6	35	15	0	0.1
United States	36	6.1	18.1	-0.8	3.1	90	60	0	0.1
Venezuela									
Median	18	6.5	32.0	-0.2	2.8	42.9	57.7	0.0	0.1

Notes of Table 5.2 apply.

then converted in local currency using nominal exchange rates. I denote exchange rates in direct quotation, i.e. the price of one foreign currency unit in local currency units. An increase in the nominal exchange rate signals depreciation of local currency relative to the foreign currency. The exchange rate, thus involves a local (origin) and foreign (target) currency. The default target currency is the US dollar, which served as the main currency during the time covered.

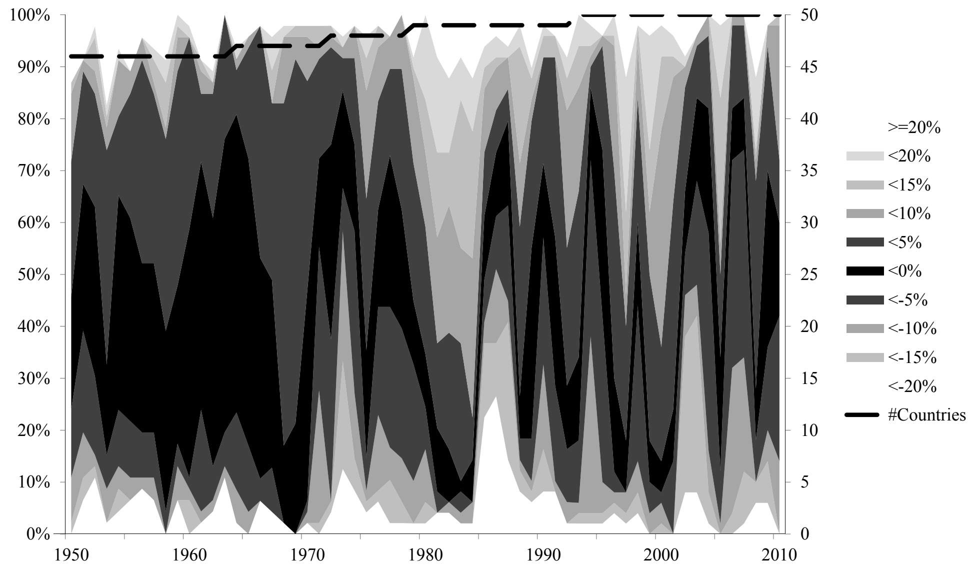
The development of the nominal exchange rate carries little information for a long-term investor. Very high local inflation, for example, will most likely depreciate the local currency relative to the foreign one. The exchange rate movement becomes more interesting when comparing it to the inflation differential of the two countries. Relative PPP as described in Section 3.3.7 predicts a constant real exchange rate that equals the nominal exchange rate minus the two countries' inflation differential. An increase in the real exchange rate would signal a devaluation of the local currency. The local investor would lose purchasing power relative to his international peers. The flip-side would be a gain to this investor's foreign investments. I will summarize the exchange rate data in its real rather than its nominal form to highlight this fact. The series is labeled USD_{PPP}.

The nominal exchange rate data is obtained from GFD. In case of multiple exchange rate quotes it is the market US dollar exchange rate relevant for the local investor. Black market rates are estimated in case no quotes are available. This aims to value foreign investments over time even though the value might not be directly realizable in the extremest of situations. The real exchange rate is computed by subtracting the inflation differential between local inflation and foreign inflation.

Figure 5.9 shows the real exchange rates in the dataset. Exchange rate data is fairly complete with 46 countries available throughout the sample. The Czech Republic, Saudi Arabia, China, and the Russian Federation are added subsequently and complete the series in 1993. Dark shadings indicate little exchange rate movements and dominate until 1973. The time of Bretton Woods brought relatively stable real exchange rates for the majority of countries. Exchange rate volatility increased significantly after its break-up in the early 1970s and remains elevated especially since 1985. Movements beyond 5% or even 10% a year are common, appreciations and depreciations again alternate in three year cycles.

Table 5.11 presents the summary statistics of real exchange rates for each

Figure 5.9: Real exchange rates in the dataset (USD_{PPP})



Notes of Figure 5.2 apply.
Compare to Kaserer and Rödel [2011].

country separately. The empirical data by and large supports stable real exchange rates as predicted by relative PPP. The median real exchange rate move is close to zero and the Kwiatowski-Philipps-Schmidt-Shin test rejects stationarity for only two series at 5% significance (Saudi Arabia and New Zealand). New Zealand experienced the largest real appreciation against the dollar with an average exchange rate decline of -3% a year. On the opposite side, the Polish and Chinese currency has depreciated in real terms by about 3% annually. The exchange rate volatility was highest in the emerging markets Indonesia, Iran, and Argentina which underwent several high inflation periods. Hong Kong, Canada, and Singapore enjoyed the most stable real exchange rate to the US dollar. Hong Kong has explicitely pegged and closely managed its currency against the Sterling or US dollar, Singapore has tightly controlled its exchange rate against an undisclosed baskets of major currencies. Canada and the US are economically and financially integrated and geographic neighbors - again, both factors supporting synchroneous currency

Table 5.11: Summary statistics of real exchange rates (USD_{PPP})

Country	N	Distribution				Time series properties			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	61	0.5	34.9	0.4	5.8	56	3	0	0.0
Australia	61	-1.4	9.5	-0.4	3.8	0	41	0	0.1
Austria	61	-1.5	10.0	-0.2	2.7	5	9	0	0.0
Belgium	61	-0.6	9.9	-0.1	2.8	1	2	0	0.0
Brazil	61	0.4	20.5	0.6	3.3	6	62	0	0.0
Canada	61	-0.2	6.0	-0.2	5.1	0	96	0	0.1
Chile	61	2.0	23.7	1.7	9.7	2	0	0	0.0
China	32	3.0	11.0	0.7	4.2	1	29	0	0.0
Colombia	61	1.3	17.4	0.5	4.0	0	21	0	0.0
Czech Republic	47	2.4	19.1	3.2	17.3	25	5	0	0.1
Denmark	61	-1.4	9.6	-0.1	2.5	1	5	0	0.0
Egypt	61	0.8	12.6	2.1	9.9	27	30	0	0.1
Finland	61	-0.5	10.6	0.5	3.1	31	23	0	0.0
France	61	-0.5	9.8	-0.1	2.7	3	4	0	0.0
Germany	61	-0.7	11.1	0.1	3.2	95	66	0	0.0
Greece	61	0.0	11.4	1.3	8.1	37	52	0	0.0
Hong Kong	61	-0.2	5.2	-0.8	5.5	46	0	0	0.1
Hungary	61	1.3	23.4	5.4	38.1	0	92	0	0.1
India	61	1.1	9.2	1.2	6.0	94	33	0	0.1
Indonesia	61	2.6	41.7	2.1	18.0	0	70	0	0.0
Iran	61	0.9	39.8	6.3	45.6	1	84	0	0.1
Ireland	61	-1.0	9.1	-0.1	2.8	0	39	0	0.0
Israel	61	1.6	12.3	1.9	7.8	0	70	0	0.1
Italy	61	-0.7	9.2	0.0	3.5	0	6	0	0.0
Japan	61	-2.0	10.6	0.3	3.2	1	54	0	0.1
Korea, Republic Of	61	1.4	28.5	0.9	5.8	0	0	0	0.0
Malaysia	61	0.9	7.8	1.9	14.9	16	99	0	0.0
Mexico	61	-0.6	20.1	3.1	20.1	43	5	0	0.0
Morocco	61	0.6	8.4	0.3	2.5	61	1	0	0.1
Netherlands	61	-1.3	9.8	0.0	2.7	1	6	0	0.0
New Zealand	61	-3.0	12.1	-0.4	3.8	0	24	0	0.2
Norway	61	-1.5	9.1	-0.1	3.6	0	100	0	0.0
Pakistan	61	2.1	14.0	3.4	21.9	1	3	0	0.0
Peru	61	-2.0	23.1	-2.9	19.2	5	52	0	0.0
Philippines	61	1.3	11.7	0.9	4.3	52	13	0	0.0
Poland	61	2.9	30.7	3.4	20.6	0	88	0	0.0
Portugal	61	-1.0	9.2	-0.2	2.8	0	6	0	0.1
Russian Federation	18	-11.3	33.2	-1.0	7.1	0	90	0	0.1
Saudi Arabia	39	0.3	8.6	-1.9	6.6	0	0	3	0.4
Singapore	61	-0.3	6.9	-1.2	8.0	77	16	0	0.1
South Africa	61	0.0	14.2	0.1	5.3	0	79	0	0.0
Spain	61	-0.5	11.7	0.6	4.0	99	1	0	0.1
Sweden	61	-0.6	10.3	0.6	3.1	0	14	0	0.0
Switzerland	61	-1.3	10.3	-0.1	2.9	3	16	0	0.1
Taiwan	61	0.2	14.6	1.5	10.4	0	14	0	0.1
Thailand	61	-0.2	12.2	0.9	10.3	4	3	0	0.0
Turkey	61	0.0	14.1	0.5	3.3	12	49	0	0.1
United Kingdom	61	-0.5	10.1	0.4	3.7	1	71	0	0.0
United States									
Venezuela	61	0.0	18.3	3.1	18.3	4	92	0	0.1
Median	61	-0.1	11.3	0.4	4.7	1.3	23.7	0.0	0.0

Notes of Table 5.2 apply.

developments. The exchange rate is on median right skewed indicating that major depreciations are more frequent than appreciations. The distribution is fairly peaked with a median Kurtosis of 4.7. As suggested by the exchange rate regime shift already, homoscedasticity is rejected for most series.

In summary, real exchange rates are highly stationary. This suggests that international diversification provides favorable inflation hedging at least in the long-run for the price of short-term volatility.

5.3.6 Gold

Gold proxies the return of physical gold holdings in local currency. It trades at one global price more than any other commodity. The local gold performance is, thus, a combination of physical commodity exposure and exchange rate performance. The performance is gross of transaction fees and storage costs.

The gold prices are from GFD and reflect the gold spot price according to the afternoon fixing in London quoted in US dollar per ounce. The exchange rates used in the conversion are market rates as described in the previous section.

Figure 5.10 shows the real gold returns in the dataset. The time series for gold is complete for the time covered. The availability of local gold returns depends on the exchange rate as described in Section 5.3.5. The macro pattern also follows the exchange rate with a relatively stable period during Bretton Woods, when gold was fixed at 35 US dollar per ounce for most of the time and exchange rates relatively stable. After its break-up, gold first entered a period of rapid appreciation with a climax in 1980 and then of continued high volatility and gradual decline until 2000 when it started to rally up again surpassing previous heights. The common global component of all local series introduces high cross-correlation across markets.

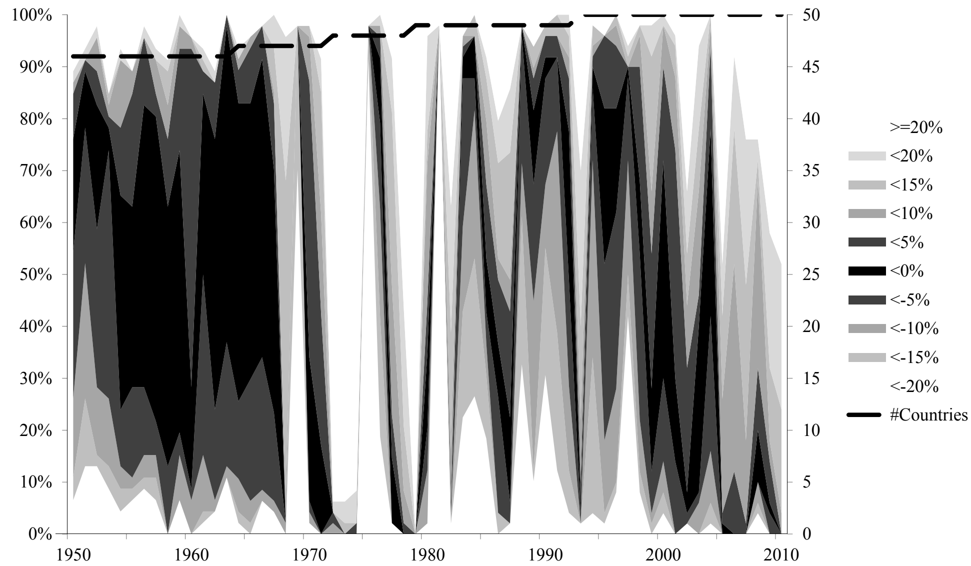
Table 5.12 presents the summary statistics of real gold returns for each country separately. Gold yielded a median real return of 2.1% annually. This significantly exceeds the median return of 1.3% to bills. Despite gold's reputation as safe harbor, the data uncovers a staggering 18.7% median annual volatility. The volatility for the US investor is of similar magnitude even though he does not face exchange rate risk explicitely but rather implicitely by the law of one price and changing

Table 5.12: Summary statistics of real gold returns

Country	N	Distribution				Time series properties			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	61	2.6	36.7	0.0	5.8	98	12	0	0.1
Australia	61	0.7	18.6	0.9	6.9	94	53	0	0.1
Austria	61	0.7	17.0	1.2	6.2	71	5	0	0.1
Belgium	61	1.6	17.4	1.4	6.8	58	6	0	0.1
Brazil	61	2.5	26.8	0.7	3.7	20	82	0	0.1
Canada	61	1.9	18.9	0.6	5.7	98	2	0	0.1
Chile	61	4.2	31.1	2.0	11.9	14	38	0	0.1
China	32	5.0	20.7	0.7	5.8	0	88	0	0.2
Colombia	61	3.5	23.1	0.1	2.8	4	69	0	0.1
Czech Republic	47	6.1	25.3	1.1	5.3	43	30	0	0.1
Denmark	61	0.7	17.2	1.6	7.6	57	5	0	0.1
Egypt	61	3.0	25.1	2.1	11.6	69	78	0	0.1
Finland	61	1.7	18.5	0.7	4.4	94	15	0	0.1
France	61	1.7	16.8	1.1	5.8	64	10	0	0.1
Germany	61	1.4	17.5	1.1	5.8	95	18	0	0.1
Greece	61	2.2	18.0	0.7	4.7	90	27	0	0.1
Hong Kong	61	2.0	18.2	0.7	5.0	44	4	0	0.1
Hungary	61	3.4	30.2	3.2	18.3	3	90	0	0.1
India	61	3.3	16.9	1.0	5.6	76	12	0	0.1
Indonesia	61	4.8	44.4	1.6	14.2	0	63	0	0.0
Iran	61	3.1	42.1	4.8	32.1	3	52	0	0.0
Ireland	61	1.1	17.7	1.0	4.9	61	4	0	0.1
Israel	61	3.8	19.7	0.7	4.0	26	23	0	0.1
Italy	61	1.4	17.1	1.1	4.9	54	2	0	0.1
Japan	61	0.1	20.0	2.0	10.6	58	53	0	0.1
Korea, Republic Of	61	3.6	32.7	0.2	3.5	0	14	0	0.0
Malaysia	61	3.1	17.6	0.9	6.9	82	19	0	0.1
Mexico	61	1.6	29.1	0.9	7.5	39	20	0	0.1
Morocco	61	2.7	17.4	1.0	5.2	85	14	0	0.1
Netherlands	61	0.9	17.2	1.4	6.8	59	7	0	0.1
New Zealand	61	-0.9	26.5	-0.1	3.7	14	3	0	0.1
Norway	61	0.7	17.9	1.3	6.8	70	16	0	0.1
Pakistan	61	4.2	23.9	2.1	11.6	19	83	0	0.1
Peru	61	0.2	29.7	-1.7	10.2	15	13	0	0.1
Philippines	61	3.4	18.4	0.4	3.9	100	70	0	0.1
Poland	61	5.1	35.9	1.9	10.5	0	27	0	0.1
Portugal	61	1.2	18.0	0.9	5.5	39	13	0	0.1
Russian Federation	18	-5.7	33.1	-0.9	5.2	0	50	0	0.1
Saudi Arabia	39	4.9	23.7	0.2	5.3	0	17	0	0.1
Singapore	61	1.9	17.6	0.8	7.6	90	29	0	0.1
South Africa	61	2.1	17.7	1.0	4.3	12	30	0	0.1
Spain	61	1.6	17.6	0.8	4.1	93	28	0	0.1
Sweden	61	1.5	18.2	1.1	5.0	61	11	0	0.1
Switzerland	61	0.8	17.1	1.1	8.0	41	36	0	0.1
Taiwan	61	2.4	21.3	0.6	4.2	0	84	0	0.1
Thailand	61	1.9	18.6	0.4	4.9	78	43	0	0.1
Turkey	61	2.2	20.8	1.0	5.5	53	20	0	0.1
United Kingdom	61	1.6	17.8	0.8	4.1	51	13	0	0.1
United States	61	2.2	18.8	0.7	5.3	69	2	0	0.1
Venezuela	61	2.2	25.6	0.6	4.2	13	29	0	0.1
Median	61	2.1	18.7	0.9	5.6	53.4	19.9	0.0	0.1

Notes of Table 5.2 apply.

Figure 5.10: Real gold returns in the dataset



Notes of Figure 5.2 apply.

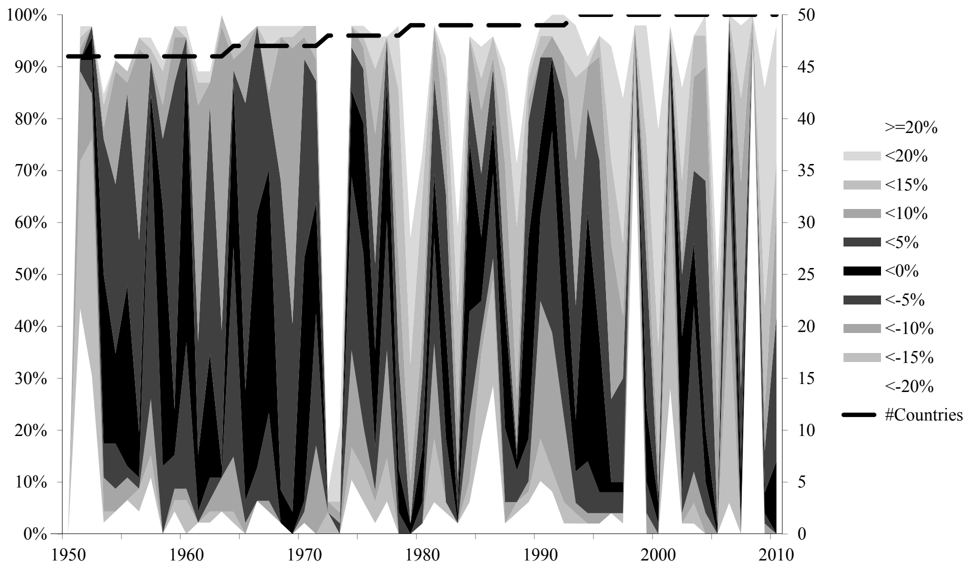
real exchange rates. The skewness is positive driven by the two rallies in the 1970s and 2000s. The Augmented Dickey-Fuller test rejects unit-roots in all countries and the Kwiatowski-Philipps-Schmidt-Shin test can only reject stationarity for China and Hong Kong at a 5% significance (none at 1%). This indicates that gold is a strong inflation hedge in the long-run.

5.3.7 Commodities

The commodities time series represents the total return for a broad basket of (rolling) commodity futures. As a large share of futures are traded in US dollar the performance again bases on one global series that is localized with the market exchange rate.

The underlying US dollar return is the Reuters/Jeffries-CRB Total Return Index with GFD extension as provided from GFD. It originates from the Com-

Figure 5.11: Real commodity returns in the dataset



Notes of Figure 5.2 apply.

modity Research Bureau's index that started in 1957 and its basket has been updated continuously to reflect the current importance of the single commodities. Before this, an index of the Bureau of Labor Statistics has been used. As of 2010, the commodity index covers 19 commodities. Agricultural products constitute 41% of the index, petroleum products and natural gas 39%, and metals 20%.[9]

Figure 5.11 shows the real commodity returns in the dataset. As in the case of gold, the data availability is restricted by the exchange rates only. The shaded areas paint a very consistent return pattern characterized by high volatility and cross-correlation. The Bretton Woods period with its relatively stable exchange rates hardly leaves its traces. Returns beyond 20% per year, indicated by the white areas, are less frequent than in the case of equities or infrastructure.

Table 5.13 presents the summary statistics of real commodity returns for each

[9]Source: Jefferies Financial Products, LLC (2010) Thomson Reuters/ Jefferies CRB Index Materials, http://www.jefferies.com, accessed April 5, 2010.

country separately. The median return to commodities was 2.2% which is close to the gold return. It differs by country depending on the relative exchange rate gains or losses of the local currencies. High return implies exchange rate depreciation against the US dollar. Median volatility stands at 15.8% with a slightly positive skewness and a kurtosis of 4.6. The consistent, high noise pattern is confirmed by homoscedasticity supported for the majority of countries, little serial correlation at the one-year horizon, and no support for non-stationarity: unit-roots are rejected and stationarity has to be accepted for all series at 1% significance. This supports the claim of commodities to hedge inflation in the long-run.

5.3.8 International equities

The increasing financial openness today allows broad international equity diversification. Besides direct investments in the equity indices of foreign countries, many investors simply invest in broad international equity index - based on equity direct investments or swaps. International equities reflect the total return to such an index in local currency. The most prominent examples and benchmarks in this study are the MSCI World (MSCI W) and MSCI Emerging Markets (MSCI EM) indices from Morgan Stanley Capital International Inc. (MSCI) which cover 24 developed and 21 emerging economies weighted by market capitalization. Table 5.1 provides an overview of the country index memberships.

The performance data is obtained from GFD and matches the total gross returns as available from the MSCI website http://www.msci.com. I use the GFD extension of these indices from 1949 until their respective index start in 1969 and 1987 and label them Developed Markets Equity (DM) and Emerging Markets Equity (EM), respectively, to distinguish them from the pure, non-extended series from MSCI. The extended indexes aim to reflect ex-ante knowledge which is especially crucial to minimize a performance bias in the emerging markets index. For example, Africa carries a relatively heavy weight compared to Asia after World War II as most of the investors were expecting this to be the next growth market.

