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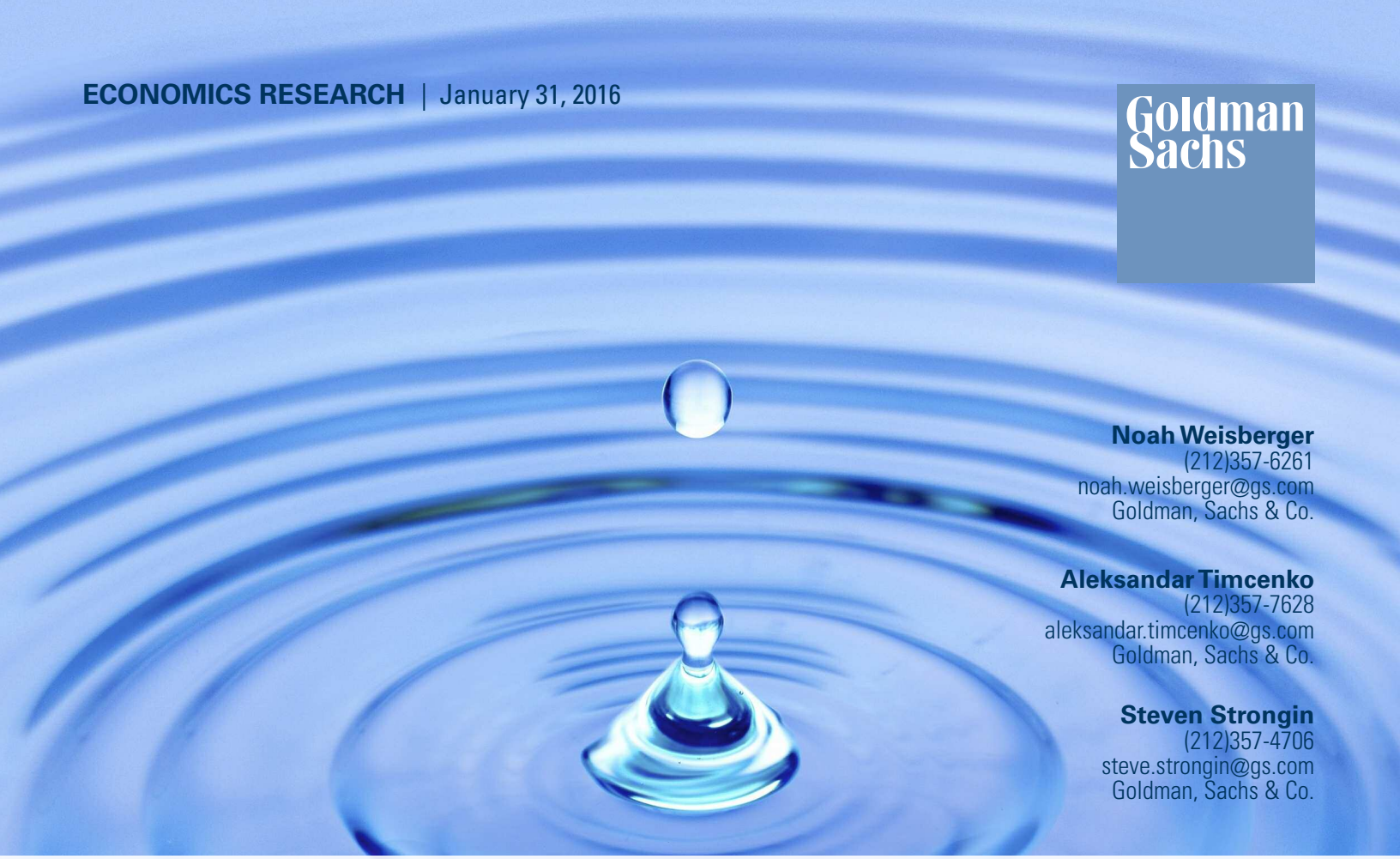

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Global Economics Paper: 228

Wavefronts 2.0: The impact of macroeconomic shocks on markets

• In this *Global Economics Paper* we develop a set of tools to track the impact of a shift in macro view across a wide set of markets in a consistent and comprehensive way. These tools expand the framework we introduced for equities with our Wavefront models in 2004 and can also be deployed to infer from price action the set of macroeconomic scenarios that is being reflected by markets.

• The focus on the impact of macroeconomic risks and the implicit pricing of those risks is based on the observation that the macroeconomic outlook is a primary building block in the investment process. Yet, each market tends to have its own set of particular risk factors, and its own lingua franca associated with them. While these market-specific risk categories have their own macroeconomic linkages, they do not travel well across market and investment-style borders.

• While the basic insight is quite simple – different markets price a common set of macroeconomic risks – the toolkit we have developed is quite rich. It quantifies asset exposures to key macroeconomic risks and can be used to aid in: (1) taking directional macroeconomic risks, (2) hedging directional macroeconomic risks and (3) looking across markets for the best way to implement a view about a specific macroeconomic risk.

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1. Wavefronts 2.0: The impact of macroeconomic shocks on markets

This Global Economics Paper develops a set of tools to track the impact of a shift in the macroeconomic landscape across a wide set of markets in a consistent and comprehensive way. These can also be deployed to infer from price action the set of macroeconomic scenarios that is being reflected by markets.

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The focus on the impact of macroeconomic risks and the implicit pricing of those risks is based on the observation that the macroeconomic outlook is a primary building block in the investment process, nearly without regard to style or market. Yet, each market tends to have its own set of particular risk factors, and its own *lingua franca* associated with them. Bond investors may focus on duration and curvature, equity investors may focus on earnings yield and P/E ratios, while carry and monetary policy are key considerations for FX investors. These market-specific risk categories surely have their own macroeconomic linkages, yet they do not travel well across market and investment-style borders. The vocabulary of one market does not necessarily translate directly into that of another.

To build a multi-market vocabulary, we deploy risk models that link asset markets to macroeconomic risk factors, which are a natural source of commonality. Markets and market participants need to consider a common set of macroeconomic risks; they also share a common set of macroeconomic information. After all, regardless of investment style or market, there is but one US GDP report and one employment situation report that must be digested by all. It therefore stands to reason that markets, regardless of their idiosyncrasies, need to confront the evolving macroeconomic landscape in a consistent and coherent way. In this context, developing a vocabulary to think about the impact of ***common macroeconomic risks across different markets*** is critical.

At its core, such a framework ought to address two critical questions:

- *How does a given asset respond to a given macroeconomic risk?*
- *What implicit macroeconomic risks are being priced by assets at a point in time?*

The analytic framework developed to address these questions will allow investors to understand which macroeconomic risks drive which assets, how exposed a given asset or portfolio is to those macroeconomic risks, which macroeconomic risks are in focus at a point in time, and how a given market has shifted its view of a specific macroeconomic risk.

In this *Global Paper* we outline a methodology that links asset returns to a common set of ***market-based macroeconomic risk factors***. We start by building a set of such factors to capture key economic risks: economic growth (with geographic specificity), policy, inflation and supply-side shifts. We use these risk factors to explain asset returns over time and to quantify each asset's exposure to these macroeconomic risks. We then demonstrate that differences across assets in terms of their macro exposures determine differences in relative returns. We also show that assets and asset markets tend to converge to a common, implied, macroeconomic view.

While the basic insight is simple – most markets price a common set of macroeconomic risks – the toolkit developed below is quite rich. It quantifies asset exposures to key macroeconomic risks and can be used to aid in: (1) taking directional macroeconomic risks, (2) hedging directional macroeconomic risks and (3) looking across markets for the best way to implement a view about a specific macroeconomic risk.

2. The impact of common macroeconomic risks across markets

In this paper, we develop a methodology that tracks the impact of various macroeconomic risks on asset prices and that also can be used to discern what market prices are implicitly saying about those macroeconomic risks. In this context, we note five key lessons.

1. Market-based macroeconomic risk factors reflect the data and explain asset returns.

2. Macroeconomic risks affect a wide range of assets across several key markets in a systematic and consistent way.

3. Getting the macroeconomic view right matters.

4. Markets tend to converge to a common macroeconomic view.

5. Assets tend to revert to their macroeconomic fundamentals over time.

1. ***Market-based macroeconomic risk factors reflect the data and explain asset returns.*** We explore a set of seven ***market-based macroeconomic risk factors***:
   - US economic growth
   - Chinese economic growth
   - European economic growth
   - US financial conditions
   - European financial conditions
   - US inflation
   - Oil prices (as a proxy for supply-side shocks)

   These risk factors are *market-based*, allowing them to be directly linked to asset prices. They are correlated to important macroeconomic data and explain a significant portion of asset returns across a wide range of markets, justifying their use in a macroeconomic risk framework.

2. ***Macroeconomic risks affect a wide range of assets across several key markets in a systematic and consistent way.*** The proposed macroeconomic risk framework generates estimates of each asset's exposure to each of the seven market-based macroeconomic risk factors. These macroeconomic exposures are the vocabulary that facilitates comparisons across markets in order to determine how macroeconomic risks affect markets.

3. ***Macroeconomic views can inform relative returns.*** Not only do macroeconomic risks matter for a given asset's return over time, they also help determine relative returns across assets at a point in time. Differences across assets with respect to their exposure to a macroeconomic risk determine differences in relative returns across those assets. Hence, views about the likely evolution of macroeconomic risks can be expressed in relative value ways.

4. ***Markets tend to converge to a common macroeconomic view.*** Given that relative asset returns are driven by relative exposures to macroeconomic risks, at any point in time it is possible to back out from relative asset performance an *implied* shift in macroeconomic views. This allows us to assess how each market's macroeconomic views are evolving over time. For example, nothing forces equities and bonds to have the same view of the relevant macroeconomic risks. Indeed, over short periods of time, different markets do express different macroeconomic views, but disagreements do not last long. Over longer periods, markets tend to say similar things about the macroeconomic landscape. Understanding what a market is saying about a specific risk is a key aid in understanding where a given macroeconomic view has been fully priced by the market and where a given view has room to run.

5. ***Assets tend to revert to their macroeconomic fundamentals over time.*** Given that assets tend to price macroeconomic risks consistently, when an asset diverges from its macroeconomic fundamentals, it should revert to its underlying fundamental macroeconomic drivers.

3. Defining market-based macroeconomic risk factors

Linking price action directly to macroeconomic data is fraught with complexities. One workaround is to link low-frequency macroeconomic data trends to trends in low-frequency fundamental data, such as revenues and earnings. These linkages lie at the heart of our Wavefront models[1]. However, apart from equities (and corporate credit, which we do not include in this work), such tools cannot be extended to markets that lack such low-frequency, non-market-based fundamental data.

This approach relates asset prices to market-based macroeconomic risk factors, as opposed to the economic data themselves. We focus on macroeconomic risks that are part of the economic debate and that have plausible market corollaries.

Instead, we adopt an approach that relates asset prices to ***market-based macroeconomic risk factors***, selected on an *a priori* basis, as opposed to the economic data themselves. This mitigates the need for fundamental data and circumvents timing and expectations issues. It is consistent with the academic approach, pioneered by Fama and French, and further extended into a broader class of arbitrage pricing theory (APT) models. However, it does require that the identified *market-based macroeconomic risk factors* themselves relate to some (Platonic) notion of true macroeconomic risk (see Appendix 1).