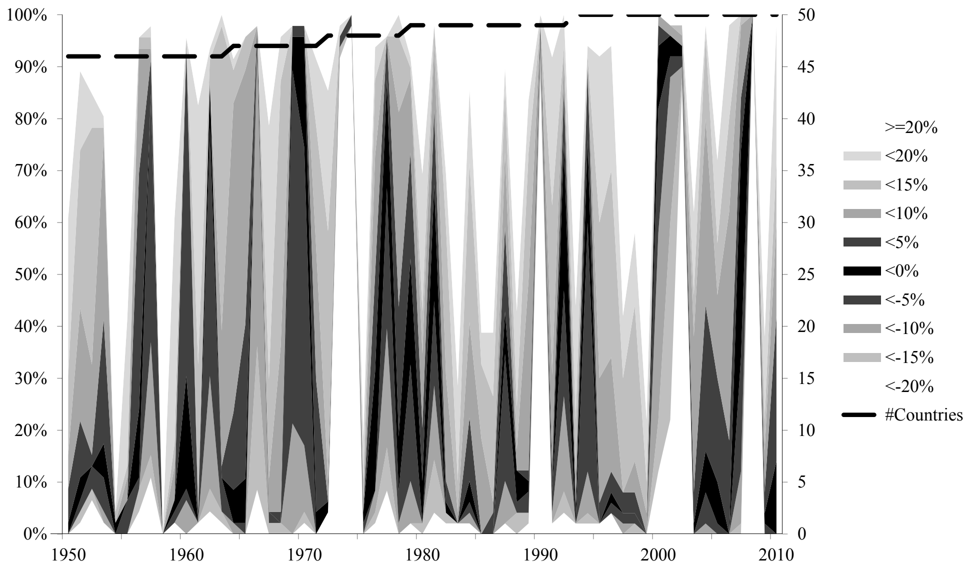
The high level statistical properties of DM and EM are fairly similar. I highlight these with the example of DM. Figure 5.12 shows the real DM returns in the dataset. The data availability is fairly complete and only constrained by the availability of exchange rate data. The GFD extensions increase data history and

Table 5.13: Summary statistics of real commodity returns

Country	N	Distribution				Time series properties			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	61	2.8	37.8	0.5	5.4	39	3	0	0.0
Australia	61	0.8	12.5	0.0	3.3	90	19	0	0.1
Austria	61	0.8	15.2	-0.3	3.5	19	36	0	0.0
Belgium	61	1.7	15.3	-0.1	3.3	9	59	0	0.0
Brazil	61	2.6	22.7	0.6	2.7	2	30	0	0.0
Canada	61	2.0	11.5	0.3	4.1	35	75	0	0.1
Chile	61	4.3	27.2	2.6	15.2	1	2	0	0.0
China	32	4.4	15.5	-1.5	6.3	0	7	0	0.0
Colombia	61	3.6	20.0	0.1	3.0	5	14	0	0.0
Czech Republic	47	5.0	22.7	1.3	8.8	11	37	0	0.1
Denmark	61	0.8	14.7	-0.2	3.3	4	45	0	0.0
Egypt	61	3.1	18.5	0.6	7.8	8	28	0	0.1
Finland	61	1.8	14.3	-0.4	3.3	2	36	0	0.0
France	61	1.8	14.9	-0.3	3.3	12	37	0	0.0
Germany	61	1.5	15.9	0.1	3.3	73	18	0	0.0
Greece	61	2.3	15.5	0.2	3.9	49	9	0	0.0
Hong Kong	61	2.1	12.8	-0.6	5.2	9	30	0	0.0
Hungary	61	3.5	26.8	3.4	22.5	2	87	0	0.1
India	61	3.4	13.7	0.1	3.9	52	29	0	0.1
Indonesia	61	4.9	43.6	1.7	14.3	0	93	0	0.0
Iran	61	3.2	41.5	5.4	37.7	2	84	0	0.0
Ireland	61	1.2	15.4	0.1	3.2	30	31	0	0.0
Israel	61	3.9	15.3	-0.1	4.6	48	12	0	0.0
Italy	61	1.6	14.9	-0.1	3.7	6	39	0	0.0
Japan	61	0.2	17.2	-0.3	6.0	1	41	0	0.0
Korea, Republic Of	61	3.7	33.1	0.5	5.8	0	1	0	0.0
Malaysia	61	3.2	13.6	-0.5	5.3	0	6	0	0.0
Mexico	61	1.7	22.7	1.8	10.0	76	5	0	0.0
Morocco	61	2.8	14.6	-0.4	4.3	37	27	0	0.0
Netherlands	61	1.0	15.0	-0.1	3.2	4	53	0	0.0
New Zealand	61	-0.8	21.7	-0.4	4.5	0	98	0	0.1
Norway	61	0.8	12.3	0.2	2.8	73	89	0	0.0
Pakistan	61	4.3	19.5	2.8	17.2	7	40	0	0.0
Peru	61	0.3	26.3	-2.1	12.8	3	85	0	0.0
Philippines	61	3.6	16.3	0.1	3.4	23	6	0	0.0
Poland	61	5.2	33.1	2.3	13.2	0	94	0	0.0
Portugal	61	1.3	15.1	0.0	3.5	10	35	0	0.0
Russian Federation	18	-9.4	31.6	-1.7	6.5	1	57	0	0.1
Saudi Arabia	39	3.2	15.9	-1.3	5.4	57	95	0	0.0
Singapore	61	2.0	12.3	-1.2	6.4	1	5	0	0.0
South Africa	61	2.3	13.8	0.1	3.3	22	42	0	0.1
Spain	61	1.8	16.8	1.1	7.7	45	44	0	0.0
Sweden	61	1.6	14.1	0.4	3.1	59	57	0	0.0
Switzerland	61	0.9	15.8	-0.2	4.0	5	27	0	0.0
Taiwan	61	2.5	17.8	-0.3	5.2	0	26	0	0.0
Thailand	61	2.0	16.0	-0.7	8.2	67	8	0	0.1
Turkey	61	2.3	17.4	0.4	3.0	1	39	0	0.0
United Kingdom	61	1.7	13.9	0.3	3.3	79	26	0	0.0
United States	61	2.3	12.8	-0.3	5.6	18	48	0	0.0
Venezuela	61	2.3	23.6	1.4	10.2	3	50	0	0.1
Median	61	2.2	15.8	0.1	4.6	8.4	36.1	0.0	0.0

Notes of Table 5.2 apply.

Figure 5.12: Real developed markets equity returns in the dataset (DM)



Notes of Figure 5.2 apply.

combined with nominal exchange rates allow to study the hypothetical performance of international equity baskets for a diverse country and time scope. I leverage this information when studying the inflation linearities. For a significant portion of the observations, actual investability would have been constrained by a lack in financial openness. This might bias the actual inflation hedging properties. When investigating the inflation hedging characteristics of international diversification I will use only a subset of these observations based on financial openness as defined in section 5.2.3. The summary statistics of this subsample are provided in Table 5.4. The return pattern seems consistent throughout time and is characterized by high volatility yet less extreme return values compared to domestic equity. The exchange rate regime switch in the early 1970s has not significantly changed the picture except in the immediate transition period, with two years of returns beyond +/-20% a year.

Table 5.14 presents the summary statistics of real developed markets equity returns for each country separately. The median return stands at 6.3% which comes close to the median return to domestic equities of 6.8% and significantly exceeds other international assets. It is highest in Poland (9.4%) and lowest in New Zealand (3.5%). The median volatility is 20.3%, i.e. two thirds of domestic equities, which is driven by the broad geographic diversification and the heavy weight of relatively less volatile developed markets such as the United States. The series exhibits little heteroscedasticity and autocorrelation at the one year lag. The stationarity tests again create hope for international equities to be a favorable inflation hedge. Unit-roots can be rejected for all series at 1% significance and stationarity cannot be rejected at the 1% for a single country (only for the Czech Republic and Saudi Arabia at the 5% level).

5.3.9 International bills and bonds

Investments in foreign bills and bonds are another example for international diversification. Bil. I. and Bnd. I. reflect the performance of investments in the major developed market sovereign bills and bonds respectively. The prerequisite of financial openness as discussed for international equities applies.

The performance data is obtained from GFD and I construct a portfolio of investments in the United States, Japan, Germany, and the United Kingdom weighted 2:2:1:1 and rebalanced annually. This simple proxy is only used in the inflation hedging linearity analysis.

Figure 5.13 shows the real international bill returns in the dataset. International bond returns follow a more volatile pattern. The difference is comparable to domestic bills and bonds. I do not present these in detail as the time series is only used at the side line. The availability of exchange rate data again constrains the data history. The return pattern somewhat overlays the real exchange rate movements of Figures 5.9 and 5.5. The less volatile Bretton Woods exchange rate regime is clearly visible and its end marks a break-point to a more volatile period. Returns beyond +/-20% constitute about 15% of all observations.

Table 5.15 presents the summary statistics of real international bill returns for each country separately. The median real return is 2.0% and positive in all cases except New Zealand, the country with the strongest currency appreciation in the sample, and the Russian Federation which only covers two decades and major

Table 5.14: Summary statistics of developed market equity returns (DM)

Country	N	Distribution				Time series properties			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	61	7.0	38.9	-0.3	6.5	61	4	0	0.0
Australia	61	5.1	17.3	-0.4	3.7	47	19	0	0.1
Austria	61	5.0	19.4	-1.0	4.1	10	83	0	0.1
Belgium	61	5.9	19.6	-1.1	4.4	9	76	0	0.1
Brazil	61	6.9	26.1	0.5	3.4	2	87	0	0.1
Canada	61	6.3	15.9	-0.7	3.7	51	29	0	0.1
Chile	61	8.5	27.4	-0.2	4.8	12	1	0	0.0
China	32	9.3	20.8	-0.9	5.1	11	83	0	0.0
Colombia	61	7.8	25.3	0.0	2.8	6	64	0	0.1
Czech Republic	47	7.0	24.9	1.2	8.8	22	29	0	0.2
Denmark	61	5.1	19.4	-1.0	4.3	10	85	0	0.1
Egypt	61	7.3	20.9	-0.4	5.5	7	78	0	0.1
Finland	61	6.0	19.7	-1.0	4.2	12	88	0	0.1
France	61	6.0	18.9	-1.0	4.3	6	63	0	0.1
Germany	61	5.8	19.4	-0.9	3.8	10	79	0	0.1
Greece	61	6.5	20.3	-0.8	3.9	25	40	0	0.1
Hong Kong	61	6.3	18.9	-1.0	4.7	25	94	0	0.1
Hungary	61	7.8	29.5	2.5	16.8	24	70	0	0.0
India	61	7.6	19.2	-0.7	3.9	72	91	0	0.1
Indonesia	61	9.1	46.6	1.3	13.4	0	46	0	0.1
Iran	61	7.4	44.7	4.5	30.8	1	42	0	0.1
Ireland	61	5.5	19.9	-0.7	3.4	10	75	0	0.1
Israel	61	8.1	20.4	-0.5	4.6	94	54	0	0.1
Italy	61	5.8	18.4	-1.0	4.2	3	80	0	0.1
Japan	61	4.5	19.7	-1.3	5.8	2	76	0	0.1
Korea, Republic Of	61	7.9	32.2	1.1	4.9	0	6	0	0.0
Malaysia	61	7.4	20.4	-0.6	4.2	18	72	0	0.1
Mexico	61	5.9	26.6	1.3	7.8	76	35	0	0.0
Morocco	61	7.1	18.9	-1.0	4.3	12	62	0	0.1
Netherlands	61	5.2	19.5	-1.0	4.0	8	64	0	0.1
New Zealand	61	3.5	22.1	-1.1	5.7	0	90	0	0.1
Norway	61	5.0	18.2	-1.2	4.3	14	57	0	0.1
Pakistan	61	8.6	24.6	0.3	6.1	42	54	0	0.1
Peru	61	4.5	29.5	-1.5	7.9	6	16	0	0.0
Philippines	61	7.8	20.3	-0.6	3.9	33	92	0	0.1
Poland	61	9.4	35.1	1.7	10.4	1	94	0	0.1
Portugal	61	5.5	20.0	-1.2	4.8	10	69	0	0.1
Russian Federation	18	-6.3	36.2	0.1	4.9	3	48	0	0.1
Saudi Arabia	39	5.2	22.4	-1.3	4.5	76	15	0	0.2
Singapore	61	6.2	20.1	-1.1	4.8	26	74	0	0.1
South Africa	61	6.5	20.3	-0.9	5.0	7	71	0	0.1
Spain	61	6.0	21.4	-0.5	3.6	70	49	0	0.1
Sweden	61	5.9	18.1	-1.0	4.3	22	58	0	0.1
Switzerland	61	5.2	21.4	-1.2	4.4	8	93	0	0.1
Taiwan	61	6.7	24.5	0.4	5.1	1	79	0	0.1
Thailand	61	6.3	18.8	0.0	4.5	74	82	0	0.1
Turkey	61	6.5	22.0	-0.1	3.4	22	88	0	0.1
United Kingdom	61	6.0	17.9	-0.9	3.7	60	86	0	0.1
United States	61	6.5	17.3	-1.0	4.4	8	98	0	0.1
Venezuela	61	6.5	26.0	0.9	9.4	3	93	0	0.1
Median	61	6.3	20.3	-0.7	4.5	10	71	0	0.1

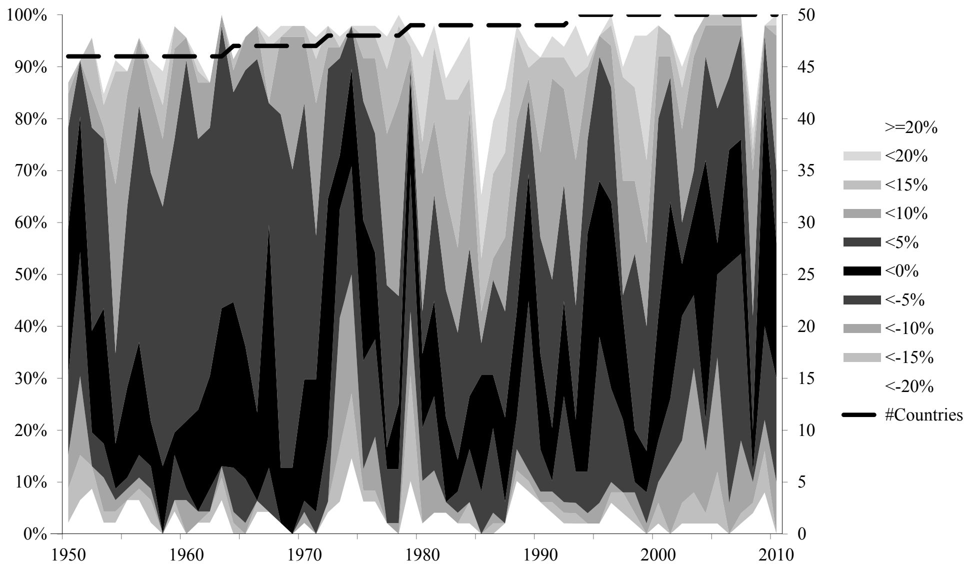
Notes of Table 5.2 apply.

Table 5.15: Summary statistics of international bill returns (Bil. I.)

Country	N	Distribution				Time series properties			
		μ	σ	Skew.	Kurt.	$BPCW_p$	$BG_{1,p}$	ADF_p	$KPSS_t$
Argentina	61	2.6	34.3	0.4	5.3	63	2	0	0.0
Australia	61	0.7	9.8	0.0	5.0	0	34	0	0.2
Austria	61	0.6	7.5	-0.4	4.4	96	32	0	0.1
Belgium	61	1.5	7.0	0.0	4.1	11	5	0	0.1
Brazil	61	2.5	20.8	0.7	3.2	9	55	0	0.0
Canada	61	1.9	8.3	0.4	3.0	1	93	0	0.1
Chile	61	4.2	24.7	1.5	8.9	4	0	0	0.0
China	32	4.9	12.9	0.4	2.7	3	93	0	0.1
Colombia	61	3.5	18.6	0.5	3.5	0	38	0	0.0
Czech Republic	47	4.4	18.1	3.4	18.0	35	3	0	0.2
Denmark	61	0.7	6.7	0.0	3.1	16	17	0	0.1
Egypt	61	3.0	13.1	1.5	5.8	15	46	0	0.1
Finland	61	1.7	9.1	0.7	4.1	25	26	0	0.1
France	61	1.7	7.4	0.0	2.7	85	5	0	0.1
Germany	61	1.4	8.1	0.7	5.0	16	58	0	0.1
Greece	61	2.2	9.9	1.8	10.5	2	80	0	0.0
Hong Kong	61	1.9	7.1	0.0	3.1	65	27	0	0.1
Hungary	61	3.4	23.0	5.5	39.6	0	82	0	0.1
India	61	3.2	9.6	1.0	5.6	94	77	0	0.2
Indonesia	61	4.7	41.8	2.1	18.2	0	58	0	0.0
Iran	61	3.1	39.2	6.2	45.4	1	85	0	0.1
Ireland	61	1.1	6.9	0.1	3.3	3	72	0	0.1
Israel	61	3.7	12.1	2.2	8.8	0	100	0	0.0
Italy	61	1.4	6.8	0.2	4.0	1	20	0	0.1
Japan	61	0.1	6.8	0.0	3.1	7	69	0	0.1
Korea, Republic Of	61	3.6	28.5	0.9	5.8	0	1	0	0.0
Malaysia	61	3.1	8.8	0.7	6.0	56	15	0	0.1
Mexico	61	1.6	21.8	2.3	13.7	29	9	0	0.0
Morocco	61	2.7	7.4	0.3	3.6	13	2	0	0.1
Netherlands	61	0.8	6.8	0.5	3.6	7	9	0	0.1
New Zealand	61	-0.9	15.4	-0.3	3.4	1	34	0	0.1
Norway	61	0.7	7.4	0.1	4.8	0	76	0	0.1
Pakistan	61	4.2	14.8	2.9	17.0	2	28	0	0.1
Peru	61	0.1	24.0	-2.6	19.1	5	49	0	0.0
Philippines	61	3.4	12.2	0.7	3.5	50	35	0	0.0
Poland	61	5.0	31.4	3.3	19.6	0	86	0	0.0
Portugal	61	1.2	7.3	-0.2	5.0	8	11	0	0.1
Russian Federation	18	-10.2	33.7	-0.7	6.9	0	84	0	0.1
Saudi Arabia	39	2.2	11.3	-0.5	4.4	0	0	1	0.3
Singapore	61	1.9	7.7	-0.7	5.9	16	1	0	0.1
South Africa	61	2.1	12.6	0.2	5.0	0	91	0	0.1
Spain	61	1.6	9.6	1.0	5.0	21	9	0	0.1
Sweden	61	1.5	8.2	0.6	3.8	0	22	0	0.1
Switzerland	61	0.8	7.5	0.0	4.9	22	34	0	0.1
Taiwan	61	2.4	14.9	1.4	8.6	0	15	0	0.1
Thailand	61	1.9	11.8	0.6	7.8	14	21	0	0.1
Turkey	61	2.1	13.8	0.5	3.4	11	48	0	0.1
United Kingdom	61	1.6	8.2	0.5	5.1	0	89	0	0.0
United States	61	2.1	5.7	0.6	4.0	6	15	0	0.1
Venezuela	61	2.2	19.9	2.4	12.8	3	95	0	0.1
Median	61	2.0	10.6	0.5	5.0	6	34	0	0.1

Notes of Table 5.2 apply.

Figure 5.13: Real international bill returns in the dataset (Bil. I.)



Notes of Figure 5.2 apply.

currency distortions. The return volatility in the United States, Hong Kong, and a number of European countries is below 7%, which is the fruit of diversification and lower than the real exchange rate volatility against the US dollar. While international bills can be considered a relatively safe investment for these stable countries they are still highly volatile for most emerging countries. The Breusch-Pagan/ Cook-Weisberg test rejects homoscedasticity for almost half the countries at 5% significance which reflects the switch from a low to a high volatility regime. In contrast to domestic bills, international bills do not exhibit unit-roots (except Saudi Arabia) and the null of stationarity is mostly accepted (except Australia, Czech Republic, India, Saudi Arabia). Exchange rate moderation again seems to work in favor for inflation hedging.

5.4 Synopsis

The data availability and mean returns by country and time series are summarized in Table 5.16. The economic time series ΔCPI and ΔGDP are available for all countries and mostly from the start in 1949 until 2010. These series will be used as independent variables later. Returns for domestic fixed income are mostly available from 1949 for the advanced economies. Bills become fairly complete by 1960 and bonds by the mid 1990s. Equities and infrastructure are more fragmented and need as long as 1976 and 1991 respectively to become available for half the countries. The gradual availability may introduce a country and time bias in the results. I will filter for common observations when comparing the different assets to circumvent this problem. The international time series are all fairly complete and limited by the same explanatory variables and exchange rates. Coefficients will not suffer from different underlying samples.

The statistical nature of the asset returns differs remarkably. The economic time series are fairly persistent and slow moving. Bills and bonds have the lowest median returns followed by infrastructure and general equity. This ranking follows the common economic perception with an increasing risk alongside. Only infrastructure shows a slightly higher volatility than equity which is likely to be driven by the in parts low level of diversification within the country indices. The international assets show a wide median return spectrum but are all characterized by quick exchange rate and asset price movements. This poses a fundamental empirical challenge: a slow moving economic time series can only explain a small fraction of the noise in equity returns or exchange rate movements. The coefficient of determination will likely be low especially for short time windows. So even statistically significant results will still pose significant investment risk when applied in practice.

The correlation matrix provided in Table 5.17 highlights the interplay of the individual time series for all observations (upper part) and excluding inflation outliers (lower part). The explanatory variables exhibit very low correlation which makes them suitable for a multivariate regression. The domestic assets are again fairly independent of each other which conceptually sets them apart as different asset classes, the only exception being the positive correlation of equities and listed infrastructure. The international assets correlate strongly with one another which is driven by the common exchange rate component. Consequently we

Table 5.16: Average returns and data availability by country

Country	ΔCPI		ΔGDP		Bills		Bonds		Equity		Infra.		USD_{PPP}		Gold		Commod.		DM		EM		Bil I		Bnd I	
	SY	μ	SY	μ	SY	μ	SY	μ	SY	μ	SY	μ	SY	μ	SY	μ	SY	μ	SY	μ	SY	μ	SY	μ	SY	μ
Argentina	49	51.6	49	2.8	85	-5.8	91	-2.4	66	2.2	92	3.5	49	0.5	49	2.6	49	2.8	49	7.0	49	8.1	49	2.6	49	4.2
Australia	49	5.2	49	4.0	49	1.0	49	1.9	49	6.4	72	6.5	49	-1.4	49	0.7	49	0.8	49	5.1	49	6.1	49	0.7	49	2.3
Austria	49	3.6	49	4.0	49	1.7	49	3.2	69	4.3	88	7.2	49	-1.5	49	0.7	49	0.8	49	5.0	49	6.1	49	0.6	49	2.3
Belgium	49	3.4	49	2.6	49	2.7	49	3.5	50	5.6	72	6.9	49	-0.6	49	1.6	49	1.7	49	5.9	49	7.0	49	1.5	49	3.2
Brazil	49	57.6	49	4.8	94	13.0	93	-8.0	54	7.5	93	4.5	49	0.4	49	2.5	49	2.6	49	6.9	49	7.9	49	2.5	49	4.1
Canada	49	3.7	49	3.7	49	1.9	49	3.2	49	6.2	72	8.7	49	-0.2	49	1.9	49	2.0	49	6.3	49	7.3	49	1.9	49	3.5
Chile	49	28.2	49	3.7	49	-6.5			82	15.4	89	13.3	49	2.0	49	4.2	49	4.3	49	8.5	49	9.6	49	4.2	49	5.8
China	78	5.1	78	9.4					92	-4.3	93	5.7	78	3.0	78	5.0	78	4.4	78	9.3	78	12.1	78	4.9	78	7.5
Colombia	49	13.6	49	4.2			93	2.3	87	4.4			49	1.3	49	3.5	49	3.6	49	7.8	49	8.9	49	3.5	49	5.1
Czech Republic	63	3.8	85	1.3					94	6.9	93	6.5	63	2.4	63	6.1	63	5.0	63	7.0	63	10.9	63	4.4	63	6.6
Denmark	49	4.7	49	2.4	49	3.2	49	3.9	69	7.1	93	10.0	49	-1.4	49	0.7	49	0.8	49	5.1	49	6.1	49	0.7	49	2.3
Egypt	49	7.4	52	4.9	51	0.1	2	0.2	94	13.0	98	21.1	49	0.8	49	3.0	49	3.1	49	7.3	49	8.4	49	3.0	49	4.6
Finland	49	5.2	49	4.1	49	2.2	59	3.7	61	9.1	94	15.2	49	-0.5	49	1.7	49	1.8	49	6.0	49	7.1	49	1.7	49	3.3
France	49	4.7	49	3.2	49	1.4	49	2.8	49	6.1	72	7.5	49	-0.5	49	1.7	49	1.8	49	6.0	49	7.1	49	1.7	49	3.3
Germany	49	2.6	49	3.6	49	1.6	49	4.0	49	6.8	72	5.9	49	-0.7	49	1.4	49	1.5	49	5.8	49	6.9	49	1.4	49	3.0
Greece	49	8.3	49	4.1	49	1.5	92	7.6	76	4.7	96	0.1	49	0.0	49	2.2	49	2.3	49	6.5	49	7.6	49	2.2	49	3.8
Hong Kong	49	4.1	60	6.3	67	-0.5	93	4.1	69	10.6	72	9.8	49	-0.2	49	2.0	49	2.1	49	6.3	49	7.4	49	1.9	49	3.6
Hungary	49	7.1	49	4.6					91	7.4	97	-3.5	49	1.3	49	3.4	49	3.5	49	7.8	49	8.9	49	3.4	49	5.0
India	49	6.2	49	4.5	49	0.9	49	-0.4	87	11.3	89	8.9	49	1.1	49	3.3	49	3.4	49	7.6	49	8.7	49	3.2	49	4.9
Indonesia	49	25.1	58	4.8	89	4.6			87	9.5			49	2.6	49	4.8	49	4.9	49	9.1	49	10.2	49	4.7	49	6.4
Iran	49	11.8	59	4.1					98	17.5			49	0.9	49	3.1	49	3.2	49	7.4	49	8.5	49	3.1	49	4.7
Ireland	49	5.5	49	3.9	49	1.3	49	1.5	88	3.5	99	-15.9	49	-1.0	49	1.1	49	1.2	49	5.5	49	6.5	49	1.1	49	2.7
Israel	49	20.9	50	6.0	84	5.8	93	5.1	92	4.4	92	7.5	49	1.6	49	3.8	49	3.9	49	8.1	49	9.2	49	3.7	49	5.4
Italy	49	5.7	49	3.2	49	1.6	49	2.7	49	3.5	72	5.6	49	-0.7	49	1.4	49	1.6	49	5.8	49	6.9	49	1.4	49	3.0
Japan	49	3.3	49	5.0	49	1.2	49	3.1	49	7.1	72	1.9	49	-2.0	49	0.1	49	0.2	49	4.5	49	5.5	49	0.1	49	1.7
Korea, Republic Of	49	13.9	53	6.2	50	-1.8	56	12.6	62	10.7	88	16.9	49	1.4	49	3.6	49	3.7	49	7.9	49	9.0	49	3.6	49	5.2
Malaysia	49	2.7	55	6.0	59	1.5	60	3.8	72	5.1	86	4.6	49	0.9	49	3.1	49	3.2	49	7.4	49	8.5	49	3.1	49	4.7
Mexico	49	16.1	49	4.6	61	2.5	94	8.5	87	14.6	91	11.0	49	-0.6	49	1.6	49	1.7	49	5.9	49	7.0	49	1.6	49	3.2
Morocco	49	4.5	52	3.8			93	6.1	94	10.3	4	12.9	49	0.6	49	2.7	49	2.8	49	7.1	49	8.1	49	2.7	49	4.3
Netherlands	49	3.6	49	3.2	49	0.7	49	2.5	50	6.9	94	3.7	49	-1.3	49	0.9	49	1.0	49	5.2	49	6.3	49	0.8	49	2.5
New Zealand	49	5.7	49	3.1	49	2.2	49	1.4	86	0.7	91	7.7	49	-3.0	49	-0.9	49	-0.8	49	3.5	49	4.5	49	-0.9	49	0.7
Norway	49	4.8	49	3.4	49	1.0	49	1.3	69	5.8	99	-4.3	49	-1.5	49	0.7	49	0.8	49	5.0	49	6.1	49	0.7	49	2.3
Pakistan	49	6.9	53	4.3	49	0.2	49	-0.4	87	6.3	92	-2.4	49	2.1	49	4.2	49	4.3	49	8.6	49	9.6	49	4.2	49	5.8
Peru	49	36.8	49	3.9			93	7.6	92	16.5	94	-3.8	49	-2.0	49	0.2	49	0.3	49	4.5	49	5.6	49	0.1	49	1.8
Philippines	49	7.4	49	4.3	49	2.0	96	10.9	81	7.2	87	10.5	49	1.3	49	3.4	49	3.6	49	7.8	49	8.9	49	3.4	49	5.0
Poland	49	15.3	80	2.4	82	-1.7	99	6.9	91	10.5	98	-2.0	49	2.9	49	5.1	49	5.2	49	9.4	49	10.5	49	5.0	49	6.7
Portugal	49	7.3	53	2.8	49	-0.4	75	2.2	88	1.9	95	8.1	49	-1.0	49	1.2	49	1.3	49	5.5	49	6.6	49	1.2	49	2.8
Russian Federation	92	37.6	95	4.0	92	-23.6	93	-16.1	94	-5.3	98	7.1	92	-11.3	92	-5.7	92	-9.4	92	-6.3	92	-4.1	92	-10.2	92	-7.2
Saudi Arabia	71	3.8	71	3.7	91	2.4			85	7.5	2	3.4	71	0.3	71	4.9	71	3.2	71	5.2	71	8.8	71	2.2	71	4.5
Singapore	49	2.5	57	7.1	59	1.1	87	2.0	69	6.4	93	1.2	49	-0.3	49	1.9	49	2.0	49	6.2	49	7.3	49	1.9	49	3.5
South Africa	49	7.3	49	3.3	49	0.7	49	1.5	60	7.8	96	18.9	49	0.0	49	2.1	49	2.3	49	6.5	49	7.6	49	2.1	49	3.7
Spain	49	6.8	49	3.9	49	0.3	49	0.9	49	5.1	87	10.7	49	-0.5	49	1.6	49	1.8	49	6.0	49	7.1	49	1.6	49	3.2
Sweden	49	4.7	49	2.5	49	1.3	49	1.8	49	8.4	88	6.4	49	-0.6	49	1.5	49	1.6	49	5.9	49	6.9	49	1.5	49	3.1
Switzerland	49	2.5	49	2.6	49	0.4	49	1.7	66	5.3	74	5.4	49	-1.3	49	0.8	49	0.9	49	5.2	49	6.2	49	0.8	49	2.4
Taiwan	49	6.3	49	7.5	61	1.2	94	5.5	87	6.4	91	-6.9	49	0.2	49	2.4	49	2.5	49	6.7	49	7.8	49	2.4	49	4.0
Thailand	49	4.3	49	5.8	49	2.5	79	7.3	75	7.9	90	9.7	49	-0.2	49	1.9	49	2.0	49	6.3	49	7.3	49	1.9	49	3.5
Turkey	49	25.3	50	4.1	72	2.5	95	-25.5	86	10.5	93	-1.4	49	0.0	49	2.2	49	2.3	49	6.5	49	7.6	49	2.1	49	3.8
United Kingdom	49	5.2	49	2.3	49	1.5	49	2.5	49	6.6	81	10.5	49	-0.5	49	1.6	49	1.7	49	6.0	49	7.0	49	1.6	49	3.2
United States	49	3.7	49	3.2	49	1.0	49	2.2	49	6.8	73	6.1	49	0.0	49	2.2	49	2.3	49	6.5	49	7.6	49	2.1	49	3.8
Venezuela	49	14.5	49	3.9	49	-2.6	83	-3.8	87	0.0			49	0.0	49	2.2	49	2.3	49	6.5	49	7.6	49	2.2	49	3.8

Abbreviations: SY Start year 19xx, μ logarithmic annual real returns, Infra. Infrastructure, Commod. Commodities, P25 25 percentile.

Table 5.17: Correlation matrix

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
All observations															
ΔCPI	(1)	1.00													
Δ(ΔCPI)	(2)	0.00	1.00												
ΔGDP	(3)	0.00	-0.08	1.00											
Bills	(4)	0.01	-0.32	-0.04	1.00										
Bonds	(5)	-0.47	-0.14	-0.05	0.22	1.00									
Equity	(6)	-0.07	-0.03	-0.05	0.05	0.15	1.00								
Infra.	(7)	-0.04	-0.03	0.02	0.09	0.19	0.76	1.00							
USD_{PPP}	(8)	0.03	0.08	-0.11	0.09	-0.10	-0.06	-0.10	1.00						
Gold	(9)	0.00	0.13	-0.07	-0.21	-0.20	0.00	-0.06	0.37	1.00					
Commod.	(10)	0.03	0.08	0.00	-0.07	-0.19	0.29	0.10	0.54	0.43	1.00				
DM	(11)	-0.04	-0.03	-0.11	0.14	0.00	0.60	0.47	0.41	0.07	0.51	1.00			
EM	(12)	-0.07	0.02	-0.06	-0.01	-0.11	0.63	0.48	0.22	0.29	0.57	0.71	1.00		
Bil. I.	(13)	0.00	0.08	-0.13	0.13	-0.06	-0.08	-0.09	0.98	0.36	0.47	0.42	0.19	1.00	
Bnd. I.	(14)	0.00	0.06	-0.13	0.15	-0.01	-0.09	-0.09	0.97	0.32	0.43	0.40	0.15	0.99	1.00
Observations excluding inflation outliers															
ΔCPI	(1)	1.00													
Δ(ΔCPI)	(2)	-0.09	1.00												
ΔGDP	(3)	0.15	-0.02	1.00											
Bills	(4)	-0.14	-0.37	-0.04	1.00										
Bonds	(5)	-0.27	-0.08	-0.10	0.35	1.00									
Equity	(6)	-0.16	-0.04	-0.02	0.08	0.17	1.00								
Infra.	(7)	-0.12	-0.04	0.04	0.12	0.21	0.74	1.00							
USD_{PPP}	(8)	-0.02	0.04	-0.04	0.08	-0.05	-0.07	-0.10	1.00						
Gold	(9)	0.01	0.09	-0.01	-0.25	-0.20	0.01	-0.05	0.33	1.00					
Commod.	(10)	0.01	0.04	0.06	-0.08	-0.18	0.30	0.11	0.52	0.41	1.00				
DM	(11)	-0.12	-0.06	-0.07	0.16	0.02	0.60	0.48	0.41	0.06	0.51	1.00			
EM	(12)	-0.10	0.00	-0.02	0.00	-0.14	0.63	0.48	0.21	0.28	0.57	0.71	1.00		
Bil. I.	(13)	-0.07	0.03	-0.05	0.12	0.00	-0.10	-0.10	0.98	0.31	0.44	0.41	0.18	1.00	
Bnd. I.	(14)	-0.08	0.01	-0.06	0.14	0.06	-0.11	-0.10	0.96	0.27	0.40	0.40	0.13	0.99	1.00

Notes: Pearson pairwise correlation coefficients based on logarithmic annual real returns. Inflation outliers are the 10% most extreme inflation observations, namely below -5% and above 21%.
Abbreviations: Infra. Infrastructure, Commod. Commodities.

would expect similar inflation hedging dynamics within the international assets and different ones against and within domestic assets with the notable exception of equities and infrastructure.

The correlation coefficients with inflation provide a first glimpse on the inflation hedging characteristics. When including all inflation observations, all real asset returns besides bonds exhibit low correlation with coefficients between -0.07 and 0.03. This indicates favorable inflation hedging as real returns do not decrease (significantly) with higher inflation. The result is more mixed when excluding the 10% most extreme inflation observations and only looking at inflation between -5% and 21% per year. The domestic assets' coefficients range below -0.12 which indicates a decline in real returns at higher inflation. All international assets, especially commodities and gold perform superior to the domestic assets.

Chapter 6

Inflation hedging and the linearity assumption

Conventional wisdom expects equities to behave like real assets that hedge inflation, and bills or bonds to behave like monetary assets that suffer during inflation. Inflation hedging research unearthed the opposite, as presented in Chapter 3. Equities were a perverse hedge while bills hedged inflation effectively. I argue that this is due to narrow framing and focus on low inflation rates. This chapter researches this based on a very broad dataset covering 50 countries, from Argentina to Venezuela, across 60 years, from 1949 to 2010. The panel covers notorious low inflation countries such as Switzerland or Germany as well as many incidents of hyper inflation across Latin America and Asia. The analysis distills the impact of inflation and income level to find out, if equities are a superior hedge and the monetary assets an inferior hedge at high inflation. It also covers several other asset classes to provide a broad basis for further discussions. The chapter closely follows my joint working paper "About the (Non-)Linearity in Inflation Hedging' with Professor Kaserer [Kaserer and Rödel, 2011]. I describe the motivation of the paper before introducing the methodology. The empirical results are then presented by inflation level and income level before discussing the implications and limitations of this research. A summary follows at the end of the chapter.

6.1 Motivation

Historic evidence and common sense prescribe real assets, including equities, and international diversification as treatment against inflation fears. Their real value shall move independently of monetary indexation. Fergusson [2010] highlights this splendidly in his account on the Austrian and German hyperinflation in the early 1920s based on contemporary witnesses: "‘Speculation on the stock exchange has spread to all ranks of the population and shares rise like air balloons to limitless heights’ (P. 25). “I hardly know a single German of either sex who is not speculating in the foreign currencies’ (P. 47). Academic literature has unearthed almost the opposite. For example, most papers from the first run on inflation in the 1970s until today report equities to be a perverse hedge: Their real returns tend to decrease with higher inflation. They only seem to hedge inflation in the very long-run.

This chapter investigates if the gap between academic research and common sense arises from a narrow view on the data. It analysis a broad panel that includes low and high inflation levels, rising and declining inflation rates, experience from advanced and emerging economies. Most importantly, it separates the analysis of high and low inflation levels which was, to the best of my knowledge, not in focus of existing research.

6.2 Methodology

This chapter focuses primarily on equities and international assets. In contrast to fixed income, their cash flows are defined ex-post, especially when looking at long horizons, triggering a shift from expected to realized returns and inflation.[1] The ex-post Fisher equation, which has been described in more detail in section 3.2.1, is:

$$r_n = \alpha + \beta\pi + \epsilon.$$

[1] This shift reliefs me from artificially reconstructing long-term consensus inflation expectations which certainly would be a challenge in such a broad and long panel. The approach is common in the literature, see for example Boudoukh and Richardson [1993] or Engsted and Tanggaard [2002].

An asset with $\beta = 1$ is considered a perfect hedge against inflation. The equation illustrates the concept of ''local consumer & global investor': The investor essentially wants to hedge his local purchasing power with whatever asset he can invest in, domestic and international alike. This concept is applied across all 50 countries in the sample. Although an imperfect but stable relation would already suffice to create a synthetic hedge (see Schotman and Schweitzer [2000]), transaction costs and the potential necessity of short-selling limit the use of synthetic hedges in practice, especially for retail investors.

Testing this relationship requires to answer several key questions. The first one is about a suitable investment horizon. Most existing research focuses on monthly, quarterly, or annual computation periods. I will focus on horizons beyond one year, mostly five years, to understand the long-term investment implications and avoid short-term distortions in the data. Commodity prices exemplify this: Do higher commodity prices cause inflation or are they caused by inflation? How do higher commodity prices move along the value chain and when do they translate into higher producer and consumer prices? What additional delays are caused through measurement and reporting? When are changes in inflation reflected in the prices of other assets, i.e. how sticky are investor expectations and how quickly do they trade? Short-horizon return data seems likely to be distorted by all of these effects. Long-term, overlapping observations increase the persistence in the time series, especially for inflation. While appearing non-stationary in the most common tests, corrections for regime shifts or the use of covariates support stationarity or at least only indicate fractional integration of inflation.[2] I also find this pattern in my data. Accounting for fractional integration is difficult in the panel setting, so I have to accept a potential bias towards zero in the coefficients. The long overlap creates severe auto-correlation for which standard corrections like Newey-West prove insufficient. Britten-Jones *et al.* [2011] propose a matrix transformation for the regressors to improve the statistical properties of the estimated coefficients. I extend their transformation to a panel setting. Therefore I rewrite the ex-post Fisher equation in its vector form with the time dimension t and introduce a $(T-k)+1 \times T$ matrix A_k with entries $a_{i,j} = 1 \; if \; i \leq j \leq i+k-1$ and 0 to compute the overlapping long-term data. Afterwards, I summarize the regressors in a $(T-k)+1 \times l$ matrix $X_{k,c}$ with the first C columns

[2] Romeroavila and Usabiaga [2009] provide a more recent overview and a battery of tests for 13 OECD countries.

consisting of 1 in case of country c and 0 otherwise, and the coefficients in the $l \times 1$ vector $\vec{b_k}$:

$$A_k \vec{r_{n,c}} = \sum_{c=1}^{C} (\alpha_c \vec{1}) + \beta A_k \vec{\pi_c} + \vec{\epsilon_c} = X_{k,c} \vec{b_k} + \vec{\epsilon_c} \tag{6.1}$$

with k denoting the overlap in years. Britten-Jones *et al.* [2011] show that the coefficient vector $\vec{b_k}$ should be estimated from the transformed, non-overlapping equation

$$\begin{aligned} \vec{r_{n,c}} &= \hat{X}_{k,c} \vec{b_k} + \vec{\epsilon_c} \; with \\ \hat{X}_{k,c} &= A'_k X_{k,c} (X'_{k,c} A_k A'_k X_{k,c})^{-1} X'_{k,c} X_{k,c}, \\ c &= 1, ..., C \end{aligned} \tag{6.2}$$

to properly account for auto-correlation in the standard errors.

The second question is about control variables. Triggered by Fama and Schwert [1977], the equity risk premium hypothesis identifies inflation uncertainty or change in expected inflation as one relevant factor for valuation changes. I proxy expected inflation with last period's inflation which is efficient according to Ang *et al.* [2007]. Inspired by the proxy hypothesis, I introduce economic growth to account for the heterogeneous growth patterns in my panel. Country dummies account for systematic institutional or political influence on returns. Finally, the inflation hedging properties depend on the investment horizon which is nicely visualized in recent vector auto regressions, e.g. Amenc *et al.* [2009]. The idea has already been recognized by Bodie [1976] who simply compares different computation horizons. Similarly I will test the robustness of my results for different investment horizons rather than including it dynamically in the regression.

The third question is about the data. The panel aims to maximize inflation heterogeneity and spans across 50 countries and 61 years. The asset menu includes domestic bills, bonds, equities as well as international bonds and equities, US dollar cash, a broad commodity index, and gold. The macro-economic and total return data reveal considerable heteroscedasticity, auto- and cross-correlation for which I account with spatial correlation-consistent standard errors (SCC-SE) according to Driscoll and Kraay [1998]. More details on this in Chapter 5.

In summary, Equation (6.2) extends in its nominal form to

$$\vec{r_{n,c}} = \hat{X_{k,c}} \vec{b_k} + \vec{\epsilon_c}$$

and in its real form to

$$\vec{r_{r,c}} = \vec{r_{n,c}} - \vec{\pi_c} = \hat{X}_{k,c} \vec{b_{r,k}} + \vec{\epsilon_c}. \tag{6.3}$$

The columns of matrix $\hat{X}_{k,c}$ contain vectors for the country dummies, the inflation rates π, change in expected inflation $\Delta\pi$, and economic growth ΔGDP. $\vec{b_k}$ is estimated for each asset and various computation horizons k. I typically regress on real returns which alters the null hypothesis to being a perfect inflation hedge or $\beta_r = 0$ (equal to $\beta_n = 1$) without affecting the other parameter estimates.

The model results will be tested for robustness against methodology (no transformation), potential misspecification (excluding ΔGDP and Δinflation), data subsamples (shorter time period, high or low income countries), and a potential break-point with the fall of Bretton Woods in 1970.

6.3 Empirical results

Table 6.1 shows the main results from the panel regression of real asset returns on inflation, change in expected inflation, and real economic growth calculated on rolling returns and an investment horizon of five years. Bills and bonds clearly fail to protect against inflation indicated by their negative coefficients. They perform even worse during rising inflation expectations. In contrast, all real and international assets hedge inflation well. Their inflation coefficients are either statistically insignificant or very close to zero. International assets further benefit from rising inflation. The hedging properties are fairly consistent for one- to 20-year horizons. These results are surprising given the findings of earlier research which were horizon dependent and largely negative, especially for equities.

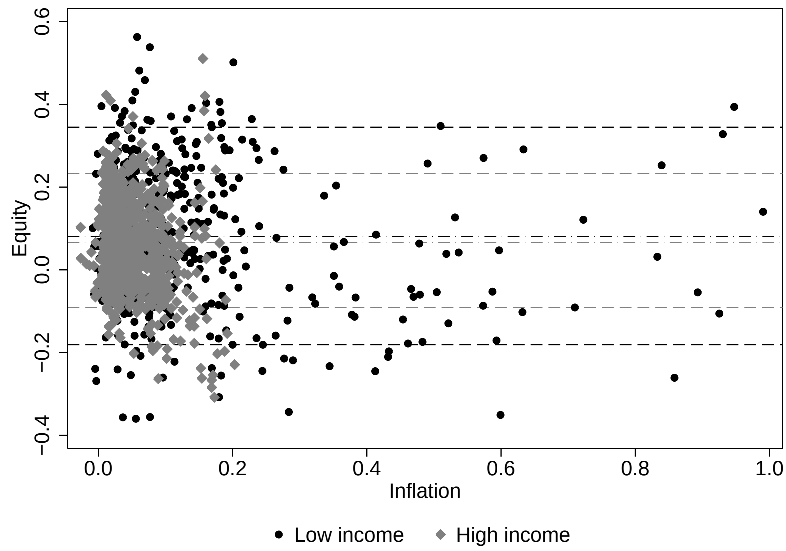
A scatter chart of real equity returns and inflation visualizes the underlying dynamic (Figure 6.1). Existing research focuses on high income countries which cover an inflation range between -3% to 21% and real equity returns between -31% to 51%. Low income countries add considerable variation to inflation (-2%

Table 6.1: Regression of real returns on inflation, change in inflation expectations, and real economic growth

	Domestic assets			International assets						
	Bills	Bonds	Equ.	Com.	Gold	DM	EM	Bil.I.	Bon.I.	USD
Inflation	-0.29***	-0.80***	0.01	-0.05	-0.09	-0.06	-0.01	-0.05	-0.05	-0.09**
p-val.	0.00	0.00	0.88	0.28	0.16	0.35	0.80	0.25	0.31	0.03
ΔInfl.	-0.49***	-0.34	-0.26	0.32***	0.41***	0.17	0.24*	0.23***	0.19**	0.20**
p-val.	0.00	0.32	0.12	0.01	0.01	0.13	0.09	0.01	0.04	0.03
ΔGDP	-0.14	-0.56**	1.13**	-0.17	-0.13	-0.51	-0.33	-0.41**	-0.62**	-0.48*
p-val.	0.35	0.02	0.04	0.45	0.72	0.27	0.44	0.04	0.02	0.06
N	2,219	1,749	1,825	2,787	2,787	2,787	2,787	2,787	2,787	2,787
R^2	0.17	0.13	0.01	0.03	0.03	0.01	0.01	0.03	0.02	0.02

This table provides an overview of the hedging characteristics across the ten assets covered. Across all countries and years covered, the real and international assets hedge inflation fairly well shown by the close to zero or statistically insignificant coefficients.
Note: Regression $\vec{r_{r,c}} = \hat{X}_{k,c}\vec{b_{r,k}} + \vec{\epsilon_c}$ with $\vec{b_{r,k}}'$ = (Country Dummies, Inflation, ΔInflation, ΔGDP) at the five-year horizon k and SCC-SE. *, **, *** for 10%, 5%, 1% significance.
Abbreviations: Equ.: Domestic equities; Com.: Commodities; DM: Developed markets equity; EM: Emerging markets equity; Bil.I.: Bills International; Bon.I.: Bonds International; USD: US dollar.
Compare to Kaserer and Rödel [2011].