Generally speaking, we focus on macroeconomic risks that are part of the economic debate and that have plausible market corollaries. (Appendix 2 outlines the guiding principles we followed in selecting risk factors.) Specifically, we identify three broad buckets of relevant macroeconomic risks, with several variants in each bucket (see Exhibit 1):

1. *Economic growth*, which includes US growth, European growth and China growth.
2. *Policy measures*, which includes US inflation expectations, US financial conditions and European financial conditions.
3. *Oil prices*, which we view as a supply-side driver.

In this *Global Paper*, we focus on these three 'families' of risks and corresponding seven risk factors. However, the framework can easily accommodate additional 'period-piece' factors that may be relevant at a given point in time.

We define the ***market-based US growth risk factor*** as the first principal component extracted from the US 10-year yield, the trade-weighted CAD and our Wavefront Consumer Growth basket. Defined this way, the underlying assumption is that, over time, what drives the common co-movement of these assets is a forward view of US growth. We then use this extracted factor – which is essentially a portfolio of the (weighted) underlying assets – to track this risk and to explain asset returns elsewhere. The units of the resulting factor have no physical meaning, so we scale the factor's mean and volatility to match US real GDP growth, so that its units can be interpreted more directly[2].

To verify the validity of this factor, we inspect its relationship to the economic data themselves.

[1] See *Introducing Wavefronts: A new way of trading macro equity views*, April 28, 2004 and *Global Economics* Paper: 221: "A macroeconomic view of the US equity market", September 25, 2013.

[2] See *Global Economics Weekly 12/15:* "Assets in a Three-Risk World", April 18, 2012.

Exhibit 1: Market-based macroeconomic risk factor constituents

Market-based Risk Factor	Constituents
US growth (Bloomberg symbol GSWBUSGF)	US 10-year Treasury Yield
	Trade-weighted CAD
	Wavefront Consumer Growth basket
European growth (Bloomberg symbol GSWBEUGF)	Eurostoxx consumer discretionary and industrial sectors vs. staples
	German real 10-year yield
	Trade-weighted PLN and SEK
China growth (Bloomberg symbol GSWBCHGF)	Chinese H-shares vs. S&P 500
	12-month CNY forward
	3-month copper futures
US Financial Conditions (ex-S&P 500)	Fed Funds
	TED spreads
	US 10-year Treasury Yield
	BBB Credit Spread
	Trade-weighted USD
European Financial Conditions	3-month Euribor Interest Rate
	Real Aggregate Corporate Bond Yield
	Equities relative to nominal GDP
	Trade-weighted EUR
US Inflation	US inflation swap
Oil Price	2-year oil swap

Source: Goldman Sachs Global Investment Research.

We find that the market-based US growth risk factor does indeed move closely with the US PMI, a measure of US economic growth, both on a levels basis and over a longer period of time in terms of year-on-year changes (see Exhibit 2). The PMI is only one of many possible growth measures, but we focus on it because it is monthly, is available fairly close to its reference month and is common across various geographies. On a 12-month-change basis, the correlation between the market-based US growth factor and the PMI is around 0.47. However, the market-based US growth risk factor is even more correlated to our proprietary Current Activity Index (CAI), which includes consumer data, as well as industrial and externally driven growth data (0.60 on a 12-month change basis).

Similarly, the ***market-based China growth risk factor*** is the first principal component of the ratio of the Chinese H-share market to the S&P 500, 3-month copper futures and the 12-month forward points of the CNY. This market-based China growth risk factor tends to be correlated with the Chinese PMI both in levels and changes (see Exhibit 3), and some of our proprietary measures of China growth[3]. We have matched the market-based factor's mean and volatility to China real GDP growth, to better facilitate interpretation of the factor's units.

[3] See *China: Taking stock of China activity: Updating our Current Activity Indicator*, November 18, 2015.

The ***market-based European growth risk factor*** is the first principal component across Eurostoxx Consumer Discretionary and Industrial sectors relative to the Eurostoxx Staples sector, real 10-year German yields, and the average of the trade-weighted Polish Zloty and Swedish Krona[4]. This market-based European growth risk factor tends to be correlated with European PMI data in levels and changes (see Exhibit 4) and is scaled to match units of the European CAI.

Turing to market-based economic risk factors that relate to policy and financial conditions, we lean heavily on the work of our US and European economic teams and use the ***US Financial Conditions Index***[5] and ***European Financial Conditions Index***[6]. The details of how these risk factors were constructed differ from the simple PCA approach used to define the market-based growth risk factors above, but the concept is the same. Both the US and European FCIs extract information from *multiple* markets, instead of relying on a single policy tool measure, to gauge the degree of financial accommodation. Both FCIs weigh the underlying bits in a way that produces an index that best captures the stance of financial conditions as it pertains to future economic growth prospects. For the US FCI, the underlying inputs are the level of Fed funds, TED spreads, 10-year Treasury yields, BBB credit spreads, the US Dollar and a (normalized) level of the S&P 500 index. For the European FCI, the underlying inputs are 3-month Euribor interest rates, the real aggregate corporate bond yield, the level of the equity market (relative to nominal GDP) and the trade-weighted Euro.

Our third measure in the policy bucket is ***US inflation*** as measured by 1-year inflation swaps.

Finally, we construct the ***oil risk factor*** from long-dated crude oil prices. Specifically, we isolate supply-driven price moves by controlling for demand-side dynamics. (See Appendix 3 for details.)

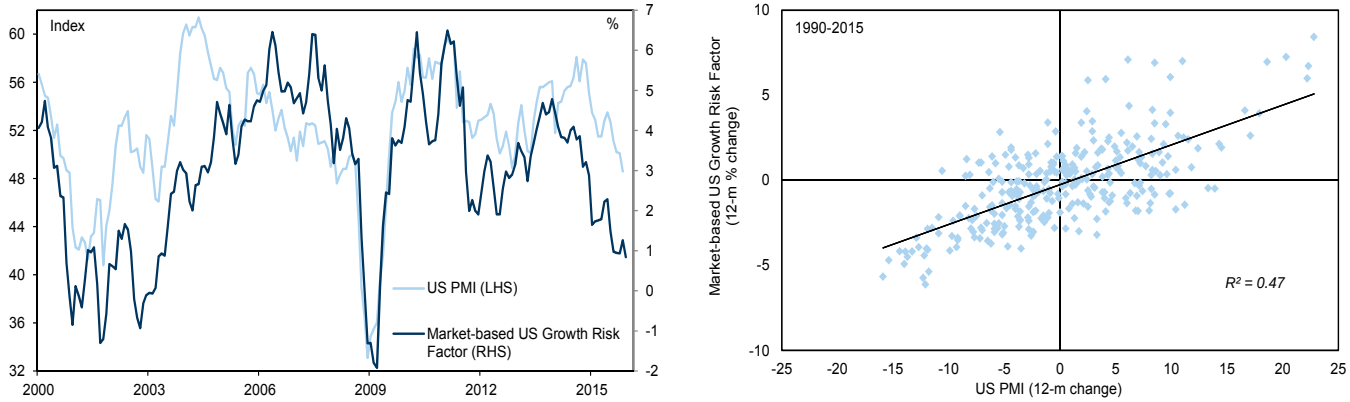
Critically, all of the variables included in constructing the macroeconomic risk factors are market prices, not economic data. Markets anticipate and are, by their nature, forward-looking. Hence, attempts to link economic data directly to market performance tend to become primarily models of how expectations are formed rather than the true economic linkages. Furthermore, as the formation of market expectations tends to be fairly unstable, such models tend to mirror this instability and have deeply unstable coefficients. In our experience, modelling 'market to market' linkages has proven to be far more robust.

[4] See *Global Economics Weekly 15/10*: "A market perspective on European growth", March 11, 2015.

[5] See *US Economics Analyst 15/19: "*Financial Conditions: Moving on from the Crisis", May 8, 2015.

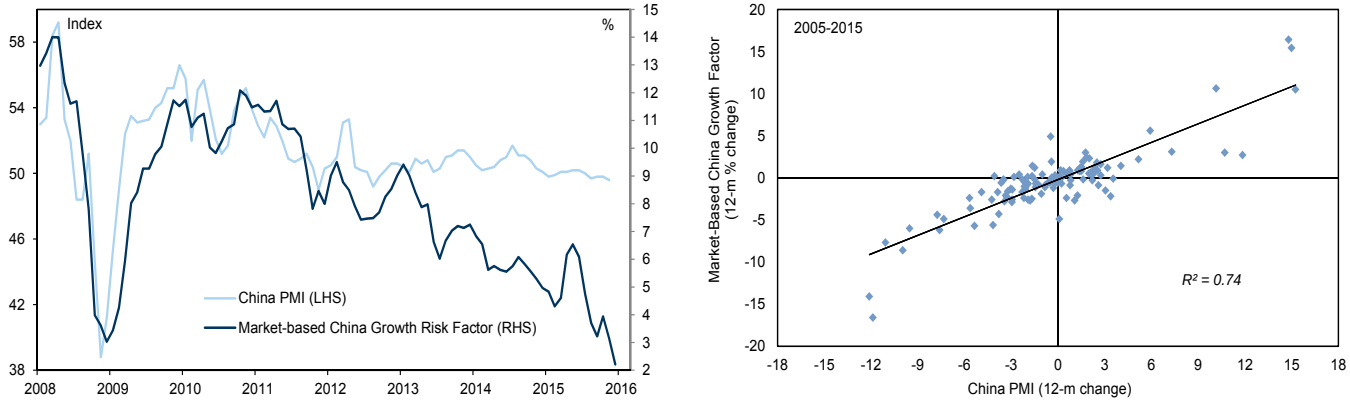
[6] See *European Weekly Analyst 07/33*: "The new Euroland FCI: A useful but flawed tool", September 27, 2007.

Exhibit 2: The market-based US growth risk factor tends to move with the US PMI index



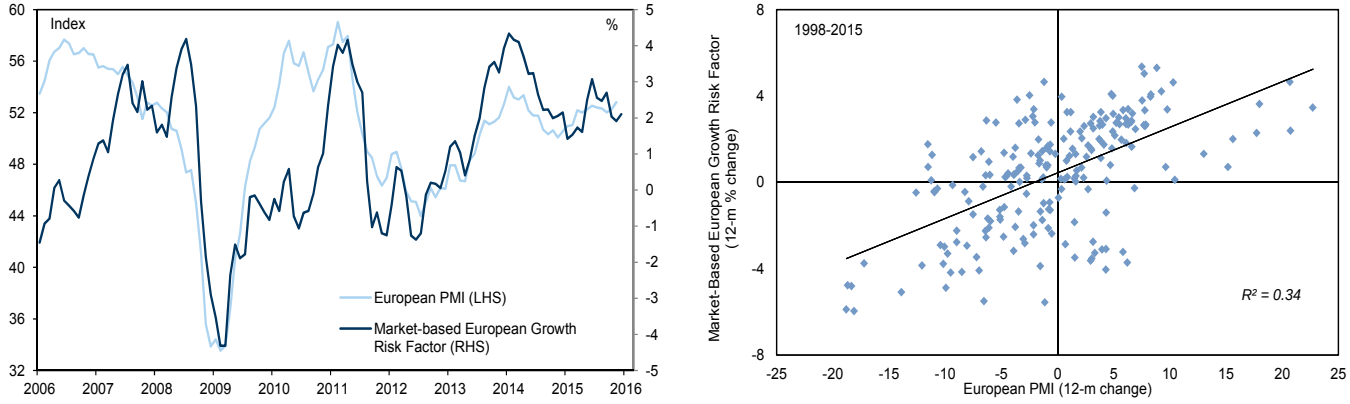
Source: Goldman Sachs Global Investment Research.