Figure 6.1: Real five year equity returns over inflation by income level



Existing research focused on high income countries. Including the high inflation experience of low income countries extends this relatively narrow and tall column to a broad window - this naturally drives the good hedging results of equities.
Note: The dashed dotted and dashed lines show the mean and 5/95 percentiles respectively for high income countries (in gray) and low income countries (in black). More extreme values for inflation up to 267% for low income countries not shown in this graph. The upper end of inflation is driven by observations in Latin America and Eastern Europe.
Source: Kaserer and Rödel [2011].

to 267%) but only comparatively little and balanced variation to equity returns (-42% to 56%). Thus, any linear regression across all observations will yield coefficients close to zero as long as the Fisher hypothesis proves approximately true.

Fisher's proposed linear inflation hedging might be an oversimplification for the broad dataset. A stable monetary regime with low and predictable inflation should support corporate profitability and in turn lead to high real returns. As soon as inflation becomes substantial, businesses suffer from distorted planning and face asynchronous, sudden cost and price movements. This should impact corporate profitability and decrease the return to equity.[3] In cases of even higher

[3] See Mankiw [2001] for a general introduction on the costs of inflation.

Table 6.2: Regression results for real equity returns by subclusters

	Total	Inf$^+$	Inf^o	Inf$^-$	Inc$^-$	Inc$^+$	Inc$^-$, Inf^H
Inflation	0.01	0.06	-0.82	-1.30	0.04	-0.78	-0.24
p-val.	0.88	0.46	0.34	0.24	0.58	0.20	0.58
ΔInflation	-0.26	-0.26*	-0.42	-0.46	-0.20	-2.85**	-0.06
p-val.	0.12	0.09	0.20	0.73	0.22	0.02	0.87
ΔGDP	1.13**	0.92	0.08	2.20***	1.86**	1.14	2.09***
p-val.	0.04	0.48	0.92	0.00	0.02	0.11	0.01
N	1,625	296	401	928	583	1,042	489
R^2	0.01	0.04	0.07	0.03	0.02	0.04	0.03
Return	0.07	0.04	0.05	0.08	0.07	0.06	0.09
$\sqrt{VIF}$	2.25	2.49	4.07	2.92	2.32	2.29	2.38

The inflation coefficients differ between high and low inflation periods clearly opposing the linear relationship that dominates existing research. Moreover, low income countries prove more robust on inflation than high income countries do.
Note: Regression $\vec{r_{r,c}} = \hat{X}_{k,c}\vec{b_{r,k}} + \vec{\epsilon_c}$ with $\vec{b_{r,k}}'$ = (Country Dummies, Inflation, ΔInflation, ΔGDP) at the five-year horizon k and SCC-SE. *, **, *** for 10%, 5%, 1% significance.
Abbreviations: Inc$^{+(-)}$: High (low) income; Inf$^{+(o,-)}$: High (mid, low) inflation; Inf^H: Inflation range of high income countries; Return: Median asset return; $\sqrt{VIF}$: Square root of maximum variance inflation factor of the independent variables.
Source: Kaserer and Rödel [2011].

inflation, established counter mechanisms like cost/ price indexing together with a decreasing attractiveness of the monetary assets prevent from a further loss in real returns. Subdividing the regression by inflation level helps to detect such a pattern and should yield negative hedging when inflation is low and positive hedging when it is high, the latter at lower real returns. I cluster the observations by inflation levels of less than 5%, 5% to 10%, and greater than 10% with bucket sizes of approximately 2:1:1, varying with data availability.

Table 6.2 shows the detailed results for real equity returns. Equity indeed provides a strong hedge against serious inflation (Inf^+). When looking at nominal returns, inflation alone explains 40% of the return deviation, although, this is likely to be upward biased by the weakly non-stationary returns. When inflation levels are lower, the hedging quality diminishes as shown in Inf^o and Inf^- with inflation coefficients of around -1, yet not statistically significant on the five-year horizon. In other words, nominal returns move independent of inflation, economic growth becomes a more significant factor. At the same time, a stable monetary environment seems to support higher real rates on average of 8%, twice as much as during high inflations and 60% more than during medium inflation.

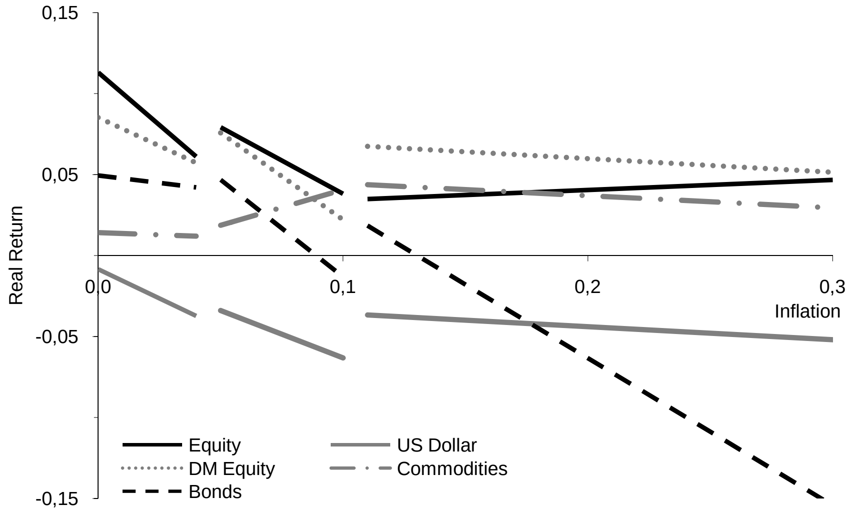
Overall, inflation hedging of equities appears strongly nonlinear. The average real returns are highest at low inflation. It decreases quickly as equities fail to hedge low inflation and only stabilizes beyond an inflation rate of around 10%. Then equities hedge inflation effectively. This pattern is visualized in Figure 6.2. I have amongst others tested a logarithmic functional form for equities which significantly increases the R^2. However, I refrain from specifying a formal relationship for any of the assets before having a more thorough theoretical foundation.

Commodities are the only asset with a positive slope on inflation (Figure 6.2). While the return during low inflations stays at a meager 1%, it increases to 4% during more substantial inflations. Moreover, the coefficients on Δinflation are positive throughout. This is even more pronounced for low inflation environments at the one-year horizon which confirms the good short-run hedging capability mentioned in earlier research (details in Table 6.3).

In contrast to the broad commodity index, gold fails to provide an inflation hedge in the low inflation cluster. But, it provides the strongest hedge against an increase in inflation amongst the assets analyzed. An 1% increase in Δinflation goes along c.p. with an additional 2.5% real return in high income countries (see appendix Table 6.4 for details). A regression including US-inflation indicates that gold is not only a bet for increasing local inflation but even more for US-inflation: both coefficients swing around two.

In summary, the hedging duality observed in domestic equity repeats itself in US dollar cash. It originates from the cross-correlation of domestic inflation rates and essentially shapes the behavior of international bills, bonds, and developed markets equity. Only emerging markets equity and commodities stick out as overall hedge against the level of inflation in both, high and low inflation environments. Gold performs especially strong in phases of increasing inflation, however, it is a bet on US inflation and suffers from artificial distortions giving it little time stability.

Figure 6.2: Inflation hedging pattern by asset at the five-year horizon



This chart visualizes the expected returns of the detailed regressions by inflation level (Inf^{+}, Inf^{o}, and Inf^{-}). Most importantly it highlights the L-shaped inflation hedging of equities with a steep negative return relation on the left and effective inflation hedging to the right. The pattern for US Dollars is similar in shape but flattened out and with negative real returns. Only commodities develop positively in the mid inflation window. Bonds lose value as soon as inflation becomes substantial. Most assets exhibit clear nonlinearities in inflation hedging.
Note: All figures logarithmic, p.a.
Source: Kaserer and Rödel [2011].

Table 6.3: Regression results for real commodity returns

	Total	Inf^{+}	Inf^{o}	Inf^{-}	Inc^{-}	Inc^{+}	Inc^{-}, Inf^{H}
Inflation	-0.05	-0.08*	0.44	-0.06	-0.06	0.26	0.12
p-val.	0.28	0.10	0.21	0.87	0.23	0.32	0.37
ΔInflation	0.32***	0.32***	0.37	0.60	0.31**	1.12**	0.38**
p-val.	0.01	0.01	0.12	0.18	0.01	0.03	0.02
ΔGDP	-0.17	-0.29	-0.31	-0.17	-0.21	-0.17	-0.15
p-val.	0.45	0.32	0.45	0.55	0.43	0.53	0.65
N	2,587	664	634	1,289	1,263	1,308	1,043
R^2	0.03	0.04	0.03	0.02	0.03	0.04	0.03
Return	0.01	0.03	0.03	0.01	0.02	0.01	0.02
$\sqrt{VIF}$	2.02	1.85	3.91	2.93	1.96	2.16	2.05

Note: Regression $\vec{r_{r,c}} = \hat{X}_{k,c}\vec{b_{r,k}} + \vec{\epsilon_c}$ with $\vec{b_{r,k}}'$ = (Country Dummies, Inflation, ΔInflation, ΔGDP) at the five-year horizon k and SCC-SE. *, **, *** for 10%, 5%, 1% significance. Inc^{+} excludes inflation with high leverage: Israel between 1974-1985 with inflation up to 100%.
Abbreviations: $\text{Inc}^{+(-)}$: High (low) income; $\text{Inf}^{+(o,-)}$: High (mid, low) inflation; Inf^{H}: Inflation range of high income countries; $\sqrt{VIF}$: Square root of maximum variance inflation factor of the independent variables.
Source: Kaserer and Rödel [2011].

Table 6.4: Regression results for real gold returns

	Total	Inf^{+}	Inf^{o}	Inf^{-}	Inc^{-}	Inc^{+}	Inc^{-}, Inf^{H}
Inflation	-0.09	-0.09	0.99	-0.64	-0.09	0.42	0.07
p-val.	0.16	0.11	0.16	0.26	0.13	0.49	0.80
ΔInflation	0.41***	0.39***	0.82**	1.56***	0.38***	2.53***	0.70***
p-val.	0.01	0.01	0.03	0.01	0.01	0.00	0.00
ΔGDP	-0.13	0.36	0.24	-0.92***	0.07	-0.64	0.06
p-val.	0.72	0.39	0.69	0.01	0.86	0.19	0.88
N	2,587	664	634	1,289	1,263	1,308	1,043
R^2	0.03	0.05	0.07	0.09	0.03	0.09	0.03
Return	0.00	0.02	0.02	-0.01	0.01	-0.01	0.02

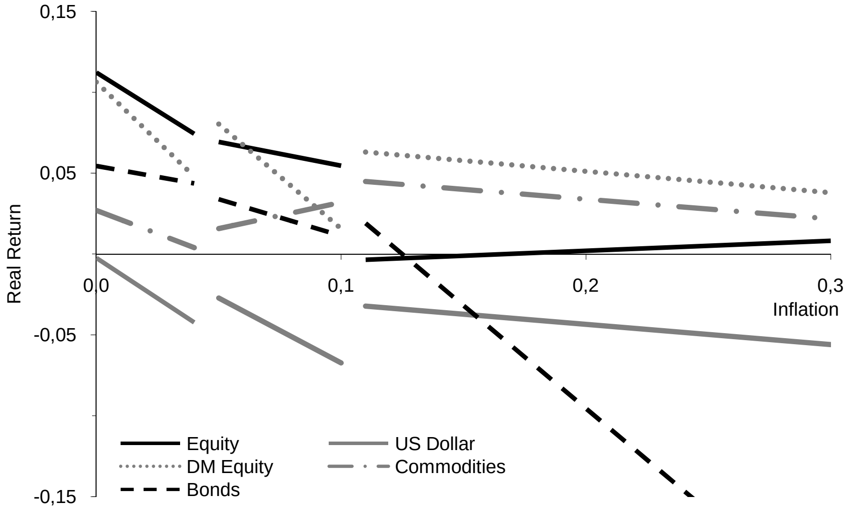
Note: Regression $\vec{r_{r,c}} = \hat{X}_{k,c}\vec{b_{r,k}} + \vec{\epsilon_c}$ with $\vec{b_{r,k}}' =$ (Country Dummies, Inflation, ΔInflation, ΔGDP) at the five-year horizon k and SCC-SE. *, **, *** for 10%, 5%, 1% significance. Inc^{+} excludes inflation with high leverage: Israel between 1974-1985 with annual inflation of up to 100%. VIF as in table 6.3.
Abbreviations: $Inc^{+(-)}$: High (low) income; $Inf^{+(o,-)}$: High (mid, low) inflation; Inf^{H}: Inflation range of high income countries.
Source: Kaserer and Rödel [2011].

The core result, a nonlinearity in inflation hedging, proves robust on the methodology, potential variable misspecification, and various subsamples. Removing the matrix transformation increases the statistical significance of the nonlinearity beyond the 5% and 1% significance level for equities and international assets respectively. Switching to shorter horizons increases the curvature in inflation hedging which further pronounces the nonlinearity and can be seen in Figure 6.3). Commodities, however, fail to protect against inflation below the two-year horizon. Omitting country fixed effects smoothes the curvatures and flattens it slightly for domestic equities which is shown in Figure 6.4.

While the impact of US-inflation has been discussed already, I also tested the regression for over-specification, i.e. without change in expected inflation and economic growth. Again, the nonlinearity remains and the curvature looks almost identical (see Figure 6.5).

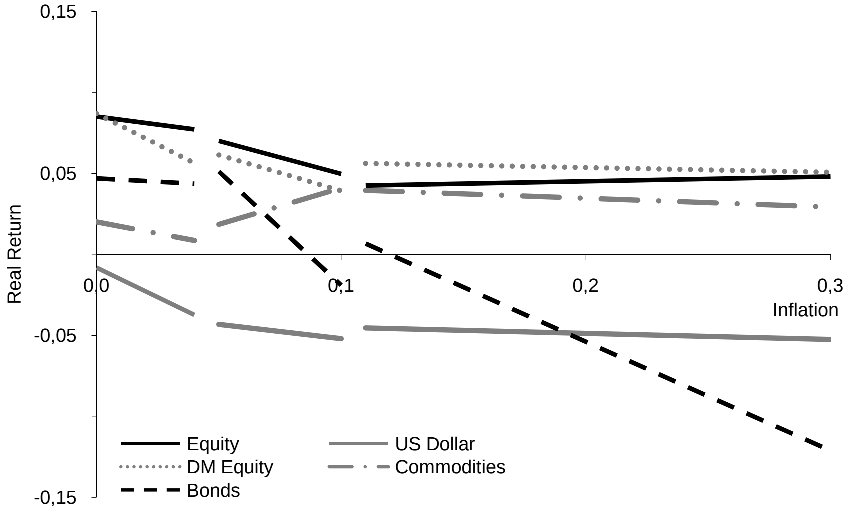
The subsamples by income are included in the respective detailed regression results and generally show a higher robustness of the low income countries against inflation. The duality remains in both subsamples. Additionally, I test time sta-

Figure 6.3: Inflation hedging pattern by asset at the two-year horizon



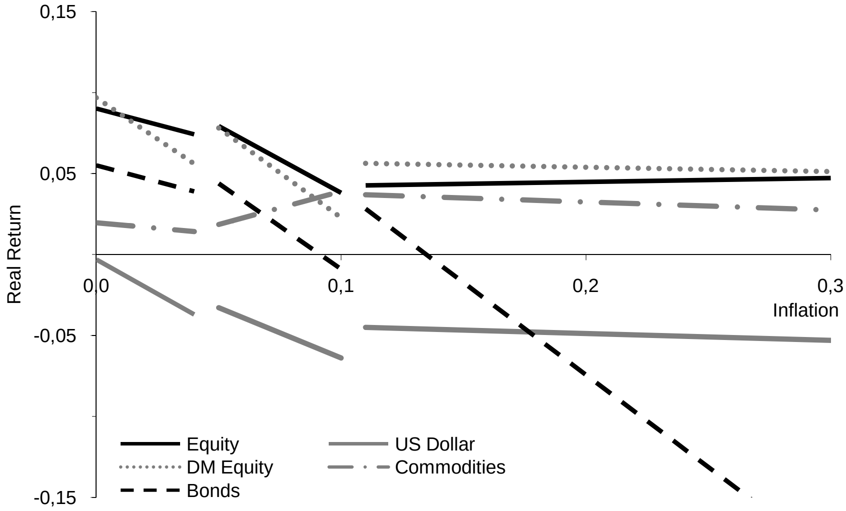
Note: All figures logarithmic, p.a.; obtained from detailed regressions Inf^{+}, Inf^{o}, and Inf^{-}.
Source: Kaserer and Rödel [2011].

Figure 6.4: Inflation hedging pattern by asset without country fixed effects



Note: All figures logarithmic, p.a.; obtained from detailed regressions Inf^{+}, Inf^{o}, and Inf^{-}.
Source: Kaserer and Rödel [2011].

Figure 6.5: Inflation hedging pattern by asset without ΔInflation and ΔGDP



Note: Five-year horizon; all figures logarithmic, p.a.; obtained from detailed regressions Inf^{+}, Inf^{o}, and Inf^{-}.
Source: Kaserer and Rödel [2011].

bility using a dummy regression for the Bretton Woods period until 1970 and the two 20-year periods of the subsequent flexible exchange rate regime. Data availability constraints the interpretation of the coefficients for equities and bonds. The results for five year investment horizons are shown in Table 6.5. The overall regression yields no statistical or conceptual significance on the dummies for inflation and Δinflation for the international assets. The introduction of flexible exchange rates did, by and large, not impact the inflation hedging characteristics. It only lead to a closer link between real economic power as measured by economic growth and currency strength.[4] The relatively high equity inflation dummy is rooted in a sample bias towards low inflation environments before 1970. Otherwise, equity results are fairly time stable. The results for monetary assets are not stable over time. They have performed weakly in the period up to 1970 which was characterized by increasing inflation and the subsequent period until 1990 which was dominated by relatively high and, in the second part, decreasing inflation levels. In contrast, bills have performed well in the relatively stable monetary conditions and pro-active monetary policy of the years 1990 to 2010. They have outperformed the other domestic assets in this environment when excluding the inflation observations with high leverage. The lower part of the table shows the results omitting high leverage observations, i.e. inflation outliers smaller than -3% or larger than 21%. These results confirm the nonlinearity for domestic assets and US dollars across subperiods. The results for gold are far from a "safe inflation hedge." During Bretton Woods, the value of gold was fixed in US dollars. This made gold an identical inflation hedge as US dollar cash holdings (almost identical results for the pre-1970 period). The decoupling in the early 1970s caused a sudden increase in the gold price which coincided with the increasing inflation environment across the globe. This is reflected in the positive coefficient on inflation and on Δinflation, especially. Gold finally diminished in value in the 1990s with its coefficients turning negative - overall, making it an instable hedge.

[4]As indicated by the positive coefficients of the Bretton Woods dummies which neutralize the impact of economic growth. The coefficient for the US dollar is -0.64 between 1970 and 1990, so stronger economic growth leads to a stronger currency and ultimately lower returns on international assets. Before 1970 the dummy is 0.63, i.e. the cumulative effect -0.01, and the impact of economic growth on international asset returns zero. The result is significant on the 1% level if omitting the matrix transformation.

Table 6.5: Time stability of regression coefficients for Bretton Woods (1970-1990) and flexible exchange rates (1990-2010)

Incl. Outlier	Bills	Bonds	Equity	Commod.	Gold	DM	EM	Bills Int.	Bonds Int.	US Dollar
Inflation	-0.38***	-1.02***	0.02	-0.03	-0.05	0.01	-0.01	0.00	0.01	-0.02
... D <=1970	-0.51***	0.44	-0.45	-0.02	-0.02	-0.10	-0.02***	-0.06	-0.06	-0.05
... D >1990	0.16	0.30*	-0.01	-0.06	-0.09*	-0.08	0.00	-0.06	-0.08	-0.08*
ΔInflation	-1.14***	-2.04***	-0.81***	0.52***	0.63**	0.00	0.33	0.23**	0.14	0.24**
... D <=1970	1.20***	1.62***	0.52	0.06	-0.12	0.39	0.10	0.27	0.44	0.26
... D >1990	0.94***	1.94***	0.67*	-0.34*	-0.38	0.16	-0.12***	-0.06	-0.01	-0.12
ΔGDP	-0.28**	-0.29	0.65	0.04	0.57	-1.26**	0.11	-0.56*	-0.76	-0.64
... D <=1970	0.68***	0.81**	0.78	0.12	-0.46	0.99*	-0.01***	0.55	0.85*	0.63
... D >1990	0.25	-0.22	0.89	-0.61*	-1.11**	0.61	-0.44	-0.23	-0.08	-0.25
N	2,047	1,577	1,625	2,587	2,587	2,587	2,587	2,587	2,587	2,587

Excl. Outlier	Bills	Bonds	Equity	Commod.	Gold	DM	EM	Bills Int.	Bonds Int.	US Dollar
Inflation	-0.52***	-0.96***	-0.83**	0.01	0.19	-0.43*	-0.43	-0.24*	-0.30*	-0.26*
... D <=1970	-0.19	0.41	-0.75	-0.02	-0.26	0.48	0.49	0.26	0.32	0.23
... D >1990	0.45***	0.79***	0.48	-0.09	-0.71*	0.48	0.76	0.27	0.32*	0.08
ΔInflation	-0.74***	-2.01***	-3.47***	1.09**	2.14**	-1.70***	0.35	-0.36**	-0.89**	-0.40
... D <=1970	0.80***	1.59***	2.46*	-1.02*	-2.25**	1.07	-0.55	0.21	0.90**	0.23
... D >1990	0.60***	1.53***	3.42***	-0.83	-1.63*	1.68**	0.25	0.60**	1.04***	0.54
ΔGDP	-0.33***	-0.28	1.34	0.08	0.48	-1.05**	0.14	-0.45	-0.63	-0.50
... D <=1970	0.71***	0.76**	0.42	0.06	-0.44	0.82*	-0.03***	0.43	0.72*	0.47
... D >1990	0.09	-0.35	0.34	-0.80**	-1.20***	0.22	-0.59	-0.51	-0.41	-0.54
N	1,944	1,553	1,531	2,351	2,351	2,351	2,351	2,351	2,351	2,351

Note: "Excluding outliers" covers the observations with the inflation range observed in high income countries excluding Israel, i.e. of annually -3% to +21%. Multi-year observations are included in the subset in which at least 66% of its years fall into. Base period extends from 1970 till 1990. Regression $\vec{r_{r,c}} = \hat{X}_{k,c}\vec{b_{r,k}} + \vec{\epsilon_c}$ with $\vec{b_{r,k}}'$ = (Country Dummies, Inflation, ΔInflation, ΔGDP) at the five-year horizon k and SCC-SE. *, **, *** for 10%, 5%, 1% significance.
Abbreviations: DM: DM Equity; EM: EM Equity; Commod.: Commodities.
Compare to Kaserer and Rödel [2011].

6.4 Discussion

The robustness tests show the stability behind the inflation hedging nonlinearity with equities turning positive and fixed income turning negative at high inflation. This section highlights the implications of this finding, its contribution to the literature, and discusses their limitations.

6.4.1 Implications

The empirical results form the foundation for conditional asset class choice. The nonlinearity implies that an asset's risk return profile depends on inflation. For example, if the investor expects low or medium inflation levels, the fixed income space offers relatively low risk investment opportunities although the average return clearly lags behind stocks. The additional return of stocks seems not to justify their additional risks at medium inflation levels around 10%. Only at high inflation, equities can play out their real asset characteristic and hedge the investor against inflation.

Exchange rates moderate inflation partially and, thus, international assets generally exhibit a more linear behavior. Especially the relatively idiosyncratic emerging market equities and commodities show little exposure to inflation levels. They provide the best inflation protection in case of an unstable inflation outlook.

6.4.2 Contributions to the literature

The broad view on inflation hedging bridges the gap between the previously conflicting evidence from academia and conventional wisdom. The conflict resolves by inflation level. Domestic assets behave somewhat counterintuitive during inflation of up to 10 to 20%. Bills and, to a lesser extend bonds, hedge fairly well against inflation. Real equity returns are significantly going down with higher inflation, just as Bodie proposed with his perverse hedge. But, the situation reverses for high inflation levels. Monetary assets loose significantly while equities start to play out their real asset characteristics. Their real returns stabilize and become independent of inflation, although at a slightly lower average level than during low inflation. The results also show that the superior hedging coefficients from emerging markets approach the level of advanced income countries after correcting for inflation level. A fact often overlooked in previous research.

Finally the results indicate the benefits of international diversification for inflation. They generally hedge inflation better than domestic assets over different horizons and inflation levels. This could be the starting point for further analysis on inflation hedging. Chapter 8 goes beyond this aggregated analysis for equities. It details the results by country and highlights several drivers behind it.

6.4.3 Limitations and directions for future research

The nonlinearity hypothesis holds against a battery of robustness tests. Nevertheless, the high volatility in stock returns complicates the statistical analysis, diminishes the coefficient of determination and limits stability tests to fairly broad sub-samples. At the same time, richer control variables, for example accounting for the inflation source, are difficult to obtain for such a broad panel. A potential coefficient bias arising from the fractional integration in inflation adds to the technical limitations. The interpretation of the inflation hedging coefficient, as in any inflation hedging research, should be interpreted directionally only.

On a conceptual level, the results aim to provide the basis for conditional asset class choice. The assets have been analyzed independent of each other. Cross-correlation and resulting benefits from portfolio diversification are not take into account at this stage yet.

Finally, the results once more challenge money neutrality and the Fisher relation. Inflation has real effects and a value transfer between creditors and debtors as well as companies and other segments of the economy takes place. A detailed analysis on the causes behind this nonlinearity is left for future research. I can only hypothesize at this stage: First, commodity prices move synchronous with inflation in general. At the same time, retail prices are fairly sticky and competitive pressure high across most industries. Higher commodity prices would squeeze producer margins at sticky prices and result in a value transfer between the industrialized countries and commodity exporting countries as well as between producers and consumers. Second, higher inflation rates and more dynamic producer prices complicate decision making. Suboptimal decisions and capital mis-allocation are the consequence. Both effects likely impact profits negatively beyond 5-10% of average annual inflation, which implies two-digit price moves in many sub-categories. Sustained rates beyond 10-20% might well lead to more flexible pricing: shorter cycles for retail price reviews, real-time online quotes, shorter duration, inflation indexed contracts along the value chain. While these counter measures are costly and will decrease the return level compared to a stable monetary environment, the costs will likely scale with higher inflation which should stabilize the returns. I would like to stress that the nonlinearity exists when controlling for inflation uncertainty. Thus, the economic explanation must go beyond the inflation uncertainty premium. I hope the nonlinearity finding inspires to search for a compelling, testable theory that can further advance this subject.

6.5 Summary

This section analyzed the long-term impact of inflation on returns to bills, bonds, equity, and several international assets across 50 countries and 61 years with spatial correlation-consistent standard errors and a matrix transformation to account for overlapping data. The main empirical finding indicates a nonlinearity in inflation hedging for most assets: Bills and bonds hedge low inflation well, but as expected, fail to protect against serious inflation. Equities and most international assets hedge serious inflation effectively in the short and long run. However, their real returns react negatively when inflation is low, especially at short horizons. Only commodities and emerging market equity hedge reliably and do not exhibit a duality. Assets in developing countries generally perform more robust against inflation than assets in developed ones. The observed nonlinearity bridges the conflict between existing empirical research, especially the perverse hedge of equities, and the common sense view of real and international assets to be an inflation hedge. Any future theory on inflation hedging should incorporate this empirical duality.

Chapter 7

Inflation hedging with infrastructure

Infrastructure enjoys a strong reputation amongst investors, a strong reputation for not only for producing stable cash flows that are backed by real assets, but also for being a strong hedge against inflation. This belief persists for years and has not yet been significantly challenged by academic research as infrastructure data is hard to come by with. My second hypothesis claims that infrastructure is a superior inflation hedge compared to equities. And this chapter is able to analyze this proposition based on a novel, proprietary dataset. The panel extends across almost 40 years and 50 countries and covers over 800 listed infrastructure companies. It analyses infrastructure as a whole, its subsectors telecommunications, transportation, and utilities, as well as subsegments with high and low pricing power. Lastly it includes international infrastructure to relate to earlier research who, due to a lack of data, repeatedly analyzed international rather than domestic infrastructure as inflation hedge.

The chapter closely follows my joint working paper "Infrastructure as Hedge against Inflation - Fact or Fantasy?" with Christoph Rothballer [Rödel and Rothballer, 2012]. I describe the motivation of the paper before introducing the methodology. The empirical results are then discussed by inflation level and income level before discussing the implications and limitations of this research. A summary follows at the end of the chapter.

7.1 Motivation

The financial crisis has once more put inflation hedging back on center stage. Institutional and private investors alike are adjusting their portfolio allocation to preserve purchasing power and seeking assets with inflation protection. Infrastructure has recently established itself as an alternative asset category which also promises to effectively hedge inflation while providing stable and relatively high returns. Therefore, the Canada Pension Plan, for example, commits USD 8 bn. for infrastructure within its bucket inflation sensitive investments. [1] The Californian pension fund CalPERS allocates 2.5bn USD in its real asset category that protects against inflation (Page *et al.* [2008]).

The investors justify the strong inflation hedging of infrastructure conceptually with its real asset characteristic, monopolistic market positions, favorable regulatory regimes, and relatively low operating costs (Inderst [2010]). The respective businesses are typically very asset intensive which shall tie their replacement value to the underlying basic goods or commodities. The monopolistic market power and favorable regimes limit the risk of price war and often even tie the price level to inflation. Moreover, the infrastructure services have relatively low price elasticity which safeguards the top-line against inflation. The share of operating costs is low which reduces the pressure from rising input prices.

However, this justification is largely conceptual and backed by very few empirical studies with varying quality. This chapter contributes to the literature by comparing the inflation hedging characteristics of listed infrastructure and equities as proposed by Amenc *et al.* [2009]. It is the first that combines a comprehensive dataset together with a robust methodology.

7.2 Methodology

The inflation hedging framework for infrastructure extends the previous section's methodology. It also regresses real returns r_r on realized inflation π, unexpected

[1] Canada Pension Plan's allocation correspond to 5.7% of assets under management (Canada Pension Plan Investment Board (2011) Infrastructure, $http://www.cppib.ca/Investments/Inflation_sensitive_Investments/infrastructure.html$, accessed Nov 20, 2011.)

inflation $\Delta\pi$, and real economic growth ΔGDP using the matrix transformation of Britten-Jones *et al.* [2011] to correct for overlapping data and correlation-consistent standard errors Driscoll and Kraay [1998] to account for the heteroscedasticity as well as the simultaneous and lagged cross-correlation in the data. The core regression equation for the annual horizon with C countries and T years

$$r_{r,c,t} = r_{n,c,t} - \pi_{c,t} = \alpha_c + \beta_r \pi_{c,t} + \gamma \Delta\pi_{c,t} + \delta \Delta GDP_{c,t} + \epsilon_{c,t} \qquad (7.1)$$
$$with\ c = 1, ..., C;\ t = 1, ..., T.$$

The matrix transformation for the multi-year rolling data to analyze the long-term hedging behavior is

$$\vec{r_{r,c}} = \hat{X}_{k,c} \vec{b_{r,k}} + \vec{\epsilon_c}\ with \qquad (7.2)$$
$$\hat{X}_{k,c} = A'_k X_{k,c} (X'_{k,c} A_k A'_k X_{k,c})^{-1} X'_{k,c} X_{k,c},$$
$$c = 1, ..., C$$

The previous chapter's Section 6.2 provides more background on the framework.

The main attention is targeted to the inflation coefficient β_r which is part of $\vec{b_{r,k}}$. It corresponds to the Fisher inflation coefficient for real returns of the previous chapter. If it is statistically insignificant and/ or close to zero, the asset's real return is unaffected by the level of inflation. The asset then is a perfect hedge against inflation. I will also highlight the impact of increasing or decreasing inflation which has frequently been interpreted as unexpected inflation or inflation uncertainty. This is captured in the γ coefficient. In case it is statistically insignificant and/or close to zero, the asset protects perfectly against inflation changes.

This methodology allows to estimate the absolute inflation hedging of infrastructure or equities. The hypothesis aims to compare both and questions if infrastructure is a superior hedge than normal equities. The answer lies in the coefficient difference between equity and infrastructure as well as its statistical significance. Therefore, equities are defined as the base and a dummy variable is introduced. The dummy equals zero in case of an equity return and one in case of infrastructure returns. The new coefficients are estimated with the data of both assets. The analysis only considers countries and times for which both time series are available to avoid a potential sample bias. The absolute coefficients values of the new regression remain identical to the equity only regression. The dummy coefficients indicate weather the two assets statistically differ in inflation hedging or not. The results reported in the next section include the inflation coefficients obtained from the original regression and the difference coefficients obtained from the extended regression with dummies.

The methodology accounts for the severe auto-correlation in the overlapping data. Both coefficient estimates for β_r might still be biased towards zero due to persistence in the data. The difference coefficient should thus be less affected by this bias which leaves the main result robust.

7.3 Empirical results

The first part of the analysis compares domestic infrastructure, its subsectors and segments depending on pricing power with domestic equities. The second part analyzes international infrastructure since previous research has partly covered it due to a lack of purely domestic indices. This also allows to roughly decompose the international inflation hedging into a (domestic) infrastructure and exchange rate components.

7.3.1 Domestic infrastructure

Table 7.1 provides the empirical results on the inflation hedging characteristics of equities and infrastructure at the one and five year investment horizon. The upper part compares general equity with general infrastructure investments. The inflation coefficients of infrastructure are slightly less negative than the ones for equities on the one-year horizon (-1.69 vs. -2.04), though the difference is not statistically significant. I obtain better inflation coefficients for infrastructure on the five-year horizon (-0.58 vs. -0.67). The difference is smaller than in the short-term comparison and again insignificant. At the same time, infrastructure reacts more sensitive to changes in inflation at long horizons (-0.45 vs. -0.16) implying worse performance during unexpected inflation shocks. The analyzed data covers only moderate inflation environments of less than 21% p.a. since the available data time series mostly cover the 1990s and 2000s. In such an inflation

Table 7.1: Inflation hedging properties of equities and infrastructure

Series	k	N	Inflation				ΔInflation			
			Coef.	p-Val.	ΔCoef.	p-Val.	Coef.	p-Val.	ΔCoef.	p-Val.
Infrastructure vs. domestic equity										
Infrastructure	1	918	-1.69	0.02	0.35	0.34	-0.22	0.40	-0.01	0.92
Equity	1	918	-2.04	0.00			-0.21	0.34		
Infrastructure	5	927	-0.58	0.42	0.10	0.76	-0.45	0.24	-0.29	0.05
Equity	5	927	-0.67	0.28			-0.16	0.70		
Infrastructure sectors vs. infrastructure/ equity										
Infrastructure	1	617	-1.96	0.01	0.34	0.42	-0.11	0.53	0.02	0.76
Telecom	1	617	-1.81	0.04	0.49	0.38	-0.10	0.53	0.02	0.77
Transport	1	392	-2.09	0.01	0.39	0.45	0.11	0.85	0.64	0.26
Utilities	1	617	-2.05	0.00	0.25	0.52	-0.11	0.52	0.01	0.89
Equity	1	617	-2.30	0.00			-0.12	0.44		
Infrastructure	5	600	-0.60	0.38	0.06	0.88	-0.26	0.42	-0.10	0.47
Telecom	5	600	-0.46	0.58	0.21	0.73	-0.48	0.18	-0.32	0.07
Transport	5	371	-1.14	0.08	-0.21	0.65	2.05	0.26	1.81	0.21
Utilities	5	600	-0.64	0.24	0.02	0.96	-0.02	0.94	0.14	0.54
Equity	5	600	-0.67	0.25			-0.16	0.63		
Static pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	655	-1.90	0.01	0.27	0.48	-0.14	0.49	0.00	0.95
High PP infra.	1	655	-1.82	0.01	0.35	0.36	-0.16	0.45	-0.02	0.81
Low PP infra.	1	655	-1.96	0.01	0.21	0.59	-0.16	0.45	-0.02	0.73
Equity	1	655	-2.17	0.00			-0.14	0.45		
Infrastructure	5	641	-0.36	0.62	0.09	0.80	-0.36	0.28	-0.20	0.16
High PP infra.	5	641	-0.16	0.82	0.29	0.42	-0.38	0.23	-0.23	0.30
Low PP infra.	5	641	-0.37	0.59	0.07	0.83	-0.36	0.26	-0.20	0.24
Equity	5	641	-0.45	0.46			-0.16	0.66		
Dynamic pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	557	-2.30	0.01	0.27	0.37	-0.17	0.41	-0.01	0.87
High PP infra.	1	557	-2.11	0.01	0.46	0.27	-0.20	0.36	-0.04	0.61
Low PP infra.	1	557	-2.29	0.02	0.28	0.53	-0.17	0.40	-0.01	0.83
Equity	1	557	-2.57	0.01			-0.16	0.37		
Infrastructure	5	527	-0.43	0.57	0.13	0.64	-0.32	0.31	-0.24	0.11
High PP infra.	5	527	-0.05	0.95	0.52	0.23	-0.33	0.29	-0.25	0.27
Low PP infra.	5	527	-0.66	0.41	-0.10	0.78	-0.28	0.34	-0.20	0.23
Equity	5	527	-0.56	0.39			-0.08	0.82		

This table compares the inflation hedging characteristics of various domestic infrastructure indices with broad domestic equity indices across 46 countries (based on real returns) at the one and five year investment horizon. The column "Coef." ("ΔCoef.") reports the coefficient estimate based on the original (extended) regression, "p-Val." the respective significance level.
Notes: For simplicity, I do not report ΔGDP coefficients. Multi-collinearity is of limited concern with the variance inflation factors $\sqrt{VIF} < 3$. The narrower anchor of transportation dilutes its comparability. R^2 ranges between 4 and 9%. 2% of the observations exhibit high leverage with annual inflation beyond 21% and are excluded from the regression.
Abbreviations: k: Investment horizon; N: Number of observations; PP: Pricing power.
Source: Rödel and Rothballer [2012].

environment the negative coefficient for real equity returns is in line with previous research. As pointed out by Kaserer and Rödel [2011], equities hedge inflation only during high inflations of above 21%, which may also hold for infrastructure, yet is not possible to be analyzed based on my dataset.

The next part of Table 7.1 compares the performance of the individual infrastructure sectors transportation, telecommunication, and utilities. The data history for transportation is considerably shorter than for the other two sectors (N=392 vs. N=617). The sample is thus restricted to telecommunication and utilities companies only. This increases the robustness of the conclusion while leaving a direct comparison of transportation subject to sample bias. While telecommunication performs slightly better with respect to the inflation level, utilities perform more robust on changes in inflation expectations at the five-year horizon. However, the differences compared to equities and infrastructure overall are insignificant, leading to the conclusion that the individual sectors exhibit fairly similar inflation hedging characteristics. The sector-specific analysis also confirms the previous finding of similar inflation hedging qualities of infrastructure and equities for a smaller sample (N=617 vs. N=918).

The above results cast doubt on the original hypothesis. Infrastructure does not appear as superior hedge. The definition of infrastructure comprises only firms that own the asset base and already excludes pure operators. It also requires a minimum of 50% of the revenues from this narrow infrastructure focus. This definition might still be too broad to benefit from the monopolistic pricing power the investor's have hoped for. Next, I explore if infrastructure with particularly high pricing power outperforms infrastructure with low pricing power or equities. First, applying a static classification of relative pricing power based on the infrastructure subsectors that splits the sample into two groups. In a second step, this grouping is refined with country- and time-specific competition data from OECD [2007] as proxy for pricing power.

The static classification models the infrastructure subsectors with a edge-node like network structure. Node-like infrastructure can be more cheaply replicated than edges. Consequently, nodal sectors are characterized by lower sunk costs and entry barriers. This increases the risk of new entry and competition and generally reduces the pricing power. Consider the case of telecommunication, for example. Edge-like fixed-line networks are very costly to install. Replicating lines is equally costly which quasi-monopolizes the infrastructure. The base stations of wireless networks function as nodes in the network. These are relatively cheap to replicate and in fact most countries have multiple overlapping wireless networks. This increases the level of competition amongst the infrastructure owners and greatly limits their pricing power. An assessment of the intra-sectoral as well as inter-sectoral competition of each subsector validates the pricing power classification. Table 7.2 details the resulting categorization. Both approaches yield the same pricing power clusters. It is kept static across countries and over time.

The dynamic classification accounts for the heterogeneity in sector competitiveness across countries and time. Thus, the competition in wireless telecommunication in Germany might advance from high pricing power to low pricing power. It might now also differ from the competition level in other countries, e.g. the People's Republic of China, which has more protected players with higher pricing power. The foundation for the dynamic classification is a competitiveness dataset compiled by OECD [2007]. The data bases on a structured questionnaire on the entry barriers, the market structure, and the vertical integration in infrastructure sectors in all OECD countries from 1975 to 2007. It includes data on electricity, gas, rail as well as fixed-line and wireless communication.[2] For each subsector-country-year combination an indicator between 0 and 6 is assigned, where 0 refers to a competitive (low pricing power) market and 6 to a regulated (high pricing power) market. 3 is the equidistant cut-off point to cluster subsectors as either high or low pricing power in a given year and country. For sectors that are not covered and for non-OECD countries the pricing power assignment of the static clustering is used in order to maintain a sufficient number of observations. The values before 1975 and after 2007 are extrapolated. The earliest value of a country represents the lower bound of pricing power and the latest value an upper bound. This implies monotonously decreasing pricing power - which is a consistent pattern in the dataset across all countries.

Table 7.1 contains the empirical results for the static and dynamic classification in the lower half. The portfolios with high pricing power provide a more robust hedge against inflation than the ones with low pricing power. This is especially pronounced at the five-year horizon for the dynamic classification. While equities have an inflation coefficient of -0.56 and low pricing power infrastruc-

[2] The published data includes telecommunication as one sector. Only the raw data allowed to compute individual index values for fixed-line and wireless.

Table 7.2: Static pricing power classification of subsectors

Subsector	Intra-modal competition	Inter-modal competition	Network type	Pricing power cluster
Telecommunication				
Satellite	Significant: satellites with same coverage	Medium: (sea) cable	Node	Low
Wireless	Significant: wireless networks with same coverage	Medium: fixed-line	Node	Low
Fixed-line	Limited: usually only in long-distance	Medium: wireless	Edge	High
Cable	Limited: usually regional monopoly	Medium: satellite, antenna	Edge	High
Transport				
Pipelines	Limited: usually little redundancy	Medium: rail, water transport	Edge	High
Airports	Medium: airports in same catchment; transfer PAX	Medium: rail, highways	Node	Low
Ports	Medium: ports serving same hinterland	Medium: rail, highways, pipelines	Node	Low
Highways	Limited: only from regional roads	Medium: rail, water & air transport, pipelines	Edge	High
Rail	Limited: usually few parallel tracks	Medium: highways, water & air transport, pipelines	Edge	High
Utilities				
Electricity	Medium: different generation technologies	Medium: other energy sources (e.g. oil)	Node	Low
Water	Limited: usually regional monopoly	None: no substitute	Edge	High
Gas	Limited: usually regional monopoly	Limited: Truck supply; other heating commodities	Edge	High
Multi	Limited: same as electricity, gas, water	Limited: same as electricity, gas, water	Edge	High

Note: Subsectors with at least significant intra-sectoral competition or with at least medium intra- and inter-sectoral competition are assigned to the high competitiveness cluster.
Abbreviation: PAX = Passenger.
Source: Rödel and Rothballer [2012].

ture of −0.66, high pricing power infrastructure hedges inflation almost perfectly (coefficient of −0.05 with a delta significance of 23%). This is the most significant outperformance of any infrastructure subsample against equities in the analysis. However, increasing deregulation of infrastructure sectors over time may have reduced the pricing power of infrastructure companies and, thus their overall suitability to serve as inflation hedge. Similar to the above results, infrastructure is more sensitive to inflation volatility suggesting that high pricing power can only be capitalized on in stable inflation environments.

The robustness is tested for different methodological standard errors, subsamples, a potential misspecification. The results for a specification without the Britten-Jones *et al.* [2011] transformation is shown in Table 7.3, for the subsample of advanced economies only in Table 7.4, and a specification with inflation as the only regressor, i.e. excluding economic growth and Δinflation in Table 7.5. The picture is remarkably consistent. It is noteworthy that the relative advantage of high pricing power infrastructure tends to be more pronounced when using less strict controls and statistical corrections. In the regression without matrix transformation, the difference dummy becomes significant at the 5% level, implying significantly better inflation hedging of infrastructure relative to equities.

Overall, the empirical results do not support the hypothesis that listed domestic infrastructure is a superior inflation hedge compared to equities. The dummies generally are statistically insignificant. The infrastructure subsegment with high pricing power represents the only exception in the analysis, however, only at the long five-year horizon.