Exhibit 3: The market-based China growth risk factor tends to move with the China PMI index



Source: Goldman Sachs Global Investment Research.

Exhibit 4: The market-based European growth risk factor tends to move with the European PMI index



Source: Goldman Sachs Global Investment Research.

4. Driving forward: The impact of macroeconomic risks on prices

We deploy these seven market-based macroeconomic risk factors to explain a wide set of asset returns across six major markets:

1. ***Global equities***, defined as country-level equity indices in local currency terms. Indices included are: Australia, Brazil, Canada, China, Czech Republic, France, Germany, Hungary, India, Indonesia, Israel, Italy, Japan, Mexico, Norway, Poland, Russia, South Africa, South Korea, Spain, Sweden, Switzerland, Turkey, the UK and the US.
2. ***Global bonds***, defined as total return 10-year sovereign bond indices. Indices included are: Australia, Austria, Canada, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, South Korea, Spain, Sweden, Switzerland, the UK and the US.
3. ***Currencies***, defined as the trade-weighted value of a country's currency. The currencies included are: Australia, Brazil, Canada, China, Czech Republic, the Euro, Hungary, India, Indonesia, Israel, Japan, Mexico, Norway, Poland, Russia, South Africa, South Korea, Sweden, Switzerland, Turkey, the UK and the US.
4. ***Commodities***, defined as total return commodity price indices, inclusive of roll-returns and based on the S&P GSCI® sub-indices. The commodities included are: aluminium, coal, coffee, copper, corn, cotton, feeder cattle, gold, heating oil, lead, soybeans, sugar, tin, wheat and zinc.
5. ***S&P 500 sectors***, defined as 10 large-cap (S&P 500) sector-level sub-indices: Consumer Discretionary, Consumer Staples, Energy, Financials, Healthcare, Technology, Industrials, Materials, Telecommunication Services and Utilities.
6. ***STOXX 600 sectors***, defined as 18 large-cap (STOXX 600) sector-level indices: Autos, Banks, Basic Resources, Chemicals, Construction, Energy, Financial Services, Food, Healthcare, Industrials, Insurance, Media, Personal Products, Retail, Technology, Telecommunication Services, Travel and Utilities.

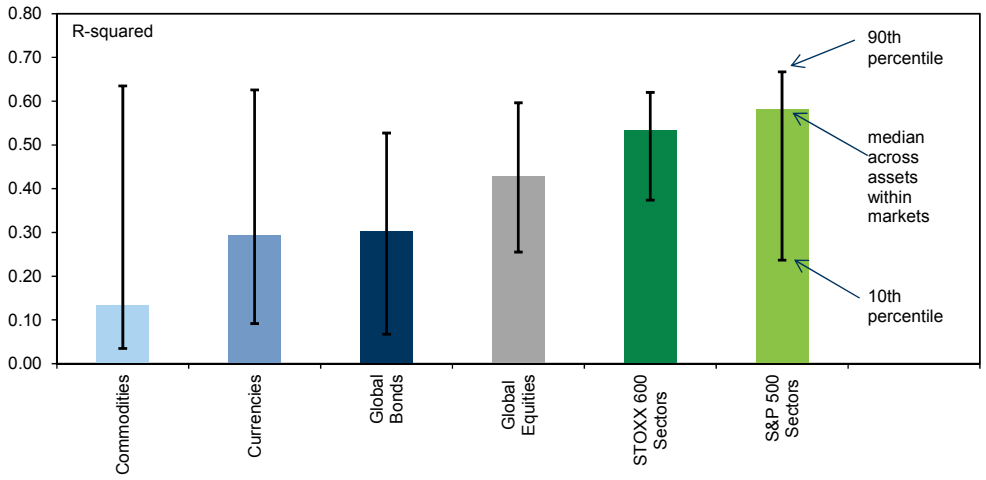
Our market-based macroeconomic risk factors capture a good deal of return behaviour for many of the assets that we consider.

For each asset we consider, we relate (monthly) asset returns to (monthly) changes in all seven market-based macroeconomic risk factors (see Appendix 6). Each asset is estimated on its own, without any cross-asset restrictions. The seven market-based macroeconomic risk factors capture a large fraction of return variation for many of the assets that we consider. Looking at the data market by market, the median R-squareds for the assets within each market range from a low of about 0.1 for commodities to 0.6 for S&P 500 sectors (see Exhibit 5).

In general, these models fit equity markets slightly better, as the median R-squared values show. But a significant proportion of assets that are well described by this macroeconomic risk framework, even within the currency, commodity and bond markets. Across all markets the 90th percentile R-squared readings are in the 0.6 - 0.7 range.

The strong explanatory power of these market-based macroeconomic risk factors, along with their correlation to the economic data themselves, provides *prima facie* evidence that macroeconomic risk models can link macroeconomic risks to asset returns, with additional evidence to be marshalled below.

Exhibit 5: Market-based macroeconomic risk factors do a good job of explaining asset returns across a wide range of markets



Source: Goldman Sachs Global Investment Research.

The asset-specific betas[7] (β_f^n) represent the key parameter of interest in terms of linking a specific asset (n) to each of the seven market-based macroeconomic risk factors (indexed by f). We term this an asset's ***exposure*** to that market-based macroeconomic risk factor. Summarizing these results, Exhibit 6 presents median exposures on a market-by-market basis (down the columns) to each of the seven market-based macroeconomic risk factors (across the rows).

Several consistent messages emerge from the market-level exposures presented in Exhibit 6:

1. Global equity indices, US equity sectors and European equity sectors all tend to have *positive exposure* to market-based economic growth risk factors, regardless of geography. The market-based US growth risk factor tends to be most prominent, but the Europe growth risk factor and China growth risk factor also matter. (Because we are looking at market medians, we cannot yet distinguish which assets within a market are *most* focused on US growth, which are most focused on European growth, etc.)
2. In contrast, bonds tend to have *negative exposure* to market-based growth risk factors, most clearly US growth risk.
3. Both the equity and bond markets tend to have *negative exposure* to financial condition measures, again most prominently US financial conditions, but European conditions as well.
4. Inflation impacts tend to be modest overall, after controlling for economic growth and financial conditions, with commodities the one market where the impact is clearest.

[7] See Appendix 5 for a full description of the mathematical notation.

These facts illustrate the utility of this type of taxonomy. The observed 'reduced form' correlation between equities and bonds likely obscures the role of the underlying macroeconomic risk that is being priced by markets at any point in time. The pattern of expected bond and equity returns should be dependent on whether the fundamental macroeconomic shock is from the growth side of the ledger – with both assets then moving in the opposite direction – or from the policy side – which would push assets in the same direction.

Market medians, while broadly instructive, do not provide the granular insight investors need. The value in having all these exposure measures in hand, ultimately, is to help think about which markets are most exposed to a given macroeconomic risk, either to best express a view about that risk, to hedge that risk, or to quantify what the market is 'thinking' about that risk. And the macroeconomic risk framework outlined here is a way of doing that consistently across markets.

These Macroeconomic Wavefronts present a menu of assets that are exposed to a given macroeconomic risk, and offer a straightforward way to express a view, to hedge a risk, or to monitor how an asset is pricing a given risk.

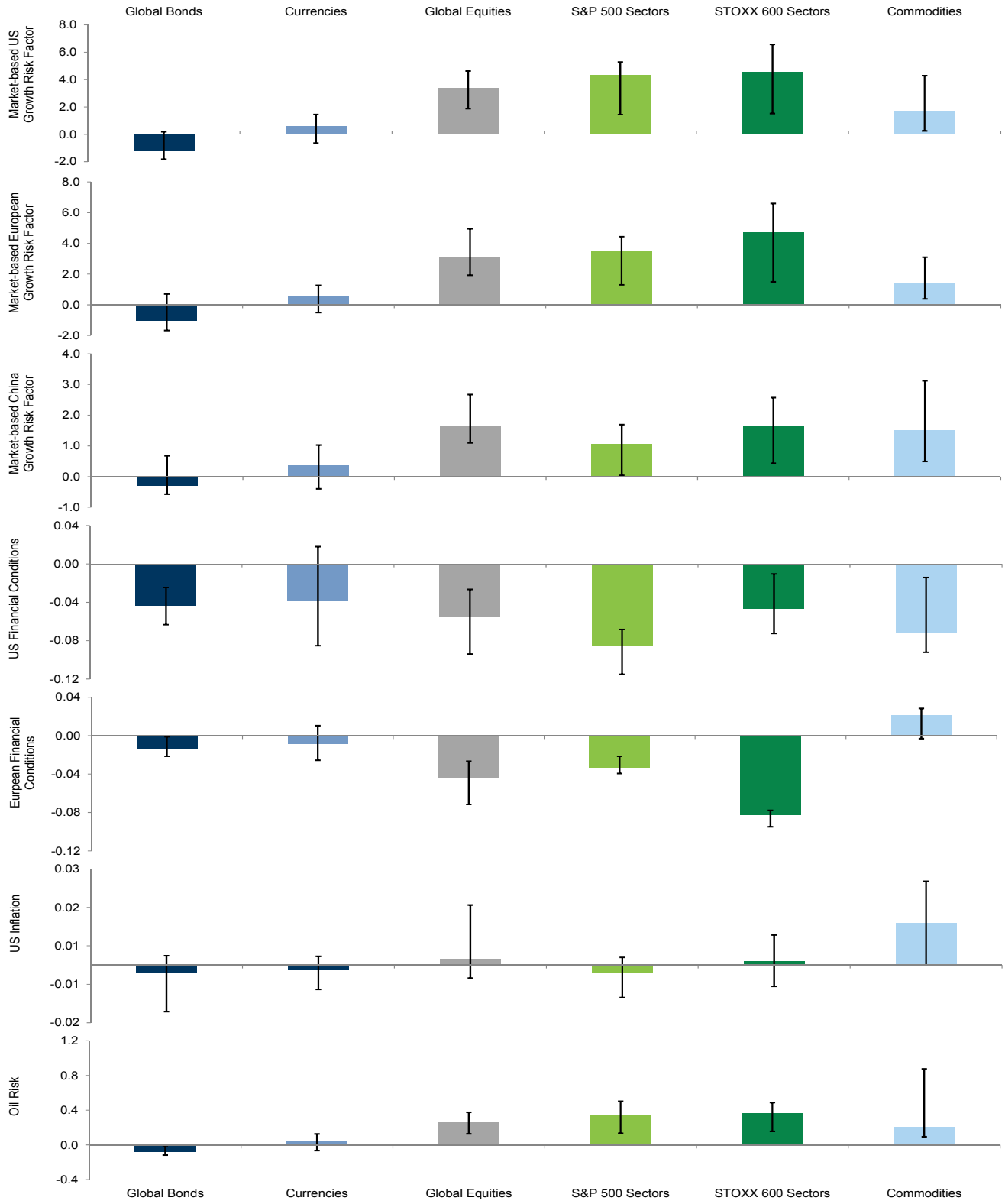
Exhibit 7 presents a set of cross-asset ***Macroeconomic Wavefronts*** for each of the seven macroeconomic risks we consider. Each Macroeconomic Wavefront is comprised of the 20 assets most and least exposed to the risk factor, regardless of market. To best facilitate comparisons across markets with very different volatilities – and hence very different betas (expected return) per unit change in a risk – we have risk-adjusted the exposures and present the standardized coefficients here. The notion is that (on a consistent risk-adjusted basis) these are the 'best' assets to express a macro view on each of the seven macroeconomic risks in our framework.

For instance, the assets most exposed to US growth risk include European and US equity sectors, such as Industrials, Materials, Technology and Financials, and equity indices such as the US, Germany and the UK. At the other end of the spectrum, several DM bond indices are most negatively exposed to US growth risk. Similarly, assets most positively levered to China growth risk include EM equity indices (Brazil, India, Russia and South Korea, alongside China itself), and several metals, such as copper, nickel, aluminum and lead. Assets most negatively levered to China growth include the JPY and USD, and also a collection of DM bond indices.

Moreover, with these asset-specific exposures in hand, it is also possible to examine the full profile of an asset with regard to its macroeconomic exposures. Thus, an asset or a portfolio that is optimized in a certain direction – be it macro or otherwise – can be analyzed for unintended exposure to other macroeconomic risks, or to construct a hedge for a given macroeconomic scenario (possibly comprised of shifts in several macro risk factors), while keeping all other factors at bay as much as possible.

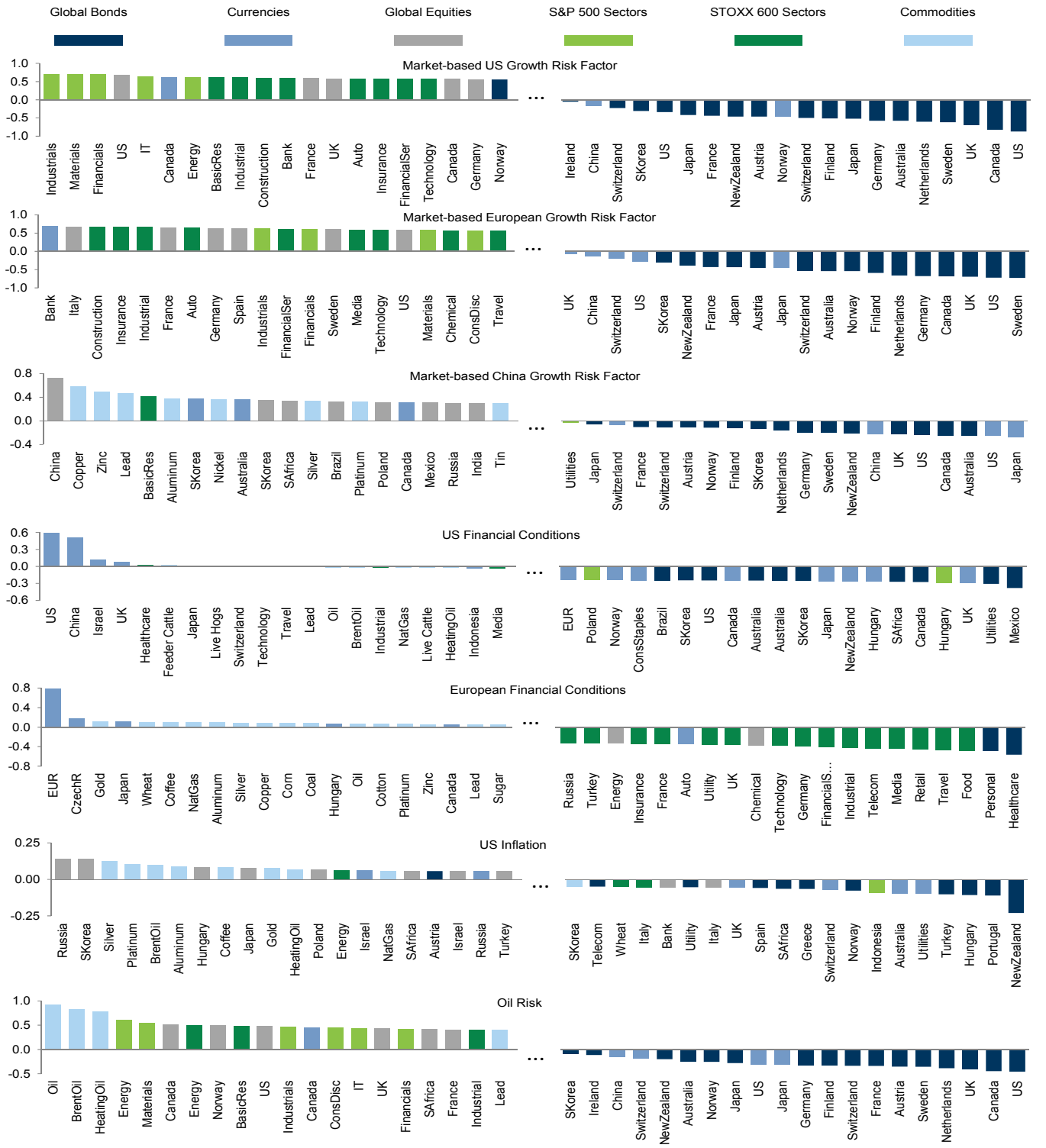
The Macroeconomic Wavefronts presented in Exhibit 7 are across all of the markets in our study and, as such, require the use of standardized coefficients. A direct comparison of betas, which are a measure of expected return per unit of change in risk, can be found in Appendix 6 on a market-by-market basis.

Exhibit 6: Assets' exposures (*beta*) to market-based macroeconomic risk factors by market
Median across assets within market, 10-90th percentile range



Source: Goldman Sachs Global Investment Research.

Exhibit 7: Cross-market Macroeconomic Wavefronts: A menu of assets with greatest and least (risk-adjusted) exposures



Source: Goldman Sachs Global Investment Research.

5. Measuring the importance of the macro view

Having estimated the relationship between a single asset's returns and changes in market-based macroeconomic risk factors *over time*, we now demonstrate that differences in estimated macroeconomic exposure *across* assets are also an important determinant of relative asset returns. We can do this by quantifying the value of macroeconomic information in the context of long/short, relative value portfolios.

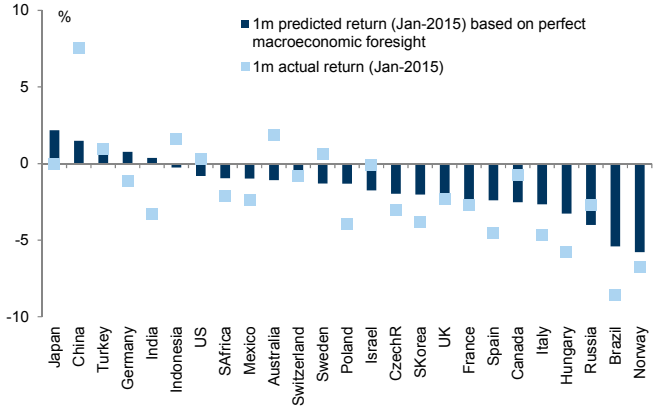
Differences in estimated macroeconomic exposure across assets are an important determinant of relative asset returns.

To this end, we conduct the following thought experiment. Suppose an investor has perfect foresight as to how the seven market-based macroeconomic risk factors will behave over the next month. With the models above, perfect macroeconomic foresight can be translated into expected returns for each asset in our universe. Suppose, further, that the investor invests on this basis, each month going long assets where expected returns based on their exposures to the *known* shifts in macro factors are highest and going short those assets with the lowest expected returns. How do such hypothetical portfolios, built on *perfect macroeconomic foresight*, perform? How do such portfolios perform under more realistic conditions as the assumption of perfect macroeconomic foresight is relaxed?

To assess perfect *macroeconomic* foresight, we compare perfect-macro-foresight performance to a performance of an even 'smarter' investor: one who constructs a long/short portfolio based on perfect *market* foresight, with full knowledge of how assets will actually perform in the coming month.

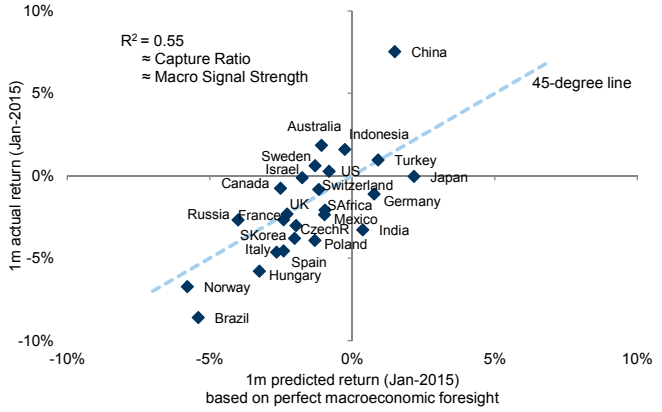
These two potential perfect-foresight portfolios are depicted in Exhibit 8, with the bars representing expected returns for global equity indices on January 1, 2015 (chosen for illustrative purposes) given perfect macroeconomic foresight and the dots representing actual returns, i.e., perfect market foresight. The ***capture ratio*** of the perfect macroeconomic portfolio, defined as the ratio of returns of these two portfolios, is a measure of the strength of the macroeconomic risk model's signal in accurately predicting asset returns on a *relative basis*. Essentially, it is the correlation between the actual returns – at a point in time across a set of assets – and the model-predicted returns (see Exhibit 9).

Exhibit 8: Actual global equity index returns on January 1, 2015 and expected returns based on perfect macroeconomic foresight



Source: Goldman Sachs Global Investment Research.

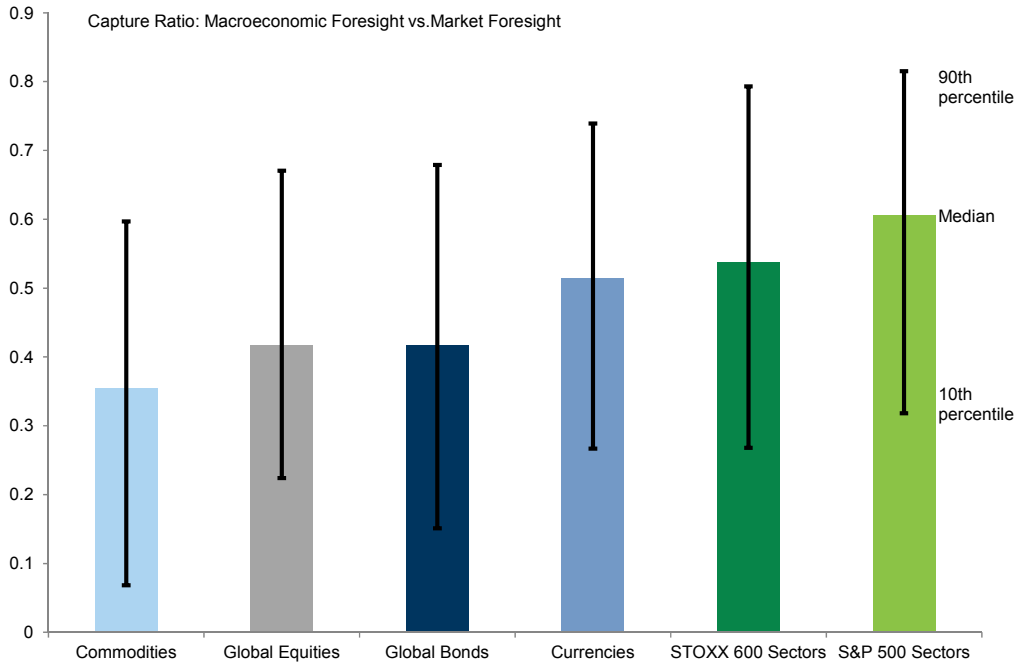
Exhibit 9: The strength of the macro risk model's signal is the correlation between actual and predicted returns



Source: Goldman Sachs Global Investment Research.