7.3.2 International infrastructure

This section complements the findings on domestic infrastructure with evidence in the international context. The central question is whether local inflation can be hedged with foreign infrastructure investments. This issue is of particular concern for large sovereign wealth funds in small countries, such as Norway's Government Pension Fund, where the local investable assets are limited and where wealth increases often come with continuous price inflation. Local assets are simply too narrow for the massive volume under management.

The conceptual motivation behind international diversification for inflation

Table 7.3: Results without matrix transformation

Series	k	N	Inflation				ΔInflation			
			Coef.	p-Val.	ΔCoef.	p-Val.	Coef.	p-Val.	ΔCoef.	p-Val.
Infrastructure vs. equity										
Infrastructure	1	918	-1.69	0.02	0.35	0.34	-0.22	0.40	-0.01	0.92
Equity	1	918	-2.04	0.00			-0.21	0.34		
Infrastructure	5	745	-0.58	0.15	0.10	0.47	-0.45	0.09	-0.29	0.06
Equity	5	745	-0.67	0.06			-0.16	0.39		
Infrastructure sectors vs. infrastructure/ equity										
Infrastructure	1	617	-1.96	0.01	0.34	0.42	-0.11	0.53	0.02	0.76
Telecom	1	617	-1.81	0.04	0.49	0.38	-0.10	0.53	0.02	0.77
Transport	1	392	-2.09	0.01	0.39	0.45	0.11	0.85	0.64	0.26
Utilities	1	617	-2.05	0.00	0.25	0.52	-0.11	0.52	0.01	0.89
Equity	1	617	-2.30	0.00			-0.12	0.44		
Infrastructure	5	440	-0.60	0.14	0.06	0.80	-0.26	0.17	-0.10	0.46
Telecom	5	440	-0.46	0.36	0.21	0.47	-0.48	0.05	-0.32	0.09
Transport	5	263	-1.14	0.06	-0.21	0.38	2.05	0.19	1.81	0.02
Utilities	5	440	-0.64	0.07	0.02	0.93	-0.02	0.90	0.14	0.31
Equity	5	440	-0.67	0.04			-0.16	0.17		
Static pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	655	-1.90	0.01	0.27	0.48	-0.14	0.49	0.00	0.95
High PP	1	655	-1.82	0.01	0.35	0.36	-0.16	0.45	-0.02	0.81
Low PP	1	655	-1.96	0.01	0.21	0.59	-0.16	0.45	-0.02	0.73
Equity	1	655	-2.17	0.00			-0.14	0.45		
Infrastructure	5	485	-0.36	0.38	0.09	0.66	-0.36	0.09	-0.20	0.15
High PP	5	485	-0.16	0.74	0.29	0.21	-0.38	0.10	-0.23	0.19
Low PP	5	485	-0.37	0.33	0.07	0.73	-0.36	0.13	-0.20	0.23
Equity	5	485	-0.45	0.21			-0.16	0.24		
Dynamic pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	557	-2.30	0.01	0.27	0.37	-0.17	0.41	-0.01	0.87
High PP	1	557	-2.11	0.01	0.46	0.27	-0.20	0.36	-0.04	0.61
Low PP	1	557	-2.29	0.02	0.28	0.53	-0.17	0.40	-0.01	0.83
Equity	1	557	-2.57	0.01			-0.16	0.37		
Infrastructure	5	391	-0.43	0.28	0.13	0.48	-0.32	0.05	-0.24	0.17
High PP	5	391	-0.05	0.92	0.52	0.05	-0.33	0.08	-0.25	0.22
Low PP	5	391	-0.66	0.09	-0.10	0.70	-0.28	0.07	-0.20	0.23
Equity	5	391	-0.56	0.14			-0.08	0.42		

This table shows the results without matrix transformation (changing the p-values at the five-year horizon). Even then, the inflation differential of infrastructure is still insignificant, except for the dynamic high pricing power strategy which becomes significant at the 5% level.
Notes: General notes and abbreviations of Table 7.1 apply.
Source: Rödel and Rothballer [2012].

Table 7.4: Results for advanced economies

Series	k	N	Inflation				ΔInflation			
			Coef.	p-Val.	ΔCoef.	p-Val.	Coef.	p-Val.	ΔCoef.	p-Val.
Infrastructure vs. equity										
Infrastructure	1	592	-1.15	0.07	0.16	0.73	-2.33	0.01	-1.05	0.08
Equity	1	592	-1.31	0.09			-1.28	0.09		
Infrastructure	5	593	-0.49	0.50	0.08	0.86	-4.34	0.02	-1.29	0.16
Equity	5	593	-0.57	0.36			-3.05	0.13		
Infrastructure sectors vs. infrastructure/ equity										
Infrastructure	1	362	-1.52	0.03	0.17	0.79	-1.63	0.11	-1.05	0.13
Telecom	1	362	-1.51	0.08	0.17	0.82	-1.62	0.16	-1.04	0.32
Transport	1	281	-1.28	0.12	0.32	0.57	1.44	0.49	1.39	0.06
Utilities	1	362	-1.50	0.01	0.18	0.75	-1.40	0.21	-0.82	0.13
Equity	1	362	-1.68	0.08			-0.58	0.57		
Infrastructure	5	351	-0.72	0.35	0.14	0.80	-4.52	0.02	-2.05	0.06
Telecom	5	351	-0.56	0.59	0.29	0.71	-6.42	0.01	-3.95	0.01
Transport	5	271	-0.81	0.21	0.02	0.96	-0.42	0.84	2.15	0.09
Utilities	5	351	-0.59	0.23	0.26	0.63	-4.30	0.03	-1.84	0.05
Equity	5	351	-0.85	0.25			-2.46	0.31		
Static pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	419	-1.27	0.05	0.11	0.83	-1.99	0.03	-0.90	0.14
High PP	1	419	-1.19	0.15	0.20	0.74	-1.93	0.09	-0.84	0.38
Low PP	1	419	-1.50	0.02	-0.11	0.81	-2.55	0.01	-1.46	0.00
Equity	1	419	-1.39	0.11			-1.10	0.17		
Infrastructure	5	413	-0.43	0.56	0.00	0.99	-3.91	0.03	-1.20	0.23
High PP	5	413	-0.01	0.99	0.42	0.46	-3.49	0.06	-0.79	0.59
Low PP	5	413	-0.46	0.50	-0.03	0.94	-4.31	0.04	-1.60	0.07
Equity	5	413	-0.43	0.49			-2.70	0.19		
Dynamic pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	339	-1.61	0.05	0.34	0.47	-2.60	0.03	-1.50	0.01
High PP	1	339	-1.44	0.15	0.51	0.48	-2.66	0.03	-1.56	0.12
Low PP	1	339	-1.91	0.03	0.04	0.95	-2.47	0.07	-1.37	0.02
Equity	1	339	-1.95	0.04			-1.09	0.31		
Infrastructure	5	325	-0.56	0.56	0.12	0.78	-4.13	0.07	-2.79	0.00
High PP	5	325	0.14	0.87	0.83	0.26	-3.60	0.10	-2.25	0.16
Low PP	5	325	-0.92	0.39	-0.23	0.71	-3.19	0.21	-1.84	0.13
Equity	5	325	-0.68	0.37			-1.35	0.50		

This table replicates the analysis for the 24 advanced economies as part of the MSCI World Index in 2010. The results are consistent to the original regression. Again, the dynamic high pricing power portfolio performs best and even reaches a positive coefficient.
Notes: General notes and abbreviations of Table 7.1 apply. 0.5% of the observations exhibit high leverage with annual inflation beyond 21% and are excluded from the regression.
Source: Rödel and Rothballer [2012].

Table 7.5: Results with inflation as only control variable

Series	k	N	Inflation				ΔInflation			
			Coef.	p-Val.	ΔCoef.	p-Val.	Coef.	p-Val.	ΔCoef.	p-Val.
Iinfrastructure vs. equity										
Infrastructure	1	917	-1.58	0.03	0.44	0.24				
Equity	1	917	-2.01	0.00						
Infrastructure	5	927	-0.36	0.63	0.14	0.68				
Equity	5	927	-0.50	0.42						
Infrastructure sectors vs. infrastructure/ equity										
Infrastructure	1	616	-1.68	0.02	0.48	0.26				
Telecom	1	616	-1.47	0.08	0.69	0.21				
Transport	1	392	-2.12	0.01	0.49	0.33				
Utilities	1	616	-1.85	0.00	0.31	0.40				
Equity	1	616	-2.15	0.01						
Infrastructure	5	600	-0.04	0.96	0.15	0.74				
Telecom	5	600	0.14	0.89	0.33	0.63				
Transport	5	371	-0.86	0.17	-0.35	0.47				
Utilities	5	600	-0.27	0.65	-0.07	0.87				
Equity	5	600	-0.19	0.75						
Static pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	654	-1.63	0.02	0.40	0.30				
High PP	1	654	-1.65	0.01	0.39	0.32				
Low PP	1	654	-1.65	0.02	0.39	0.32				
Equity	1	654	-2.02	0.01						
Infrastructure	5	641	0.02	0.98	0.19	0.63				
High PP	5	641	0.19	0.81	0.36	0.36				
Low PP	5	641	0.01	0.99	0.18	0.63				
Equity	5	641	-0.17	0.78						
Dynamic pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	556	-1.93	0.02	0.46	0.11				
High PP	1	556	-1.94	0.01	0.45	0.26				
Low PP	1	556	-1.90	0.03	0.48	0.25				
Equity	1	556	-2.38	0.01						
Infrastructure	5	527	0.12	0.88	0.17	0.60				
High PP	5	527	0.55	0.46	0.60	0.15				
Low PP	5	527	-0.08	0.92	-0.04	0.93				
Equity	5	527	-0.05	0.94						

This table presents the results without the independent variables Δinflation and ΔGDP. The inflation coefficient on the five-year horizon generally gets closer to zero for equities and infrastructure. Their difference is statistically still indistinguishable throughout. Again, the dynamic high pricing power portfolio performs best and even reaches a positive coefficient.
Note: General notes and abbreviations of Table 7.1 apply.

hedging is purchasing power parity (PPP). Inflation differentials between countries should be offset by changes in the exchange rate. Recent research generally supports PPP in the long run as surveyed by Alba and Papell [2007]. For inflation hedging, the effect should be weaker when inflations are correlated (i.e. when high domestic inflation is accompanied by high "international inflation") and stronger when the cross-correlation is low. I account for this by matching the regional footprint of the underlying assets, e.g. when comparing against the MSCI World (Emerging Markets) I rely on a developed (emerging) markets infrastructure basket.

Table 7.6 provides the empirical results for international diversification in developed market assets based on a one and five year investment horizon. The sample size depends on the availability of the international portfolio, the country's exchange rate, and equity data. These are mostly available from the sample start in 1973 increasing the statistical validity of the results. The results excluding high leverage inflation cover a similar inflation environment as in the case of domestic infrastructure (up to 21% p.a.). The coefficients on the one-year horizon are negative throughout (around -0.6), and infrastructure as well as its sectors are only insignificantly different from the equity coefficients. The same holds true for the five-year horizon where coefficients are closer to zero. When including high inflation observations, even the inflation coefficients for the one-year horizon are close to zero. This is consistent to the different dynamics of high and low inflation environments as mentioned in Kaserer and Rödel [2011]. Hence, PPP works well in the long-run or when inflation rates are significant. But, in neither case does infrastructure outperform equities. The only notable exception is the transport sector which shows a superior coefficient on Δinflation in most cases, which might be due to a sample bias as the transport firms are regionally more concentrated.[3] Similarly, emerging market infrastructure does not provide a better inflation hedge in comparison to the respective equities as shown in Table 7.7 in the appendix.

[3]The transport index shows little exposure to the US as few privatizations have taken place there (e.g. no single airport or highway, only one port). Thus, the index constituents are presumably less correlated to international inflation.

Table 7.6: Inflation hedging properties of developed market equities and international infrastructure

Series	k	N	Inflation				ΔInflation			
			Coef.	p-Val.	ΔCoef.	p-Val.	Coef.	p-Val.	ΔCoef.	p-Val.
Developed markets infrastructure vs. MSCI World (excl. Outlier)										
Infrastructure	1	1581	-0.58	0.31	0.08	0.72	-0.31	0.05	-0.03	0.67
Telecom	1	1581	-0.48	0.45	0.18	0.64	-0.28	0.07	0.00	0.98
Transport	1	1581	-0.64	0.27	0.03	0.94	-0.06	0.62	0.23	0.05
Utilities	1	1581	-0.70	0.19	-0.04	0.91	-0.24	0.14	0.04	0.61
Equity	1	1581	-0.66	0.23			-0.29	0.04		
Infrastructure	5	1660	0.16	0.78	0.08	0.72	-0.27	0.20	-0.06	0.67
Telecom	5	1660	0.21	0.77	0.13	0.70	-0.52	0.07	-0.31	0.13
Transport	5	1660	0.05	0.87	-0.03	0.94	0.24	0.14	0.45	0.01
Utilities	5	1660	-0.03	0.95	-0.10	0.74	0.00	0.99	0.21	0.25
Equity	5	1660	0.08	0.86			-0.21	0.17		
Developed markets infrastructure vs. MSCI World (incl. Outlier)										
Infrastructure	1	1799	-0.12	0.11	-0.01	0.70	0.13	0.13	-0.02	0.41
Telecom	1	1799	-0.13	0.12	-0.02	0.61	0.15	0.04	0.00	0.89
Transport	1	1799	-0.14	0.07	-0.02	0.48	0.19	0.06	0.05	0.07
Utilities	1	1799	-0.12	0.08	-0.01	0.79	0.13	0.13	-0.01	0.66
Equity	1	1799	-0.12	0.10			0.14	0.10		
Infrastructure	5	1799	-0.07	0.41	-0.01	0.53	0.21	0.03	0.00	0.94
Telecom	5	1799	-0.08	0.42	-0.03	0.51	0.14	0.14	-0.07	0.12
Transport	5	1799	-0.08	0.20	-0.02	0.50	0.28	0.02	0.08	0.06
Utilities	5	1799	-0.08	0.27	-0.02	0.53	0.27	0.01	0.06	0.12
Equity	5	1799	-0.06	0.43			0.21	0.05		

This table compares the inflation hedging characteristics of various international infrastructure indices with international equity indices across 45 countries (based on the real returns). The international indices only cover the developed market countries as in the MSCI World. The consistently insignificant difference between the two (as seen in column 7 and 11) questions the inflation superiority of infrastructure as posed by the broader investment community also on an international level.
Notes: The column "Coef." ("ΔCoef.") reports the coefficient estimate based on the original (extended) regression, "p-Val." the respective significance level. For simplicity, I do not report the ΔGDP coefficient. Multi-collinearity is of limited concern with all $\sqrt{VIF} < 2$. R^2 ranges between 2 and 11%.
Abbreviations: k: Investment horizon; N: Number of observations; ex Outliers: Inflation < 21%; Equity: MSCI World.

Table 7.7: Inflation hedging properties of emerging market equities and international infrastructure

Series	k	N	Inflation				ΔInflation			
			Coef.	p-Val.	ΔCoef.	p-Val.	Coef.	p-Val.	ΔCoef.	p-Val.
Emerging markets infrastructure vs. MSCI World Emerging Markets (excl. Outlier)										
Infrastructure	1	806	-1.32	0.19	0.16	0.69	-0.02	0.85	0.07	0.33
Telecom	1	806	-1.57	0.11	-0.09	0.88	-0.04	0.71	0.04	0.64
Transport	1	806	-1.31	0.37	0.17	0.81	0.20	0.29	0.29	0.11
Utilities	1	806	-0.88	0.44	0.60	0.08	0.02	0.86	0.11	0.27
Equity	1	806	-1.48	0.20			-0.09	0.52		
Infrastructure	5	825	-0.75	0.26	0.02	0.95	0.50	0.32	-0.16	0.32
Telecom	5	825	-0.95	0.24	-0.18	0.69	0.46	0.48	-0.21	0.49
Transport	5	825	-1.49	0.03	-0.72	0.30	0.85	0.10	0.19	0.64
Utilities	5	825	-0.45	0.44	0.32	0.46	0.58	0.14	-0.08	0.79
Equity	5	825	-0.77	0.19			0.66	0.22		
Emerging markets infrastructure vs. MSCI World Emerging Markets (incl. Outlier)										
Infrastructure	1	847	-0.08	0.58	-0.03	0.43	0.16	0.19	0.06	0.20
Telecom	1	847	-0.11	0.44	-0.07	0.22	0.16	0.22	0.06	0.35
Transport	1	847	-0.08	0.67	-0.04	0.61	0.37	0.03	0.27	0.04
Utilities	1	847	-0.03	0.85	0.02	0.73	0.18	0.16	0.08	0.32
Equity	1	847	-0.04	0.78			0.10	0.45		
Infrastructure	5	847	-0.24	0.15	-0.02	0.88	0.25	0.15	-0.05	0.33
Telecom	5	847	-0.32	0.12	-0.10	0.49	0.21	0.29	-0.09	0.39
Transport	5	847	-0.44	0.03	-0.22	0.26	0.33	0.08	0.03	0.83
Utilities	5	847	-0.13	0.39	0.09	0.44	0.30	0.05	0.00	0.97
Equity	5	847	-0.22	0.18			0.30	0.09		

This table resembles Table 7.6, but focuses on indices covering the emerging markets as in the MSCI Emerging Markets or its GFD ancestor, not developed markets. Again, the consistently insignificant difference between the two (as seen in column 7 and 11) questions the inflation superiority of infrastructure as posed by the broader investment community also on an international level.
Notes: The column "Coef." ("ΔCoef.") reports the coefficient estimate based on the original (extended) regression, "p-Val." the respective significance level. For simplicity, I do not report the ΔGDP coefficient. Multi-collinearity is of limited concern with all $\sqrt{VIF} < 2$. R^2 ranges between 1 and 3%.
Abbreviations: k: Investment horizon; N: Number of observations; ex Outliers: Inflation < 21%; Equity: MSCI Emerging Markets and GFD Extension.

7.4 Discussion

The empirical results cast doubt on the superior reputation of infrastructure as hedge against inflation. This section reflects this finding, highlights the implications for the investor and the novelty compared to existing research. Afterwards it critically reviews the limitations of this analysis.

7.4.1 Implications

The positive inflation hedging characteristics of select infrastructure seems to have been generalized too much over time. Infrastructure in general does not hedge inflation any better than equities. The reasons backing the belief that infrastructure hedges inflation – namely monopolistic market positions, favorable regulatory regimes, and low variable cost exposure – seem less effective than hypothesized.

First, regulation potentially restricts the monopolistic pricing power of infrastructure firms. The regulatory bodies have been professionalized over the last decades and their ability to effectively monitor and prescribe prices, the quality of service, the volume and costs of the investments has increased across many countries. Moreover, previously vertically integrated firms have been broken up and the asset base stripped from the operations with new competition enforced through access pricing and third-party providers. Technological progress also changed the minimum efficient scale and lowered entry barriers in selected sectors. As a result, the competitiveness in OECD infrastructure industries has increased significantly between 1975 and 2003. The OECD Energy, Transport and Communications Regulation indicator declined from about 5 to 2.5 on a scale between 6 and 0, as mentioned in Conway and Nicoletti [2006]).

Second, cost-based regulatory regimes such as rate-of-return regulation still dominate incentive-based regimes such as price or revenue caps in most infrastructure sectors across OECD countries today (Égert [2009]). Cost-based regimes do not necessarily protect against inflation if the regulated asset base is determined from historic prices and if regulatory lags are long. But also for firms under price cap regulation, a correlation between returns and the CPI is not granted. On the one hand, there may be a mismatch between the firms' cost base and the CPI goods basket. On the other hand, prices determined by the regulatory mechanism using specific inflation measures such as construction costs may not comove with consumer inflation that investors want to hedge (Armann and Weisdorf [2008]).

Third, the variable cost exposure might in fact be larger, and more exposed to inflation than expected. For example, merchant power generators rely on energy inputs, and transport infrastructure firms are indirectly exposed to energy prices as traffic volumes drop when oil prices rise. Moreover, infrastructure firms are heavily exposed to debt financing and significant annual interest expenses. The debt maturity is typically several years and the financing costs rise with higher inflation which was shown in the positive inflation coefficient in the Fisher framework for fixed income. Lastly, even when infrastructure assets themselves generate inflation-linked operating cash flows, these do not necessarily materialize for equity investors. Rising inflation increases uncertainty and therefore debt risk premiums. If refinancing is required during an inflationary period the inflation hedging characteristics are taken out, rendering highly leveraged assets less effective hedges against inflation (Williams [2007]). Moreover, if infrastructure firms issue inflation-linked bonds, the inflation hedging properties of the equity side deteriorate (Armann and Weisdorf [2008]). This phenomenon could well be the case in some mature inflation trading markets such as the U.K., where utilities account for a significant share of the inflation-linked corporate bond market.

Investors in infrastructure who seek inflation protection should conduct a careful due diligence of their investments. Infrastructure as broad basket is not enough. The investment will only hedge inflation if the underlying company has high pricing power.

7.4.2 Contributions to the literature

This analysis addresses the main shortcomings of previous research on inflation hedging of infrastructure. It leverages a novel, proprietary dataset on infrastructure returns. The panel exceeds other datasets in this domain by 20 years data history (factor 2.3) and almost 600 listed infrastructure companies (factor 3.4). Most importantly, it is granular enough to compute purely domestic infrastructure indices. This allows to separate infrastructure from exchange rate effects. The analysis also applies a more robust methodology. It applies the Fisher framework instead of pure correlation coefficients which allows to control for inflation changes and real economic effects. Moreover it applies spacial correlation-consistent standard errors according to Driscoll and Kraay [1998] to account for simultaneous and lagged cross-correlation and transforms the overlapping data with the matrix operation of Britten-Jones *et al.* [2011] to strip out the autocorrelation that arises from the overlapping data. The broad dataset and robust methodology makes this the most comprehensive infrastructure - inflation hedging research and a sound basis to separate opinion from fact.

7.4.3 Limitations and directions for future research

The analysis leaves room for future research. It focuses on stand-alone inflation hedging and not on real return targets or correlations with other assets in the investor's portfolio. The dataset, though fairly comprehensive, still does not cover high and hyperinflation phases. The conclusion and interpretation should thus be limited to annual inflations of up to 20%. It is also limited to listed firms in economic infrastructure. Unlisted infrastructure, social infrastructure, or PPP projects might show different hedging characteristics which still wait to be explored. Lastly, the analysis casts doubt on a market believe based on empirical observations. It only provides ad-hoc explanations so far and future research will have to uncover the theoretical underpinnings and sort out the relative importance of the different explanations.

7.5 Summary

The empirical results suggest that listed infrastructure is not a superior inflation hedge in comparison to equities. Infrastructure hedges inflation just as good (or bad) as other equities as the differences are negligible and statistically not significant. Similarly, none of the analyzed infrastructure sectors appears to be a superior inflation hedge. Only for infrastructure with strong pricing power as proxied by the OECD competition data, I find a slight indication that select infrastructure assets may provide inflation-linked returns at a five-year horizon. The inflation beta is close to zero, i.e. real returns are not sensitive to inflation, but the difference dummy versus equities is not significant. Investors seeking long-term inflation protection should carefully select infrastructure assets with strong pricing power and depart from the belief that infrastructure generally provides a natural hedge. This restriction limits the infrastructure investment opportunities in the sample to USD 1.1 trillion relative to the total infrastructure market capitalization of USD 3.8 trillion at the end of 2009.