Repeating this experiment every day within each market, we find that median capture ratios range from about 60% of the available return for S&P 500 sectors to about 35% for commodities (see Exhibit 10). Said differently, half of the relative asset performance is dictated by differences in exposure to macroeconomic risks, with about half of relative asset performance dictated by idiosyncratic factors that are not included in the models. Note that the macroeconomic risk models developed in Section 4 were estimated over time on an asset-by-asset basis, with no cross-asset restrictions. Yet, the models' predictions about relative returns do capture a good deal of the relative asset performance over time.

Exhibit 10: Long/short portfolios built with perfect macroeconomic foresight capture about half of the total available return



Source: Goldman Sachs Global Investment Research.

Perfect macroeconomic foresight is a valuable thought experiment, demonstrating the value of a macroeconomic view. But perfect foresight is an unrealistic benchmark for thinking about potential returns from a portfolio or strategy driven by macroeconomic risk considerations.

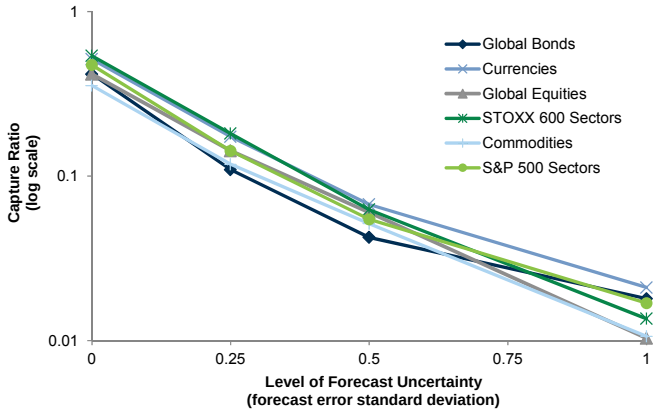
A more realistic scenario is to assume that investors do not know for sure what the upcoming shifts in macroeconomic risk factors will be, but instead each day get a draw of risk factors from the (joint) distribution of outcomes centred at that day's actual shift. The variance of that distribution is a way of capturing the degree of macroeconomic skill needed to generate returns. A high-skill investor is one with low variance around the true changes and a low-skill investor is one with high variance around true changes. In this set-up, perfect macroeconomic foresight is a special case of zero variance.

Differences in macroeconomic exposures capture about half of cross-asset return variation over time. This underscores the importance of getting the macroeconomic view right.

Exhibits 11 and 12 illustrate that as we move away from perfect foresight and as more and more volatility around the 'truth' is introduced – ranging from zero- to one-standard deviations around the truth – the capture ratio and the Sharpe ratio of macro-driven portfolios decline. However, Sharpe ratios remain a bit above one, almost up to the point when the forecast error bands are a full standard deviation wide. (In Appendix 4, we use this framework – deviations from perfect foresight – to analyze which specific bits of the forward macroeconomic risk landscape are most important for which markets.)

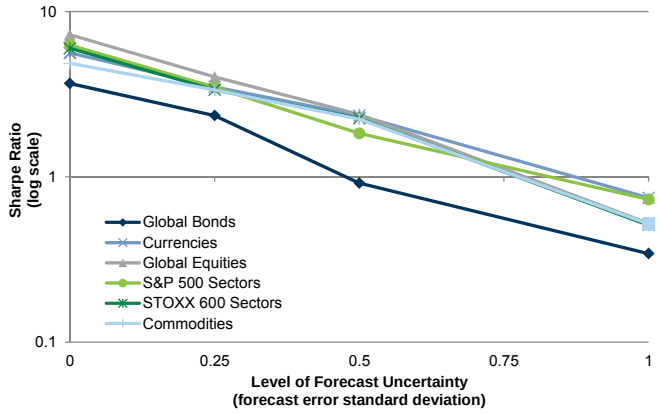
While perfect foresight is unattainable, this exercise demonstrates that differences in macroeconomic exposures capture about half of cross-asset return variation over time – with market-specific and asset-specific idiosyncratic factors responsible for the rest. This underscores the importance of getting the macroeconomic view right. The ability of differences in assets' macroeconomic exposures to capture *relative* differences in asset performance – an outcome that is not baked into the time series estimation in the previous section – is, at the very least, further confirmation that a framework for understanding macroeconomic drivers (as we have defined them) of asset returns has value and is independent validation of the models' efficaciousness.

Exhibit 11: Capture ratio at different levels of forecast uncertainty



Source: Goldman Sachs Global Investment Research.

Exhibit 12: Sharpe ratio at different levels of forecast uncertainty



Source: Goldman Sachs Global Investment Research.

6. Driving in reverse: Inferring macro shifts from price action

We have shown that shifts in market-based macroeconomic risk factors drive assets' returns over time and relative to other assets. These models generate expected returns that are most consistent with a set of observed macroeconomic shifts. This thinking can also be reversed. By reversing these models, *observed asset returns* can be exploited to generate *implicit macroeconomic shifts* that are most consistent with those observed returns. This 'reverse engineering' is one way of assessing how a given market has shifted its implicit view of a given macroeconomic risk and is the key to understanding which set of macroeconomic views is embedded in a market.

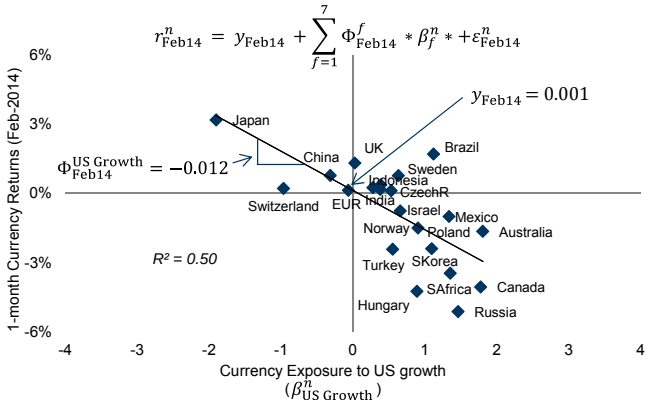
Observed asset returns can be exploited to generate implicit macroeconomic shifts. This 'reverse engineering' is the key to understanding which set of macroeconomic views is embedded in a market.

This reverse engineering approach assumes that at any point in time all a market cares about are macroeconomic risks. Differences in asset returns must be solely dictated by differences in assets' exposures to macroeconomic risks. Hence, differences in assets' returns must therefore be attributed to a change in that market's implicit assessment of the macroeconomic landscape.

Leaving the formalities of this process to Appendix 5, to back out the ***implicit market-specific shifts in macroeconomic views***, the *cross-section* of asset returns is related to the *cross-section* of macro exposures in that market. At any point in time, differences in returns across assets within a market are (assumed to be) driven *only* by differences in those assets' macroeconomic leverages. In this context, assets' leverages are treated as data and the degree to which those leverages explain returns is an implicit measure of which macro risks the assets are reflecting.

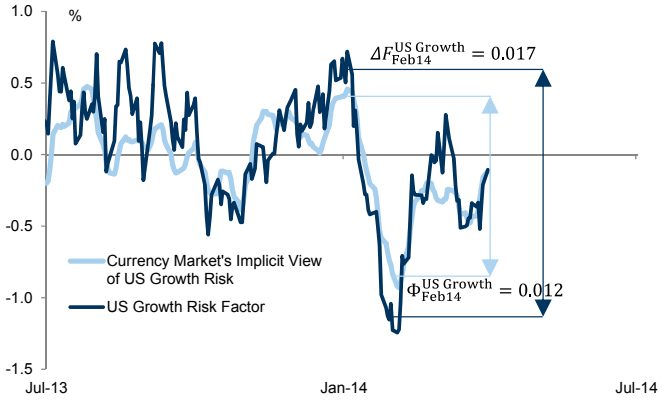
Exhibit 13 illustrates this for a particular market – Currencies – on a particular day – February 1, 2014. Differences in actual returns across currencies that day (the y-axis) are 'caused' by differences in assets' macroeconomic exposures (on the x-axis). The estimated slope is the degree to which the market has ***implicitly*** changed its view of a given macroeconomic risk. This cross-sectional regression can be run daily and, thus, can be stitched together over time, as illustrated in Exhibit 14. This process traces out the *implicit* change in view as dictated by market price action with regard to a macroeconomic risk factor, which can be compared with *actual* changes in that macroeconomic risk factor.

Exhibit 13: On February 1, 2014, currency returns were driven by US growth risk relative exposure



Source: Goldman Sachs Global Investment Research.

Exhibit 14: The currency market was implicitly raising its view of US growth, in line with the actual shift in the US growth risk factor



Source: Goldman Sachs Global Investment Research.

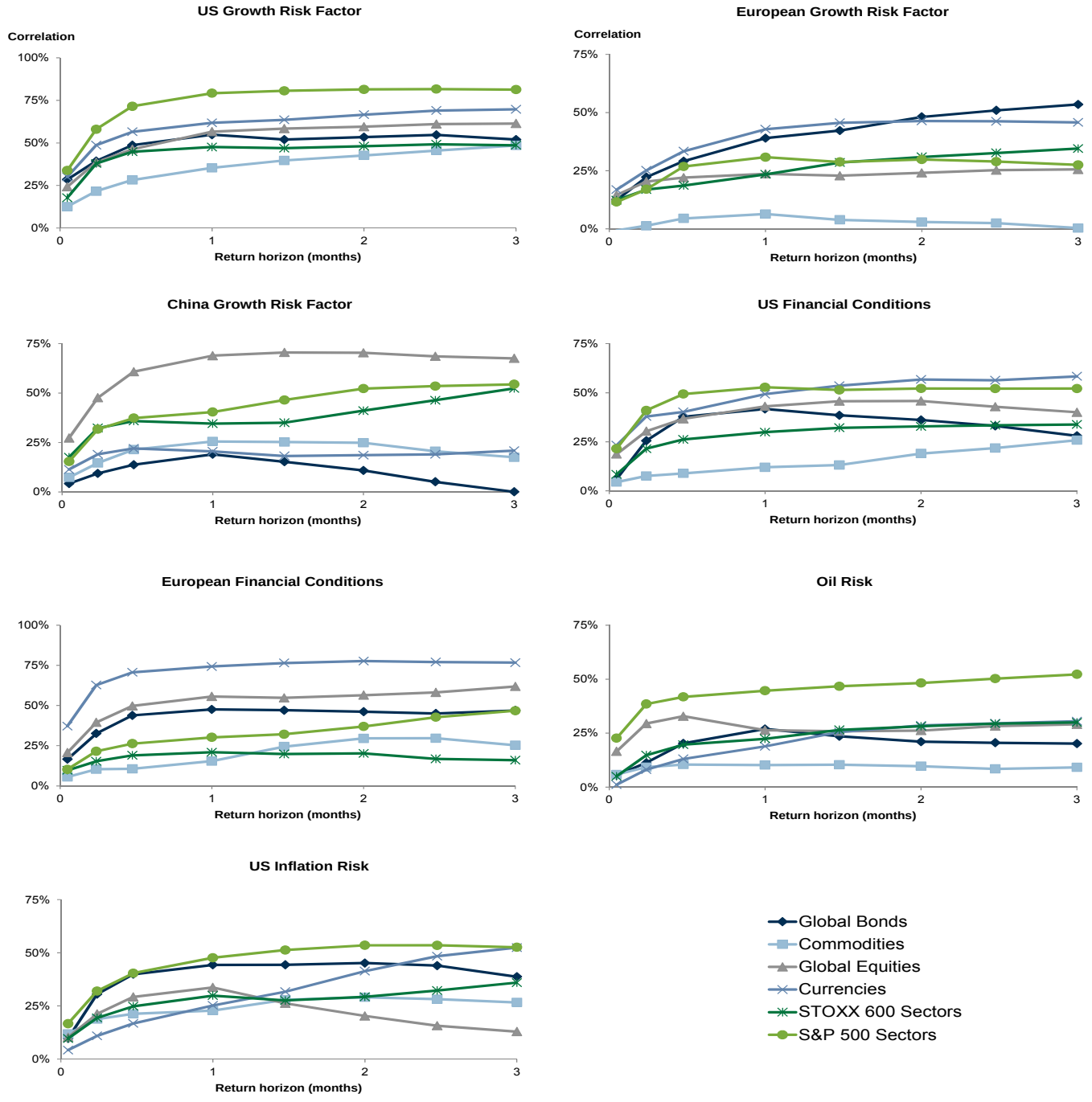
Nothing in the system requires one market to have the same implicit view about a macro risk as another market. But the empirical evidence shows that market views converge over time.

In short, this cross-sectional analysis produces a way of quantifying how much a given market has changed its view of a specific macroeconomic risk over time. That market-specific *implicit* macroeconomic view can then be compared with the 'true' evolution of the factor itself. This cross-sectional regression can be run every day for each of the six markets we consider, producing six different market-implied changes in macro view for each of the seven macroeconomic risk factors in our models.

Note that nothing in the system *requires* one market to have the same implicit view about a macro risk as another market. It is possible that the bond market, say, may seem to be pricing in a particular macro shift (for any number of bond-market-specific reasons), while other markets may be telling a different macroeconomic story. Hence, the full set of market-implied changes in view allows us to see, directly, if different markets price macroeconomic risks in a consistent way. We can also gauge whether the non-modelled idiosyncratic and market-specific returns are so big that they overwhelm the systematic pricing of macro risks.

Indeed, at any point in time, a given market may be expressing a different view of a given risk from that of the risk factor itself. As Exhibit 15 shows, the correlation between changes in *market-implied* macroeconomic risks and *actual* risk factors is moderate, particularly over short horizons. Critically, however, there does seem to be some convergence over time, with the correlation between a market's implied view of a risk and that risk factor itself climbing uniformly over time.

Exhibit 15: Market-specific implied macro views are not perfectly correlated with the macroeconomic risk factors themselves, but the correlation increases over time, as the impact of idiosyncratic factors fades and the focus on macro risks rises



Source: Goldman Sachs Global Investment Research.

7. Macroeconomic-driven reversion

Thus far we have focused on how to interpret the systematic, macro-driven component of asset returns – either in a time series or in a cross-sectional context. But there are always un-modelled shocks that pull asset returns away from what our macroeconomic risk factor models would otherwise suggest. So, what happens when models 'fail', when asset returns deviate 'significantly' from model predictions?

We look for episodes when assets have out- or underperformed macro shifts as a 'trading signal'. This macro-reversion strategy generates Sharpe ratios in the 1 to 2 range.

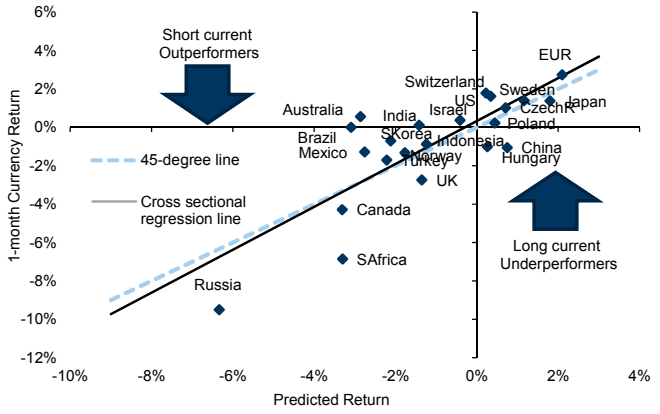
To answer this question, we combine both the time series and cross-sectional information and devise a series of back-tests on a market-by-market basis to assess the degree to which assets that have under-traded a macro shift outperform and those that have over-traded a macro shift subsequently outperform.

Exhibit 16 illustrates the selection criteria, graphing the macro-predicted return on the x-axis, the actual return on the y-axis and overlaying both a 45-degree line (which assumes that actual and macro-predicted returns should be the same – on average), and also a cross-sectional regression line, which allows for market-specific risks, and market-specific loadings on the exposures to pull returns away from the 45-degree line.

We look for episodes when assets have out- or underperformed on both counts as the 'trading signal', rebalancing this long/short portfolio monthly. This strategy generates Sharpe ratios in the 1 to 2 range, with global equity indices and the commodity market at the high end of the range, and currencies and equity sectors at the low end (see Exhibit 17). Obviously, these strategies abstract from all real-world trading issues. We suspect that, if these strategies were fully implemented, actual Sharpe ratios would be considerably lower.

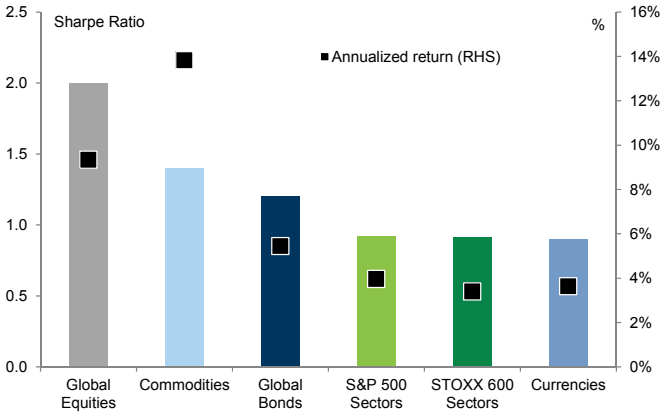
Looking at the performance of the portfolios themselves is also insightful (see Exhibit 18). For instance, while our global equity macro-reversion portfolio has a Sharpe ratio of about 2, a more profitable strategy would have been to just be long equities. Of course, the short portion also underperformed and helped to reduce the volatility of the strategy. These macro-reversion strategies and the increasing degree of correlation between implicit macroeconomic views and the actual factors (discussed in the previous section) are indicative of 'arbitrage'-type opportunities. We take a simpler view, and see this evidence as further confirmation that a macroeconomic risk framework is a valuable one for thinking about returns.

Exhibit 16: Looking for macro-reversion candidates



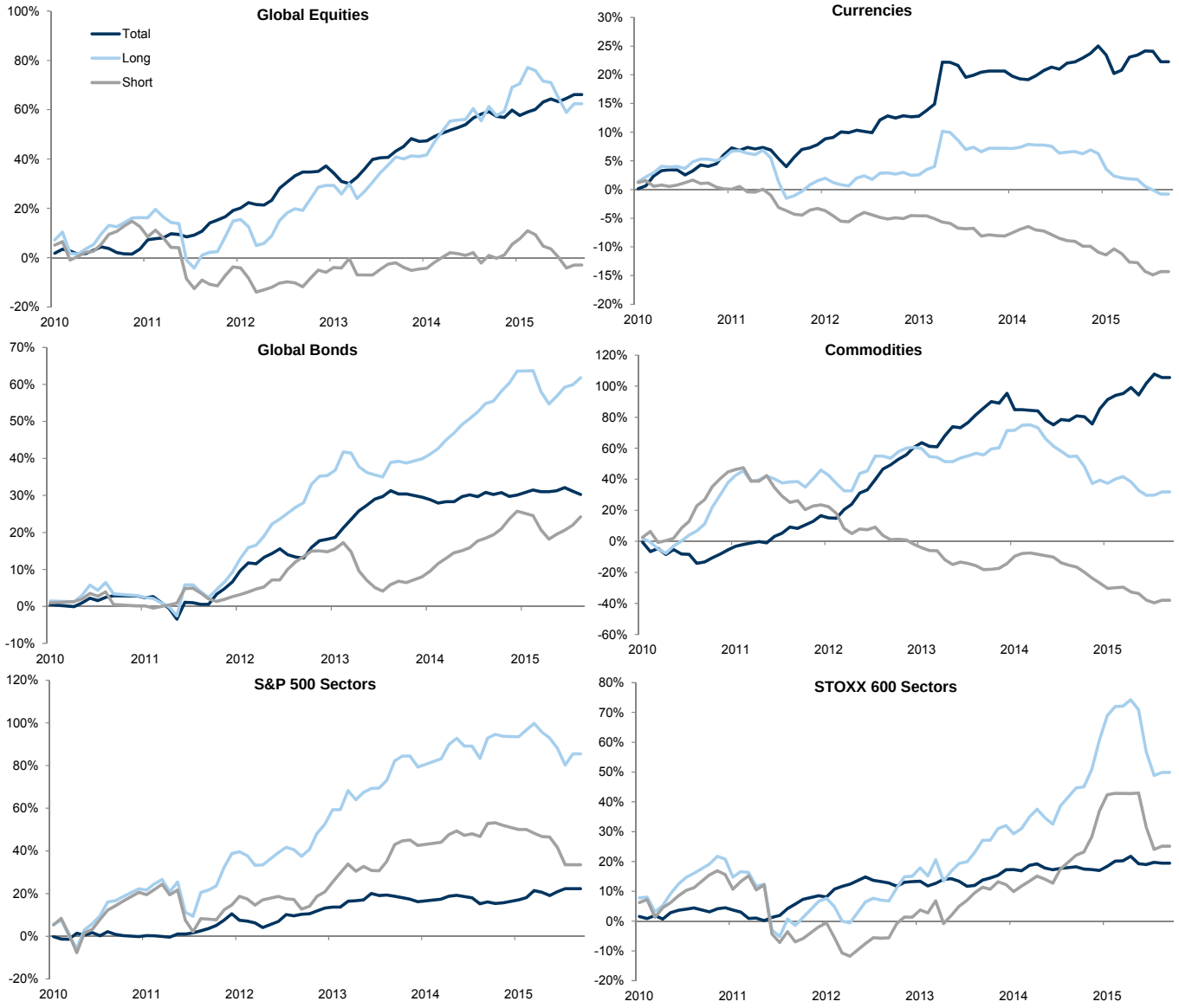
Source: Goldman Sachs Global Investment Research.