Overall, anecdotal evidence of infrastructure's monopolistic market positions, favorable regulatory regimes and low input price exposure seem to have shaped a belief in the investment community that infrastructure generally hedges inflation. However, these claims do not withstand the empirical tests, except for select infrastructure assets with particularly high pricing power.

Chapter 8

Inflation hedging with international equities

Hyperinflations often provoke capital flight. Local residents try to escape from the national currency and acquire foreign assets or foreign currency before their fiat money becomes totally worthless, often under the risk of severe legal penalty. The idea is pervasive in any high inflation environment yet uncharted territory in academic research. My third hypothesis claims that international equities provides superior inflation hedging compared to domestic equities. This chapter researches this question in the context of capital mobility and international diversification. The main question is if low to medium inflation can be hedged with international equity diversification in a system of non-fixed exchange rate regimes. The analysis focuses on 24 advanced economies between 1971 and 2010. Data on 21 emerging economies backs the analysis knowing that capital mobility would have been restricted. The first part compares the return characteristics and inflation hedging of domestic equities, the MSCI World, and the MSCI Emerging Markets. The second part investigates targeted country portfolios selected by bivariate inflation comovements.

The chapter closely follows my working paper "Inflation Hedging with International Equities' which was supervised by Professor Hodrick and Professor Kaserer [Rödel, 2012]. I describe the motivation of the paper before introducing its methodology. The empirical results are presented by investment strategy and origin country before discussing the implications and limitations of this research.

A summary concludes this chapter.

8.1 Motivation

Understanding the impact of inflation on asset returns is crucial to navigate a portfolio through the aftermath of the financial crisis with widespread quantitative easing and looming inflation fears. If exchange rates mitigate inflation differentials between countries along relative purchasing power parity, international investments are potentially useful for inflation hedging. This ''investment strategy' routinely becomes alive during high and hyperinflations, when people try to escape the domestic currency and introduce foreign currency as substitute or acquire foreign assets. Fergusson [2010] documents this splendidly on page 47 in his account on the Austrian and German hyperinflation in the early 1920s based on contemporary witnesses: "I hardly know a single German of either sex who is not speculating in the foreign currencies." In most cases, foreign currency holdings will be forbidden and capital restrictions introduced. Moreover, the strategy might also prove valuable during medium inflation in advanced countries that enjoy capital mobility.

Despite the potential benefits, to the best of my knowledge, no academic research has focused on foreign equities as inflation hedge (see Section 3.3.7 for an overview of related subjects). Even worse, exchange rate effects have been ignored, e.g. in infrastructure, where domestic and international investments have repeatedly been compared without mentioning currency effects. The last section has already uncovered spurious results in the infrastructure domain. This section analyzes the issue in more detail from the perspective of the advanced economies and medium inflation during which capital mobility was still possible historically.

8.2 Methodology

My investor aims to hedge domestic inflation with the global equity universe. For example, a German investor would want to hedge German inflation using either German or foreign equities. An US investor would aim to offset American inflation for example with German or Australian equities. I study inflation hedging across time, multiple origin countries, and for several target investment country scopings depending on equity investability. Foreign investments are always unhedged and assessed in the investor's local currency. While this exposes the investor to short-run exchange rate risk it may mitigate the inflation risk along PPP.

The analysis bases on the domestic inflation hedging framework from Sections 6.2 and 7.2. For a panel dataset with C countries and T years, the regression equation is

$$r_{r,c,t} = r_{n,c,t} - \pi_{c,t} = \alpha_c + \beta_r \pi_{c,t} + \gamma \Delta\pi_{c,t} + \delta \Delta GDP_{c,t} + \epsilon_{c,t} \qquad (8.1)$$
$$with\ c = 1, ..., C;\ t = 1, ..., T.$$

with r_r denoting the real equity return, r_n the nominal equity return, π the inflation rate, $\Delta\pi$ the unexpected inflation, and ΔGDP the real economic growth. All figures are logarithmic and the main null hypothesis is $\beta_r = 0$, i.e. a perfect inflation hedge.

All equity indices base on consistent indexing methodology. The indices are total return, market capitalization weighted indices that follow a comparable computation approach. The domestic indices are well diversified or all equity indices. Examples are the total return of the S&P 500 index, which covers the 500 largest market cap stocks of the United States, or the CDAX, an index of all equities of Prime and General Standard in Germany. The international indices cover a geographically diverse set of 24 advanced economies in the case of the MSCI W and 21 emerging economies in case of the MSCI EM.

The macro-economic and return data exhibit heteroscedasticity, auto- and cross-correlation that also leave their trace in the error term. I account for this with spatial correlation-consistent standard errors according to Driscoll and Kraay [1998].

In summary, theory expects real domestic asset returns not to be impacted by $\pi_{c,t}$ and $\Delta\pi_{c,t}$ along the prediction of money neutrality and Fisher, i.e. $\beta_r = 0$ and $\gamma = 0$, when controlling for real economic growth. The error term reflects stock market noise. I focus on annual observations and use rolling overlapping data only when analyzing inflation hedging at the five year investment horizon.

Returns to foreign equities have an exchange rate component and an equity component. For an investor from country c_1 that invests in country c_2 the real return calculates as

$$r_{r,c_1,c_2,t} = r_{n,c_2,t} + e_{n,c_1,c_2,t} - \pi_{c_1,t} \quad (8.2)$$
$$with\ c_1, c_2 = 1, ..., C;\ c_1 \neq c_2,\ t = 1, ..., T$$

with the exchange rate component $e_{n,c_1,c_2,t}$ being the differenced logarithmic exchange rate in direct notation (e.g. for a UK investor and US equity in x GBP per USD).

Inflation differentials are offset by nominal exchange rate moves in case of perfect relative purchasing power parity, such that

$$e_{n,c_1,c_2,t} = \pi_{c_1,t} - \pi_{c_2,t}. \quad (8.3)$$

This would allow to trade domestic with foreign inflation risk which can be seen when combining the previous two equations. The UK investor could then, for example, be exposed to the domestic equity inflation dynamics in the US. However, the empirical evidence on PPP is mixed and large deviations between observed and predicted exchange rates are common place in the short-run, even for large floating currencies. While the unsystematic deviations should balance out in the data, I expect two systematic deviations.

First, weak currencies are likely to face capital flight and over-depreciate at higher inflation. This generates real gains from international diversification. Similarly, investors from strong currency countries should suffer from under-appreciation in case of lower local inflation. This would make foreign equity investments a valuable strategy for investors with a weak home currency, but less valuable for investors with a strong home currency.

Second, high comovement between local and foreign inflation should neutralize exchange rate moderation. In case of perfect comovement, one percent higher local inflation would result in one percent higher foreign inflation with a zero net effect on the nominal exchange rate. Foreign equity would then react in the same way to local inflation as domestic equity. This effect should be especially pronounced within the advanced economies that exhibited a very high degree of comovement. Since 1980, international factors drove 72% of the variation in advanced economy inflation compared to only 37% in emerging economies.[1]

[1] The international factor combines a global and a regional factor. More on this

I investigate the cross-sectional heterogeneity of the inflation beta $\beta_{r,c}$ (from regression (8.1)) against currency strength and comovement as

$$\beta_{r,c} = \alpha + \beta ppp_{c,b} + \gamma\theta_{c,e}. \tag{8.4}$$

$ppp_{c,b}$ is regressed based on the annual inflation differential in equation (8.3) between country c and an equally-weighted basket b of major currencies USD, DEM/EUR, GBP, JPY, and CHF. $\theta_{c,e}$ indicates the comovement of a country c's inflation with global or regional inflation. I apply a dynamic latent factor model with a world and a regional factor following the approach of Neely and Rapach [2008][2]:

$$\pi_{c,t} = \beta_c^g f_t^g + \beta_c^e f_t^e + \epsilon_{c,t}. \tag{8.5}$$

I distinguish the two "regions' by economic development in advanced and emerging economies to match the target country set of the investor diversifying into the MSCI World or MSCI Emerging Markets. $\theta_{c,e}$ is the result of a country specific variance decomposition on the orthogonal regional and global factor as

$$\theta_{c,e} = (\beta_c^e)^2 var(f_t^e)/var(\pi_{c,t}). \tag{8.6}$$

I perform rolling regressions and average θ, so that the time period matches the data history of that country's $ppp_{c,b}$ in regression (8.4).

8.3 Empirical results

The first part of the empirical results analyzes diversification into broad international equity indices such as the MSCI World or MSCI Emerging Markets. The results indicate that cross-correlation impacts the inflation hedging of international diversification, which I investigate in more detail in the second part.

dynamic latent factor model shortly below.

[2] I have also applied their MATLAB source code and are grateful for their implementation advise.

8.3.1 Broad international equity indices

This section contrasts the inflation hedging properties of domestic and international equity indices. Table 8.1 summarizes the results for the advanced and emerging economy scopes AEb, AEn, and EEb.[3]

Domestic and international equities exhibit comparable risk-return characteristics, e.g. similar Sharpe ratios in each scoping with the MSCI EM being slightly superior in AEb (31% vs. 24-25%) and the MSCI W being less advantageous in the EEb setting (21% vs. 26%). The MSCI W consistently represents a relatively lower risk, lower return alternative with a standard deviation of only 21%.

In the broad advanced economies scoping, AEb, domestic equities provided negative inflation hedging with a coefficient of -1.3 (significant) and -0.7 (not significant) at the one and five year investment horizon. In other words, a 1%-point higher inflation level resulted in 1.3% lower real and 0.3% lower nominal returns to domestic equity for an investor in advanced economies at the one-year horizon. This confirms the perverse hedge observation in the short-run and a more neutral, but still negative behavior in the long-run. In addition, equities show high and significantly negative exposure to increasing inflation (-3.2) and real economic growth (1.4) in the long-run. International equities are less exposed to inflation. The one-year horizon is not significantly negative and of the five year domestic magnitude. The coefficients at the five-year horizon comes close to zero. In addition, the MSCI EM proves robust in bad times with positive exposure to increasing inflation and real economic decline.

The results are consistent for a specification without additional coefficients or without country fixed effects as well as for the narrow scoping AEn. EEb takes the view of an investor situated in emerging economies. Domestic equities again provide inferior inflation hedging for him compared to international equities (-1.3 vs. -0.4 and -0.8). Whereas the MSCI EM provided the best overall hedge for the investor in the advanced economies, the MSCI W hedges inflation better for the investor in the emerging economies.

The time-stability of the inflation hedging coefficient is shown in Figure 8.1 for AEb. International indices outperform domestic equity in all years except for the MSCI EM in the early 1990s. The common peak in the early 2000s could be driven

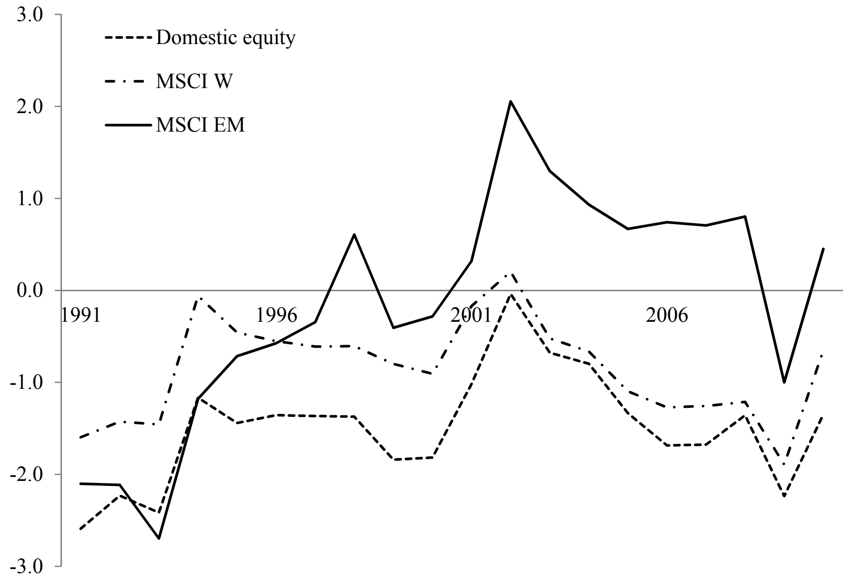
[3] As defined in Chapter 5.2.3.

Table 8.1: Inflation hedging and real return characteristics of domestic and international indices

	Real Return Statistics							**1a Returns**			**5a Returns**		
	N	Min	P50	Mean	Max	S.D.	SR	π	$\Delta\pi$	ΔGDP	π	$\Delta\pi$	ΔGDP
AEb													
Inflation	860	-6	3.1	4.6	24	4.4							
Dom. Equity	860	-105	9.0	5.5	107	28.2	24	-1.28*	-0.78	-0.09	-0.69	-3.17***	1.41**
MSCI W	860	-82	8.7	4.2	50	21.4	25	-0.68	-1.09**	-0.90**	-0.19	-3.00**	0.27
MSCI EM	860	-106	10.4	7.9	78	29.6	31	-0.76	0.82	-1.25*	-0.17	1.75*	-1.26***
AEb, only π													
Dom. Equity								-1.46**			-0.68		
MSCI W								-1.00			-0.20		
MSCI EM								-0.71			-0.18		
AEb, without country fixed effects													
Dom. Equity								-1.07*	-0.88	-0.09	-0.47	-2.77***	0.65*
MSCI W								-0.56	-1.20**	-0.72*	-0.13	-2.88**	0.15
MSCI EM								-0.65	0.69	-1.01*	-0.14	1.37	-0.57**
AEn													
Inflation	603	-6	2.3	2.9	14	2.6							
Dom. Equity	603	-105	11.9	6.8	96	26.4	34	-0.90	0.50	0.01	0.19	-2.01*	1.97***
MSCI W	603	-82	9.3	5.6	50	20.6	33	-0.47	-0.24	-0.35	0.30	-4.27***	1.46*
MSCI EM	603	-106	13.1	8.7	78	32.0	35	-0.46	2.47*	-1.51*	1.10	4.23***	1.94***
EEb													
Inflation	363	-15	5.4	6.4	24	5.2							
Dom. Equity	363	-139	11.1	8.3	101	38.4	26	-1.33**	-0.27	-0.46	-0.84	-0.07	2.54***
MSCI W	363	-69	6.6	3.8	88	20.5	21	-0.40	-0.12	-0.13	0.29	-0.51***	0.61
MSCI EM	363	-93	11.8	9.2	83	31.8	26	-0.84	-0.10	0.49	0.15	0.29	1.53***

This table summarizes the real return statistics and coefficient estimates of panel regression (8.1), $r_{r,c_1,c_2,t} = \alpha_{c_1} + \beta_r \pi_{c_1,t} + \gamma \Delta\pi_{c_1,t} + \delta \Delta GDP_{c_1,t} + \epsilon_{c_1,c_2,t}$, for domestic equity, the MSCI W, and MSCI EM at the one and five year investment horizon. The main results AEb are followed by additional robustness tests on specification (only with π coefficient, without country fixed effects), the sub-sample of financially open advanced economies AEn, and out-of-sample emerging markets EEb.
Notes: Return statistics in %, logarithmic annual real returns; significance levels of 10% (*), 5% (**), and 1% (***); S.D. standard deviation; SR Sharpe ratio based on median excess return over domestic risk-free rate.
Source: Rödel [2012].

Figure 8.1: Inflation coefficients of domestic equity, MSCI W, and MSCI EM for rolling 20a windows



The lines show the one year real return inflation coefficient β_r of panel regression (8.1), $r_{r,c_1,c_2,t} = \alpha_{c_1} + \beta_r \pi_{c_1,t} + \gamma \Delta\pi_{c_1,t} + \delta \Delta GDP_{c_1,t} + \epsilon_{c_1,c_2,t}$, for rolling 20a windows denoted at their ending year. The relatively short windows result in large coefficient standard deviations. Non of the differences reaches 5% significance.
Source: Rödel [2012].

by the coincidence of strong equity performance and elevated (not high) inflation in the late 1990s. After 2000 the MSCI W loses its edge and almost converges with the domestic index which indicates increasing comovement amongst the advanced economies. The sample only contains two non-overlapping observations which lets me turn to the cross-section for further analysis.

Table 8.2 shows significant cross-sectional variation in the inflation coefficients as well as in the relative benefit of international diversification, especially in the cases with short data history (e.g. Ireland and New Zealand). The MSCI W and MSCI EM one year inflation beta average 0.8 and 1.1 higher than the one of domestic equity. It is superior in approximately 70% of the countries. Notable exceptions are Germany, Japan, and Switzerland with a negative difference

Table 8.2: Inflation coefficient cross-section for domestic and international indices

Country		1a Horizon			5a Horizon		
	N	Domestic	ΔMSCI W	ΔMSCI EM	Domestic	ΔMSCI W	ΔMSCI EM
Australia	39	-1.20	0.45	0.38	-0.46	0.49	0.13
Austria	39	-1.13	0.45	0.18	-2.35	3.12	2.93
Belgium	39	-1.36	0.16	-0.67	-1.50	0.42	0.11
Canada	39	-0.92	0.20	0.03	-0.44	0.28	0.18
Denmark	39	-0.77	-0.02	-0.51	-0.66	0.84	-0.14
Finland	39	-2.12	1.25	1.36	-1.69	0.93	1.31
France	39	-0.80	0.71	0.25	-0.54	0.57	0.30
Germany	39	-0.50	-1.27	-0.89	-1.26	0.11	1.10
Greece	34	-0.04	0.64	0.54	2.63	-2.36	-1.55
Hong Kong	39	-2.30	1.18	1.27	0.11	-0.52	-0.38
Ireland	22	-12.16	2.40	7.85	-8.05	-2.12	9.75
Israel	18	-1.59	2.38	-0.04	-1.13	2.38	-1.21
Italy	39	-0.42	1.09	0.79	-0.66	0.81	0.53
Japan	39	-1.34	-0.59	-0.49	-1.46	-0.50	-0.63
Netherlands	39	-1.27	-0.37	-0.34	-1.53	-0.14	0.91
New Zealand	24	-7.82	4.50	5.53	-3.67	4.40	16.54
Norway	39	-2.18	2.19	1.60	-0.90	0.79	1.16
Portugal	21	-3.13	1.00	4.93	-4.74	1.71	7.01
Singapore	39	-4.75	1.29	1.77	-1.08	-1.80	-0.83
Spain	39	-1.93	1.51	1.42	-1.79	1.55	1.43
Sweden	39	-1.07	0.51	0.63	0.06	0.26	-0.36
Switzerland	39	-2.00	-0.50	0.17	-1.95	1.17	2.83
United Kingdom	39	-0.32	-0.22	-0.35	-0.35	-0.20	-0.34
United States	39	-1.11	-0.23	-0.03	-0.64	0.17	-0.01
Min		-12.16	-1.27	-0.89	-8.05	-2.36	-1.55
Mean		-2.18	0.78	1.06	-1.42	0.51	1.70
Max		-0.04	4.50	7.85	2.63	4.40	16.54
Share >0			0.71	0.67		0.71	0.63

The inflation coefficient estimates β_r are regressed for each country independently based on equation (8.1), $r_{r,c_1,c_2,t} = \alpha_{c_1} + \beta_r \pi_{c_1,t} + \gamma \Delta\pi_{c_1,t} + \delta \Delta GDP_{c_1,t} + \epsilon_{c_1,c_2,t}$, for the one and five year investment horizon. Column three shows the coefficient for domestic equity, column four and five the gap of the international index compared to the domestic one. Positive difference means a superior hedging coefficient. For example, the domestic inflation coefficient in Australia (au) is -1.2 for domestic equity. The MSCI W has a 0.45 superior inflation coefficient (i.e. -0.75. The five-year horizon bases on rolling observations and with an N of the one-year horizon minus four.
Source: Rödel [2012].

Table 8.3: Cross-sectional regression of the MSCI W and MSCI EM inflation hedging coefficients on inflation comovement and currency strength

	Horizon	**Outlier**	$\theta_{c,e}$	**PPP**$_{c,b}$	**Intercept**	**N**	**R^2 adj.**
MSCI W	1a	Y	-14.9***	1.6***		24	0.56
		N	-11.1***	1.4***		20	0.65
		Y	-18.1***	1.5**	0.78	24	0.36
	5a	Y	-15.5***	2.2***		24	0.55
		N	-8.2***	1.2***		20	0.49
		Y	-17.0***	2.1***	0.36	24	0.48
MSCI EM	1a	Y	-1.5**	-0.1		24	0.33
		N	-2.4***	0.6		20	0.60
		Y	5.5**	0.6*	-5.1***	24	0.23
	5a	Y	-3.6***	2.7***		24	0.40
		N	-1.3**	0.5		20	0.20
		Y	-2.0	2.8***	-1.1	24	0.40

The coefficient estimates base on regression (8.4), $\beta_{r,c} = \alpha + \beta ppp_{c,b} + \gamma\theta_{c,e}$, performed by horizon, without outliers (countries ie, il, nz, pt), and without intercept. $\theta_{c,e}$ represents the inflation comovement amongst the advanced economies (for the MSCI W) and between advanced and emerging economies (for the MSCI EM). Significance levels of 10% (*), 5% (**), and 1% (***).
For example, the inflation hedging of the MSCI W at the one-year horizon is negatively impacted by a high comovement amongst advanced economies ($\theta_{c,e}$) and positively by a weak domestic currency measured against a stable currency basket ($ppp_{c,b}$).
Source: Rödel [2012].

greater 0.5. These countries were often associated with strong currencies and a high level of economic integration. Equation (8.4) allows a more formal test of this hypothesis. Table 8.3 presents the results. Higher comovement of domestic inflation with the target region's inflation decreases exchange rate moderation and the inflation hedging coefficient (mostly significant at 1%). A stronger domestic currency decreases currency gains at high inflation rates and further lowers the inflation hedging coefficient (mostly significant at 1% for MSCI W). Both factors combined explain almost 50% of the deviation.

In summary, broad international equity indices generally provide superior inflation hedging against the inflation level and inflation changes compared to domestic equities. The hedge is strongest for investors with a relatively weak local currency. Lower comovement between domestic and foreign inflation further strengthens the inflation hedge. Consequently, diversification into emerging economies (MSCI EM) is most beneficial for investors in advanced economies and diversification into advanced economies for investors from emerging economies. The next section digs deeper on this pattern.

8.3.2 Quintile portfolios based on comovement

Does diversification into countries with unrelated inflation hedge better than investments in countries with high comovement? I investigate this question based on two quintile portfolios.

The investment strategy ranks all potential target countries by their historic inflation comovement and constructs one portfolio with the quintile of countries that shows the highest correlation (P1) and another one with the quintile of lowest correlation (P5). It only uses ex-ante available information. The signal for an origin country c_1 and a potential target country c_2 bases on the ten year rolling bivariate inflation coefficient $\beta_{c_1,c_2,t}$ in the regression

$$\pi_{c_2,t-i} = \alpha + \beta_{c_1,c_2,t}\,\pi_{c_1,t-i} \qquad (8.7)$$
$$with\ i = 0, ..., 9.$$

The portfolios are country-specific, dynamic over time, and equally weighted with annual rebalancing. Target countries with a $\beta_{c_1,c_2,t} > 5$ are considered too risky for investment.[4]

Table 8.4 presents the results for P1 and P5. The portfolio of highest correlated inflation countries P1 exhibits a negative annual inflation coefficient of -1.4. International equities essentially show the same coefficient magnitude as domestic equities in the previous section. The portfolio with the least correlated inflation countries P5 has a coefficient of only -0.8.[5] It better exploits exchange rate effects and, even though methodologically not directly comparable, comes close to the much broader international indices studied before.

This pattern is consistent for (a) various specifications, such as without additional control variables or fixed effects, (b) different levels of diversification, e.g. excluding diversification within currency unions (resulting in a smaller diversifica-

[4] These are less than 1% of the cases.

[5] Yet slightly more statistically significant at 3% vs. 7%.

Table 8.4: Inflation hedging and real return characteristics of the country quintile portfolios P1, P5

Horizon	Signal	Targets	FE	Px	N	Mean	S.D.	π	$\Delta\pi$	ΔGDP
AEb										
1a	β_{10}	AE	Y	P1	860	4.2	26.3	-1.35 *	-0.17	-0.76 *
				P5	860	5.8	23.9	-0.83 **	-0.14	-0.6
			Y	P1	860	4.2	26.3	-1.46 *		
				P5	860	5.8	23.9	-0.92 **		
			N	P1	860	4.2	26.3	-1.12 *	-0.34	-0.62 *
				P5	860	5.8	23.9	-0.7 **	-0.23	-0.54
		AE, nCU	Y	P1	860	4.5	26.2	-1.42 **	-0.09	-0.92 *
				P5	860	6.1	24.0	-0.9 **	-0.11	-0.64
		AE, EE	Y	P1	860	6.9	29.3	-1.59 **	0.06	-1.05 **
				P5	860	7.3	28.5	-0.78 *	0.17	-1.07 *
	β_{20}	AE	Y	P1	860	5.2	26.2	-1.31 **	-0.41	-0.13
				P5	860	4.5	25.6	-0.7	-0.45	-0.97 ***
	$\theta_{c,r}$	AE	Y	P1	860	6.4	24.9	-1.29 ***	0.23	-0.46
				P5	860	3.8	25.0	-0.62	-0.77 *	-0.92 ***
5a	β_{10}	AE	Y	P1	764	5.1	9.7	-0.97 *	-1.26	0.07
				P5	764	6.3	8.0	-0.44 *	-1.32	-0.01
		AE, EE	Y	P1	764	7.5	9.8	-1.02 **	0.7	-0.31
				P5	764	7.0	8.6	-0.33	-0.28	-0.58
AEn										
1a	β_{10}	AE	Y	P1	603	7.3	25.0	-0.9	0.43	-0.38
				P5	603	5.7	25.1	-0.63	0.03	-0.65
		AE, nCU	Y	P1	603	7.8	24.7	-1.03	0.55	-0.58
				P5	603	6.2	25.1	-0.65	0.01	-0.72

This table summarizes the real return statistics and coefficient estimates of panel regression (8.1), $r_{r,c_1,c_2,t} = \alpha_{c_1} + \beta_r \pi_{c_1,t} + \gamma \Delta\pi_{c_1,t} + \delta \Delta GDP_{c_1,t} + \epsilon_{c_1,c_2,t}$, for diversification into the quintile of countries with the highest (lowest) comovement in inflation labeld P1 (P5). The main result for AEb based on a ten year signal β_{10} and diversifying into other advanced economies is followed by additional robustness tests on specification (only with π coefficient, without country fixed effects), different diversification possibilities (nCU: excluding diversification within currency unions, EE: also into emerging economies), different signals (β_{20} with 20a history, $\theta_{c,r}$ based on dynamic latent factor model), the 5a horizon, and the AEb sub-sample.
Notes: Return statistics in %, logarithmic annual real returns; significance levels of 10% (*), 5% (**), and 1% (***); S.D. standard deviation.
Source: Rödel [2012].

tion universe and less powerful hedging) or including diversification into emerging economies (resulting in a larger diversification universe and a wider spread), (c) a longer 20 year history to compute the bivariate inflation coefficient, (d) a simpler country selection based on $\theta_{c,r}$[6], (e) for the longer five-year horizon at which the level, but not the gap decreases, (f) for the narrower AEn scoping. The return characteristics of both portfolios are fairly comparable with P5 generally being less volatile.

Figure 8.2 in the appendix shows the time-stability of the inflation hedging coefficient for P1 and P5 in AEb. The high beta portfolio P5 mostly outperforms P1 with the largest gap being between 1983 and 2008. The strategy was reversed in the mid 1990s.[7] Similar to the broad international indices, the time period is not long enough for a detailed intertemporal analysis.

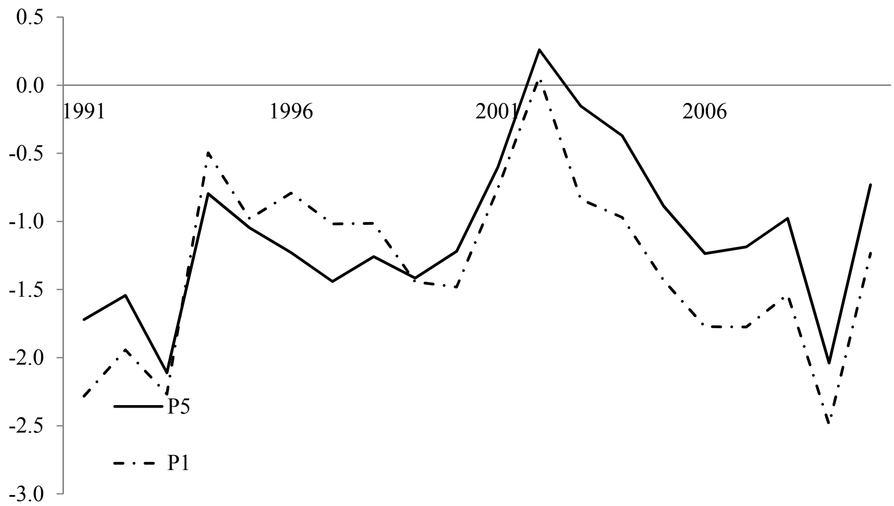
Table 8.5 shows significant cross-sectional variation in the inflation coefficients, especially if the available data history is short, e.g. Ireland and Israel. The inflation beta difference ΔP51 averages at 0.85 and is positive in 79% of the countries. The only exceptions with full coverage are Italy and Spain. Equation (8.4) allows a more formal test with the results shown in Table 8.6. The pattern matches the one for MSCI W and MSCI EM. Higher comovement of domestic inflation with the target region's inflation decreases the inflation hedging coefficient (mostly significant at 1%). A stronger domestic currency further lowers the inflation hedging coefficient (often significant at 1% for P1). Both factors combined explain almost 70% of the deviation for P1. The low beta portfolio P5 naturally is less exposed than P1, especially to comovement. The gap between the two strategies is almost entirely explained by the level of comovement. Evidence from emerging economies confirms this picture and is available upon request, knowing that investability was low until the 2000s.

In summary, inflation comovement strongly impacts the effectiveness of international equities as inflation hedge. High comovement eliminates the benefit of exchange rate moderation and renders international equities to be merely as effective as domestic equities.

[6] The signal bases on the ten year rolling $\theta_{c,r}$ from Equation (8.6). The target countries are the same for all origin countries except for the countries that are in the first or fifth quintile. These are then replaced by the next correlated one.

[7] When including earlier time periods starting 1949 with less capital mobility, P5 was superior to P1 until the 1974-1993 window.

Figure 8.2: Inflation coefficients of the country quintile portfolios P1 and P5 for rolling 20a windows



The lines show the one year real return inflation coefficient β_r of panel regression (8.1), $r_{r,c_1,c_2,t} = \alpha_{c_1} + \beta_r \pi_{c_1,t} + \gamma \Delta \pi_{c_1,t} + \delta \Delta GDP_{c_1,t} + \epsilon_{c_1,c_2,t}$, for rolling 20a windows denoted at their ending year. The relatively short windows result in large coefficient standard deviations. Non of the differences reaches 5% significance.
Source: Rödel [2012].

Table 8.5: Inflation coefficient cross-section for the country quintile portfolios P1 and P5

Country		**1a Horizon**			**5a Horizon**		
	N	P1	P5	ΔP51	P1	P5	ΔP51
Australia	39	-1.91	-1.22	0.68	-1.07	-0.35	0.72
Austria	39	-1.90	-0.03	1.87	-0.77	2.42	3.19
Belgium	39	-2.49	-2.28	0.21	-2.70	-1.43	1.27
Canada	39	-2.03	-0.80	1.23	-1.49	-0.13	1.36
Denmark	39	-1.57	-1.23	0.34	-0.57	-0.15	0.42
Finland	39	-2.06	-1.26	0.80	-1.77	-0.94	0.83
France	39	-1.06	0.00	1.06	-0.95	0.02	0.96
Germany	39	-3.56	0.60	4.16	-3.55	-0.61	2.95
Greece	34	0.36	0.04	-0.32	-0.60	0.43	1.03
Hong Kong	39	-1.19	-0.77	0.43	-0.41	-0.86	-0.44
Ireland	22	-10.70	-8.77	1.93	-8.28	-9.15	-0.87
Israel	18	0.64	0.40	-0.24	0.93	0.76	-0.17
Italy	39	0.46	0.05	-0.41	-0.15	-0.27	-0.12
Japan	39	-2.63	-1.48	1.16	-2.48	-0.73	1.75
Netherlands	39	-3.49	-1.72	1.76	-3.53	-1.60	1.93
New Zealand	24	-2.19	-3.33	-1.13	4.54	4.67	0.13
Norway	39	-0.62	-0.54	0.08	-1.02	-0.20	0.82
Portugal	21	-2.27	-1.01	1.27	-3.09	-1.36	1.73
Singapore	39	-3.71	-2.68	1.03	-3.64	-2.96	0.68
Spain	39	-0.66	-0.90	-0.24	-0.51	-0.82	-0.32
Sweden	39	-1.95	-0.60	1.35	-0.95	0.39	1.33
Switzerland	39	-3.56	-2.19	1.38	-3.26	-0.14	3.12
United Kingdom	39	-1.62	0.05	1.67	-1.71	-0.13	1.58
United States	39	-2.30	-1.89	0.41	-2.18	-0.72	1.46
Min		-10.70	-8.77	-1.13	-8.28	-9.15	-0.87
Mean		-2.17	-1.31	0.85	-1.63	-0.58	1.06
Max		0.64	0.60	4.16	4.54	4.67	3.19
Share >0				0.79			0.79

The inflation coefficient estimates β_r are regressed for each country independently based on equation (8.1), $r_{r,c_1,c_2,t} = \alpha_{c_1} + \beta_r \pi_{c_1,t} + \gamma \Delta\pi_{c_1,t} + \delta \Delta GDP_{c_1,t} + \epsilon_{c_1,c_2,t}$, for the one and five year investment horizon.
For example, the inflation coefficient of P1 in Australia (au) is -1.9 for domestic equity. P5 has -1.2 resulting in a difference ΔP51 of 0.7. The five-year horizon bases on rolling observations and with an N of the one-year horizon minus four.
Source: Rödel [2012].

Table 8.6: Cross-sectional regression of the P1 and P5 inflation hedging coefficients on inflation comovement and currency strength

	Horizon	Outlier	$\theta_{c,e}$	$\mathbf{PPP}_{c,b}$	Intercept	N	$\mathbf{R}^2$ adj.
P1	1a	Y	-19.3***	1.7***		24	0.72
		N	-13.7***	1.0		20	0.71
		Y	-18.6***	1.8***	-0.2	24	0.42
	5a	Y	-20.8***	2.6***		24	0.79
		N	-13.9***	1.2**		20	0.74
		Y	-14.7***	2.8***	-1.5	24	0.72
P5	1a	Y	-12.3***	1.1**		24	0.51
		N	-8.1***	0.7		20	0.55
		Y	-16.1***	1.0*	0.91	24	0.28
	5a	Y	-15.9***	2.7***		24	0.64
		N	-6.8**	1.0*		20	0.25
		Y	-13.3**	2.7***	-0.6	24	0.62
ΔP51	1a	Y	7.0***	-0.6*		24	0.44
		N	5.6*	-0.2		20	0.39
		Y	2.6	-0.8**	1.1	24	0.15
	5a	Y	4.9**	0.0		24	0.43
		N	7.1**	-0.2		20	0.59
		Y	1.3	-0.1	0.9	24	-0.09

The coefficient estimates base on regression (8.4), $\beta_{r,c} = \alpha + \beta ppp_{c,b} + \gamma\theta_{c,e}$, performed by horizon, without outliers (countries ie, il, nz, pt), and without intercept. $\theta_{c,e}$ represents the inflation comovement amongst the advanced economies. Significance levels of 10% (*), 5% (**), and 1% (***).
For example, the inflation hedging of P1 at the one-year horizon is negatively impacted by a high comovement amongst advanced economies ($\theta_{c,e}$) and positively by a weak domestic currency measured against a stable currency basket ($ppp_{c,b}$). The first effect is weaker for P5 so that the inflation hedging difference ΔP51 is positively linked to the overall comovement.
Source: Rödel [2012].

8.4 Discussion

This section reflects the positive inflation hedging of international equities and highlights the implications for the investor. It also critically assesses its literature contribution and limitations.

8.4.1 Implications

Academia has widely discarded domestic equities as inflation hedge. The results confirm the negative empirical findings with real returns going down almost one for one when inflation goes up. However, this does not rule out equities for investors concerned of higher inflation. I show that international equities generally serve as superior inflation protection. Moreover, investors from advanced economies gain further when diversifying into the relatively unrelated emerging markets. The investment then not only protects against higher inflation levels but also against rising inflation rates and declining real economic output.

Yet, international diversification cannot cure all inflation concerns. I identify two determinants behind the hedging effectiveness that the investor should bear in mind: Currency strength and inflation comovement. A relatively weak currency suffers over proportionally at high inflation as soon as investors lose trust and confidence in that country's monetary institutions. Capital flight and currency depreciation follows. While this diminishes the investor's local wealth it fuels the performance of his international equity investments. They appreciate in value and hedge inflation. Purchasing power parity and exchange rate moves essentially account for inflation differentials. Synchronous, perfectly correlated, inflations eliminate the benefit of exchange rate moderation and render international equities to be merely as effective as domestic equities. Thus, high financial and economic integration as well as regional proximity between the investor's home country and target investment matter.

If an investor assumes that his home currency will perform strongly and that local inflation will comove with the target country's inflation, international equities are likely to perform similar to domestic equity: Their inflation hedging will be imperfect. In contrast, if he faces a depreciating home currency and idiosyncratic inflation shocks, international equities will provide an attractive inflation hedge as long as capital mobility is not restricted. This assessment should be done forward looking and on a periodic basis as these characteristics are subject to changes in monetary policy. The results are good news for investors that need it the most, i.e. those in countries with weak currency and (high) idiosyncratic inflation shocks. Turning it around implies that it worked less for investors from the monetary most stable countries such as Germany, Japan, or Switzerland. The same criteria also apply for target country selection with a reverse sign. Investments into less correlated countries with strong currencies are likely to hedge inflation as the quintile portfolios show.[8] Their hedging effectiveness is only comparable to a broad international equity basket but does generally not exceed it.

The results also provide insights for hedging global inflation shocks. These shocks by definition imply a high degree of global comovement in inflation as expressed in the dynamic factor model. This comovement dilutes exchange rate moderation and undermines the effectiveness of international equities for inflation hedging.

8.4.2 Contributions to the literature

These findings extend the inflation hedging research towards international diversification. International equity investments generally hedge inflation superior than domestic assets. The hedge is the stronger the weaker the domestic home currency and the lower the comovement between domestic and foreign inflation. The benefit of international equities seems to be unfairly ignored by previous research. I explicitly consider exchange rate moderation and identify currency strength and inflation comovement as relevant factors. These dynamics are highly likely to influence the inflation hedging of the other international assets as well, such as international fixed income portfolios or commodity investments just to name a few. The chapter can serve as starting point for further analyses in this direction.

The results generally support purchasing power parity in the long-run. First, exchange rates moderate inflation and international diversification contributes to inflation hedging. Second, the moderation does not only relate to absolute inflation but to inflation differentials. Comovement takes over a negative role in

[8] The hedge still remains imperfect on average.

the hedging dynamics.

8.4.3 Limitations and directions for future research

The volatility of domestic equities is high and international diversification cannot reduce it. The exchange rate movement adds uncertainty which is not offset on average by the increased diversification level. Thus, any hedging strategy on such an underlying will still involve significant short-fall risks. Moreover, the results of narrow sub-periods and single countries become unstable. Again, the inflation hedging coefficients should only be interpreted directionally.

The results relate only to broad equity indices. Equity subsectors might behave differently and are subject to further research. Multi-national corporations for example might already allow ’‘international diversification’ with domestic stocks. Similarly, international diversification into fixed income or alternative investments remains largely uncharted terrain.

Lastly, history has shown that high inflation environments are susceptible for negative surprises such as capital restrictions, special taxes for foreign holdings, holding restrictions, etc. Capital mobility cannot be taken for granted and the investor has to explicitly take a stand on this before building on international diversification for inflation hedging. Or he ought to find alternatives which still allow international speculation absent of actual capital mobility, for example in the derivatives space.

8.5 Summary

International equities generally hedge against inflation level and inflation changes superior than domestic equities. The hedging effectiveness depends on the strength of the local currency. The more it (over)reacts against local inflation, the stronger the inflation protection of foreign assets. In addition, it depends on the comovement between international inflations. The lower the correlation between domestic and the target region’s inflation, the stronger the exchange rate moderation and thus inflation hedging. Overall, it works best for countries with relatively weak currencies and idiosyncratic (high) inflation, which is good news for investors that need it the most. Turning it around implies that it works less for investors from the monetary most stable countries such as Germany, Japan, or Switzerland, which have had strong currencies and suffered largely from systematic inflation shocks in the recent past.

The results are consistent with the economic predictions based on relative purchasing power parity and the observed perverse hedge of equities against inflation. Evidence from emerging economies confirms these findings for a parallel dataset knowing that investability would have been low in that case.

Chapter 9

Conclusion

This chapter identifies the overarching implications of this dissertation. Thereby it broadens the perspective of the previous chapters.

9.1 Implications for the investor

The inflation hedging literature is full of surprises. It uncovers conventional wisdom as insufficient guide to protect a portfolio against inflation up to 20%. “Real” assets often turned out to be not all that real. In contrast, monetary assets performed not all that badly, while gold was far from being a “safe harbor.” Theoretical predictions such as the neutrality of money and the Fisher hypothesis do not hold, either.

A broad perspective on inflation hedging can dissolve some of these surprises. The relationship between inflation and asset prices becomes nonlinear for most asset classes. While bills and bonds still somewhat protect against low and moderate inflation, they fail to hedge high inflation. Stocks hedge low inflation perversely but, finally, play out their real asset character during high inflation. The inflation nonlinearity highlights the importance of conditional asset class choice. The preferred investment of an investor with high inflation expectations looks very different from one with low inflation expectations.

Few assets escape from this nonlinearity and appear as strong inflation hedges.

Listed infrastructure with high pricing power hedges inflation robustly. Its real returns are independent of inflation at the five-year investment horizon for inflation up to 20%. Infrastructure with low pricing power is as poor an inflation hedge as equities. Thus, the investor needs to conduct careful due dilligence for the pricing power of its infrastructure targets.

Real commodity returns appear linear and move largely independently of inflation. The law of one price suggests that this is mostly driven by exchange rate moderation, which also drives the inflation hedging of international diversification more broadly. International equities hedge inflation very well if foreign inflation exhibits little comovement compared to domestic inflation and the domestic currency is weak. Investors should look to international assets to hedge domestic inflation. The strategy works best for those who need it the most: Investors in countries with weak currency and idiosyncratic inflation shocks.

Lastly, inflation hedging depends on the investment horizon. No single asset in the analysis perfectly hedges inflation at the relatively short one-year horizon. And even if the hedging coefficient is small, high short-term volatility puts significant uncertainty on the actual outcome of an investment. Hedging becomes easier at long horizons across all asset classes. These are good news as the concerns behind inflation hedging are typically long-term rather than short-term.

9.2 Contribution to the literature

The contributions to the literature group along the three hypotheses. The first result indicates a nonlinearity in the inflation hedging of fixed income and equities, which was not explicitly accounted for before. The high inflation experience of emerging economies allows for leaving the narrow frame of most previous research and combining the perverse hedge of equity during low inflation with the conventional wisdom of real assets, the surprisingly strong hedging of bills during low inflation with significant real losses at high inflations. The result is primarily driven by inflation level and is not an artifact of country selection. Emerging economies also exhibit nonlinearity, although to a lesser degree. Inflation hedging nonlinearity reveals strong hedging of international assets with only a slightly negative coefficient in the case of developed market equities at low inflation. This result bridges the gap between empirical research and conventional wisdom while demanding a new theory that can explain this dynamic.

The second contribution is about infrastructure. The recent growth and popularity of this asset class in the investment community was fueled in part by the perception of infrastructure to be a good hedge against inflation. No academic research has yet comprehensively analyzed this proposition. My results generally uncover this as wishful thinking rather than empirical fact. Only the subset of infrastructure firms with high pricing power, according to regulatory and market competitiveness data from the OECD, serves as an inflation hedge at the five-year horizon during low and mid inflations. The positive hedging evidence found in previous research was biased because of international diversification. Although it may disappoint some of its advocates, this represents an important finding for this relatively new investment field.

Inflation hedging has extensively been analyzed for domestic assets. Yet, virtually no research exists on international diversification. My third contribution extends inflation hedging towards international equity diversification. Focusing on the subset of countries with high capital mobility, I find that investments in broad international equity indices generally hedge inflation better than domestic equities. Exchange rate moderation works in favor of the investor. However, the benefits depend on international inflation comovement and on currency strength. A strong home currency and high inflation comovement neutralize the benefits of international diversification due to a flight toward quality and purchasing power parity. International equities then behave similarly to or even worse than domestic equities. This result opens up a new dimension to the existing body of research. And the identified factors are likely to also influence the performance of other asset classes. This work hopefully serves as starting point for future explorations.

9.3 Directions for future research

This dissertation points out several questions for future research. Firstly, what causes nonlinearity in equities? Several hypotheses try to explain the perverse hedge of equities, however, with limited success. These theories must not only be able to explain the perverse hedge, but must now also be compatible with the positive hedging found during higher inflation levels. Connecting these two legs in one compelling financial or economic theory represents the next logical step.

Secondly, what are the broader inflation hedging dynamics behind international diversification? My analysis focuses on equities during periods of capital mobility and low to medium inflation. An extension towards high inflation and the introduction of capital restrictions such as special taxes or holding restrictions would close the loop towards the first chapter on inflation nonlinearities. An investigation on bonds or other asset classes could further bolster the impact of inflation correlation and currency strength.

Lastly, most research on inflation hedging isolates the conservation of existing wealth, which is conceptually valid but not very realistic. How would the dynamics play out in an investor lifetime model that views initial wealth in a portfolio context and also incorporates uncertain future income and consumption? Academia will only be able to provide effective guidance for the investor after answering these questions.

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