Exhibit 17: Sharpe ratios for macro-reversion strategies



Source: Goldman Sachs Global Investment Research.

Exhibit 18: Cumulative performance of macro-reversion strategies by market



Source: Goldman Sachs Global Investment Research.

Taken literally, this suggests that macroeconomic 'mean-reversion' strategies could be valuable. But we tend to view these preliminary results as further evidence of the power of macroeconomic risk models to capture market dynamics rather than as an algorithmic statistical arbitrage opportunity.

8. Conclusion

In this *Global Paper*, we detail a set of macro-based risk models using common market-based macroeconomic risk factors to understand the linkages between macroeconomic risks and asset returns across a wide array of key global asset markets. This common macro risk framework (1) allows for an assessment of which macro risks matter for which assets, (2) provides a deeper understanding of the fundamental macro drivers of cross-market correlations, (3) develops a set of tools for assessing how to best express, or hedge a macro-driven risk, and (4) presents several metrics for understanding how macro risks are being priced by the markets at any point in time.

To be sure, specific risks that are best expressed in a specific market ought not to be ignored. And common macro risks are only one source of risk that determines asset returns. But it is the part that we think ought to be priced in a consistent way across markets. For investors of any style, being able to assess and monitor these risks and their impact is a necessary first step in incorporating macro considerations into the investment process.

We expect that the seven macroeconomic risk factors we present here, the 'Macro Wavefronts', which summarize the macro linkages to expected asset returns and the market-implied views of market risks, will become important elements in our tool kit for understanding the linkages between macroeconomic risks and markets.

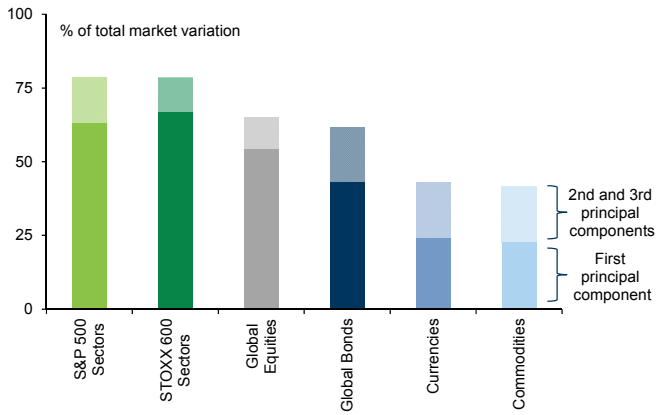
Appendix 1: Many markets, few factors

The point of departure in this paper is that a small number of common macroeconomic risk factors explain asset returns. But that foundational assumption itself can be unpacked into a set of more primitive and testable assumptions. In particular, while we assert that a small number of macroeconomic risk factors are needed to understand a wide set of assets, we can directly test the underlying assumptions that (1) market returns are driven by a small number of factors, (2) those factors are common across markets and (3) those factors are related to macroeconomic risks.

From a purely statistical perspective, we can demonstrate the fact that much of the co-movement of assets within a given market can be explained by a very small number of purely statistical factors. Using principal component analysis (PCA), most of the variation within a given market is driven by that market's own first principal component (PC1), with relatively little variation left to explain after three such components are deployed (see Exhibit A1). For example, the global equity market's first principal component captures about 60% of the total variance, while the second two components capture an incremental 15%. After three components, 75% of the variance has been absorbed. Across the markets we consider, after the first two or three components, the marginal contribution of additional components becomes quite small as the major drivers of common co-movement are absorbed and smaller and smaller bits of idiosyncratic variance are all that remains to explain. As a rule of thumb, and consistent across markets, we find that it only takes about three or four statistical factors to capture the vast majority of a market's variance.

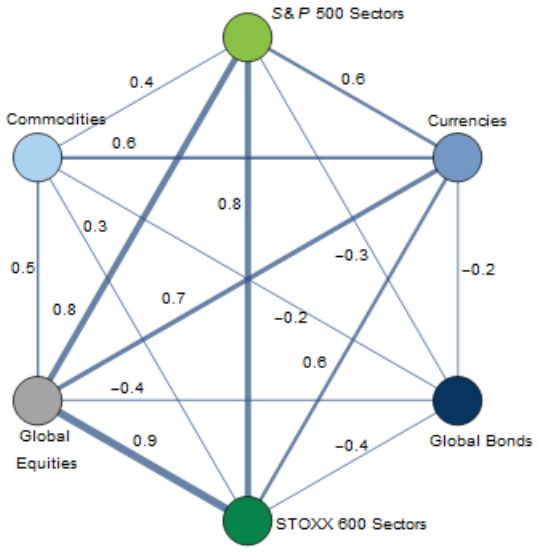
Moreover, a given market's own unique statistical factors tend to be quite correlated factors in other markets (see Exhibit A2). This is another key insight: the fact that market-specific PCs are highly correlated across markets indicates that drivers in one market share a good degree of overlap – as measured by correlation – with other markets.

Exhibit A1: The bulk of market returns are driven by only a few statistical risk factors



Source: Goldman Sachs Global Investment Research.

Exhibit A2: Market-specific statistical drivers are correlated with each other



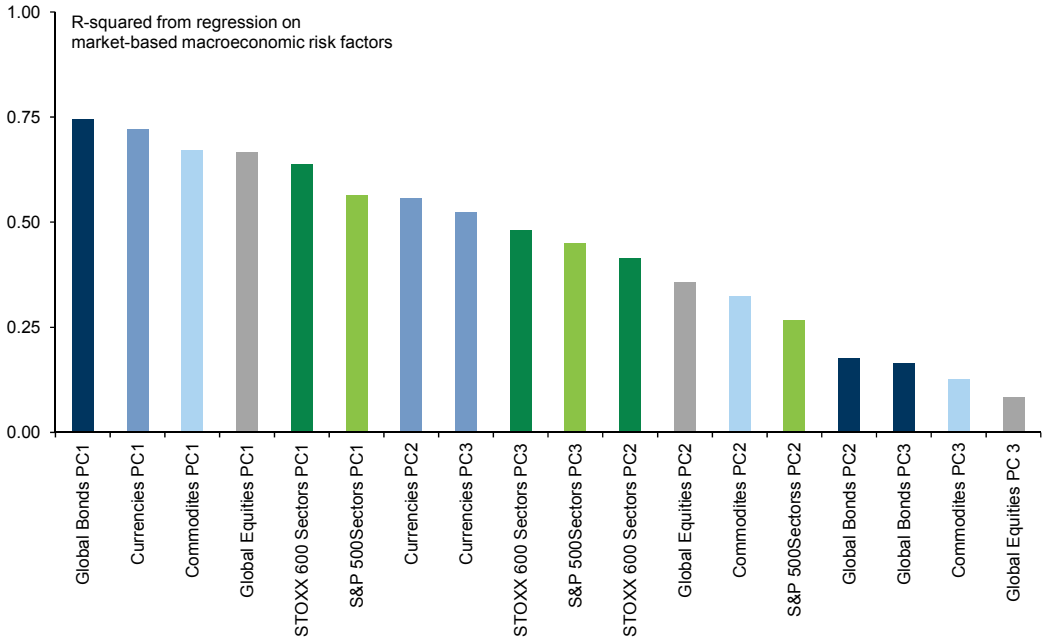
Source: Goldman Sachs Global Investment Research.

The key advantage of PCA is that it allows the data to speak freely. But this strength is also its Achilles heel; the lack of fundamental structure means that, while factors can be identified statistically and asset return covariance can be fully decomposed, there is no intrinsic identity to the resulting factors. Critically, however, these statistically built market-specific factors are, in turn, driven by our suite of market-based macroeconomic risk factors, which we derive in an entirely different way. Exhibit A3 presents R-squared values from a regression of each market's PCs on our collection of seven market-based macroeconomic risk factors. The elevated R-squared values are indicative of the macroeconomic content of these purely statistical factors.

Thus, the purely statistical evidence suggests that segmented asset markets – global equities, global bonds, currencies, commodities, STOXX 600 sectors and S&P 500 sectors – each have their own small number of statistical drivers, in general no more than three or four. These drivers represent a set of *unnamed* risks that capture the vast majority of each market's internal correlation structure across the assets within that market. Furthermore, these market-specific statistical drivers are, themselves, correlated across markets. Finally, these statistical factors are indeed driven in part by the suite of market-based macroeconomic risk factors we develop above.

This evidence provides support that a well-chosen collection of market-based macroeconomic risk factors ought to explain a wide swathe of asset returns.

Exhibit A3: Market-specific principal components are, themselves, driven by our suite of market-based macroeconomic risk factors



Source: Goldman Sachs Global Investment Research.

Appendix 2: Guidelines for selecting macro factors

The set of market-based macroeconomic risk factors here is but one of many possible choices. While there is no hard and fast criterion to define what the 'best' set of such factors would look like, there are some general principles that we followed when making our selections:

1. **Economic identity:** A factor needs to be identified with a concrete economic theme. This way, forward economic views directly translate into expectations about a market-based factor's evolution.
2. **Market building blocks:** Factors are built from tradeable assets whose market prices are tracked daily, providing a high-frequency view of the corresponding economic themes.
3. **Conceptual content:** Assets that contribute to a factor are linked to an underlying economic theme through well-understood economic channels.
4. **Correlation to macro data:** Factors should be correlated with relevant fundamental macroeconomic data.
5. **Explanatory power across assets:** When combined with other factors, each factor needs to explain a sizeable portion of asset returns over time, showing up as statistically significant for some but not necessarily all assets.
6. **Explanatory power across time:** Each factor needs to be 'in focus' sufficiently often. Intuitively, this means that changes in the factor itself are closely related with observed changes in a cross-section of asset returns.
7. **Cross-market consistency:** Asset price changes within each market relate to shifts in each macro factor implied by the market. These implied shifts should, in general, agree with actual shifts in macro factors, across different points in time and across different markets.

On the other hand, there are certain properties that we do not require from our macro factors:

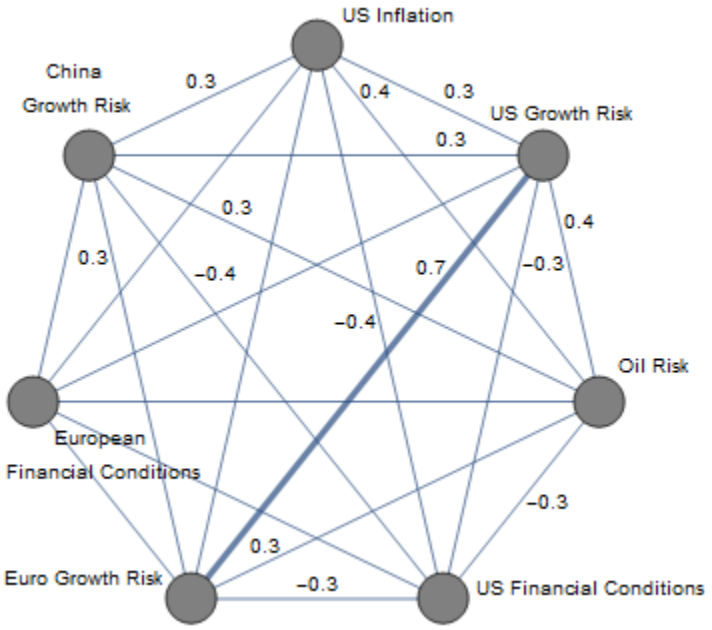
1. **Orthogonality:** Economic themes are often mutually correlated, and we have to expect that the factors will be correlated too, and, in a way, will 'fight' among themselves to explain observed asset returns.
2. **Ease of trading:** Macro factors are built off of tradeable assets, but we give no consideration to trading costs or liquidity. These issues are trumped by factors' ability to 'isolate' different economic themes to the largest possible extent.
3. **Uniformity of explanatory power:** Different factors explain (on average) different portions of asset's variability. We do not require that factors contribute equally to explaining asset returns.
4. **Universality of explanatory power:** Factors are not necessarily 'good' at explaining all assets. It is acceptable that a certain factor may not significantly contribute to explaining returns in a number of assets.
5. **Permanence of focus:** Focus on a factor may substantially oscillate over time, from nearly full to negligible. At different points in time, assets may be pricing shifts in a particular factor more consistently than at other times.

Appendix 3: US Growth Risk: First among equals

Unlike principal component analysis, which identifies uncorrelated factors to explain market performance, our market-based macroeconomic risk factors are themselves correlated. As the academic literature has discussed at length, the interconnectedness and dynamics among growth risk, policy risk and supply-side risk are complicated and, in turn, complicate inference of causes and effects. For example, growth influences policy and policy influences growth, oil shocks have a different implication for growth from the implication that growth shocks have for the price of oil, and so on.

In the context of the macroeconomic risk models presented here, the problem is particularly acute with respect to parsing out different geographic flavours of growth. The three 'flavours' of market-based economic growth risk – US, China and Europe – are highly correlated (see Exhibit A4). This degree of correlation is not surprising. Conceptually, these three factors all relate to important geographic inputs into the global growth outlook. And, in practice, all three market-based risk measures are highly correlated to measures of global growth, such as our Global Leading Indicator. Indeed, even with respect to economic outcomes directly, although regions can and do diverge, the data themselves tend to be highly correlated as well. But this high degree of correlation makes it difficult to statistically distinguish how each growth factor *on its own* affects asset returns.

Exhibit A4: Growth factors and the oil price tend to be highly correlated



Source: Goldman Sachs Global Investment Research.

To parse out some of the correlation and to deal a bit better with the causal ordering among the factors, we postulate that the market-based US growth risk factor drives the other growth factors (China and Europe) and oil, but not the other way around. Statistically, we orthogonalize European Growth, China growth and oil prices relative to US growth, and then use the uncorrelated factors in the regression analysis. This is akin to an 'ordering' restriction, with US growth assumed to come first in that causal structure. Technically, this can be thought of as creating a synthetic instrumental variable, which is correlated to asset returns but uncorrelated to US growth, or as a first stage ordering restriction.

Specifically, we run the following first stage regression:

$$\Delta F_t^f = a^f + b^f * \Delta F_t^{\text{US GROWTH RISK}} + \varphi_t^f \quad \text{(A1)}$$

where ΔF_t^f is the monthly change in the market-based European growth risk factor, the market-based China growth risk factor, or the price of oil, respectively. Each is regressed independently on $\Delta F_t^{\text{US GROWTH RISK}}$ defined as the monthly change in the market-based US growth risk factor. By construction, the residuals φ_t^f are uncorrelated to the US growth risk factor and capture the 'US growth-free' component of the relevant macroeconomic risk factor. These 'US growth-free' factors are subsequently used as risk factors in the second-stage regressions (Equation A1).

For ease of exposition and interpretation, the results and discussion in the body of the paper relate to 'all-in' risk factors and not to the ordered, 'partial' factors, described here. In particular, the measures of exposure to these risk factors also include their inherent exposure to US growth risk.

Appendix 4: Relative value of different macro views

As we have demonstrated, getting the macro view right – defined as 'knowing' how the market-based macroeconomic risk factors will evolve – is a valuable determinant of relative asset returns on a market-by-market basis. In the body of this paper, we have discussed this in an 'all-or-nothing' context, meaning that an investor has perfect foresight about the evolution of all macro factors simultaneously. We also model deviations from perfect foresight as occurring to all risk factors simultaneously.

But not all risks are equally relevant for all markets. This means that the value of macroeconomic information may differ across risk factors as well, and may be different in different markets.

To gauge how relevant it is to have the correct forward view about a specific macroeconomic risk for a specific market, we calculated the 'capture ratio' for two different scenarios, one that reflects perfect foresight for *all* risk factors, and the other that assumes perfect foresight for *all but one* factor, and some uncertainty around the actual forward change in one remaining factor. The investor incurs a 'penalty' for not having a perfect foresight for that single factor, measured as the difference in capture ratios.

Exhibit A5 presents these penalties by market and by risk factor, with deeper shades indicating that the penalty is particularly large and hence, the value of that bit of information is particularly dear. The lack of foresight with regard to the market-based US growth risk factor is most punitive across most of the markets we consider. Beyond that there is some variation about what factors matter where. For example, foresight about inflation is particularly important for the global bond market, where the penalty for the lack of foresight is 39%. Put differently, more than one-third of the available return is due to getting the inflation view correct.

Exhibit A5: The penalty for imperfect views of macro factors: Fraction of return available in a perfect-foresight strategy *not* realized due to the mismeasurement of a single factor

	US Growth Risk	Euro Growth Risk	US Financial Conditions	China Growth Risk	Oil Risk	US Inflation	European Financial Conditions
Global Bonds	54%	24%	52%	19%	23%	39%	14%
Currencies	37%	24%	42%	22%	20%	20%	24%
Global Equities	21%	24%	22%	28%	15%	16%	18%
S&P 500 Sectors	56%	13%	22%	10%	15%	10%	8%
STOXX 600 Sectors	44%	34%	22%	22%	20%	18%	16%
Commodities	34%	14%	22%	30%	31%	23%	14%
Median	40%	24%	22%	22%	20%	19%	15%

Source: Goldman Sachs Global Investment Research.

Appendix 5: Time series and cross-sectional regressions: Running the system forward and back

To measure the impact of macroeconomic shocks on asset prices, for each asset in each of these six markets, we regress monthly returns on monthly changes in all seven of our risk factors:

$$r_t^n = \alpha^n + \sum_{f=1}^{7} \beta_f^n \Delta F_t^f + \varepsilon_t^n \quad \text{(A2)}$$

This time series model relates r_t^n , defined as the 21-day return of a specific asset (n) at time (t), to 21-day changes in each of the seven market-based risk factors (f) at time (t), defined as ΔF_t^f . (Issues of correlation and causality among the risk factors themselves – and indeed among the economic concepts that they represent – loom large and are addressed in Appendix 3.)

To formally back out the implicit market-specific shifts in macroeconomic views, the cross-section of asset returns is related to the cross-section of asset exposures in that market, as Equation A3 illustrates:

$$r_t^n = \gamma_t + \sum_{f=1}^{7} \Phi_t^f \beta_f^n + \mu_t^n \quad \text{(A3)}$$

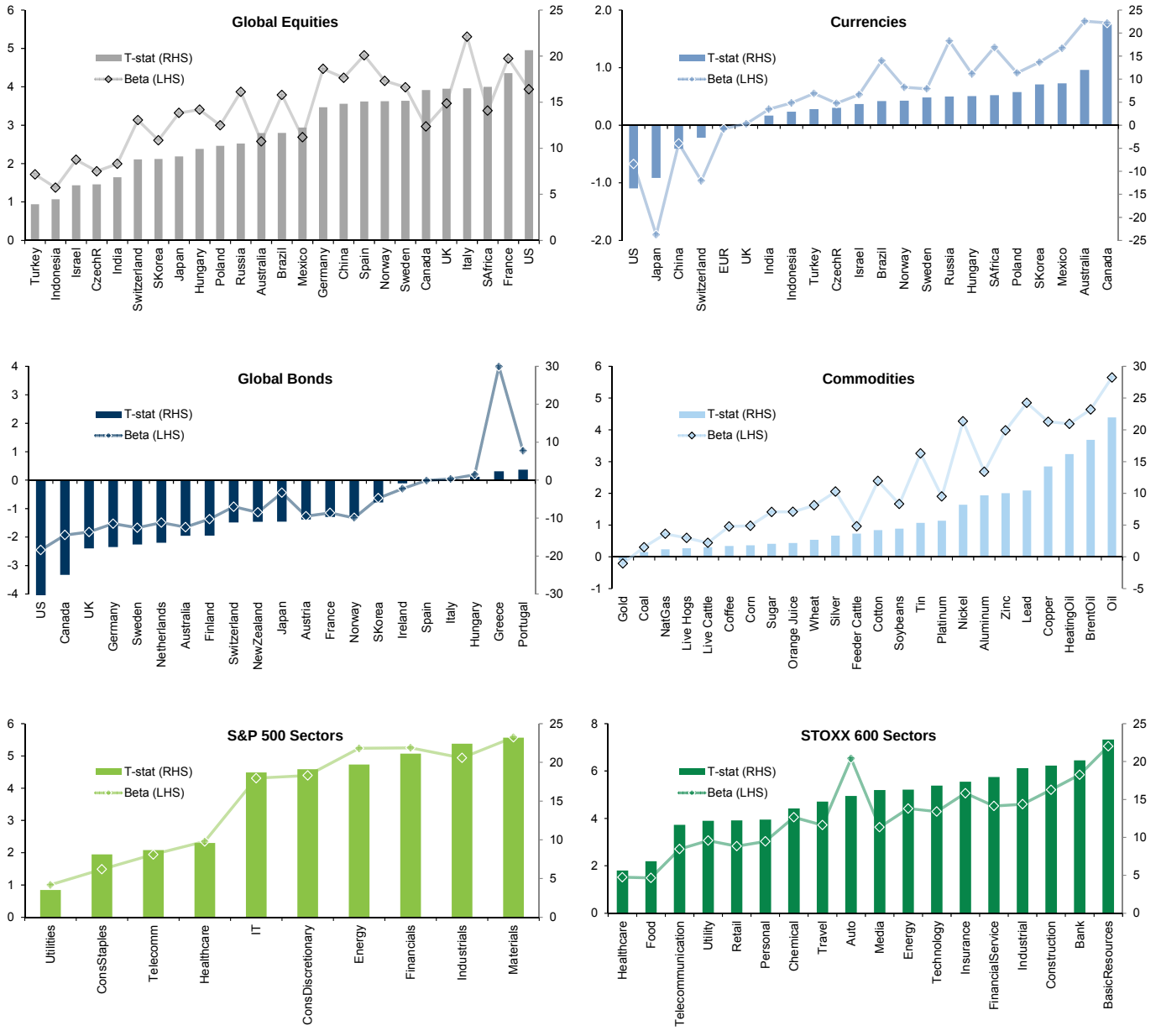
Here, in the cross-sectional regression (as opposed to the time series regression in Equation A1), r_t^n are 21-day returns for n assets (all from the same market) at some point in time t. Differences in the cross section are modelled as a function of the estimated exposures β_f^n, for each of the n assets to each of the seven macroeconomic risk factors. Note that in this context these exposures β_f^n are treated as 'data', and act as the independent (right-hand-side) variables.

The estimated slope parameters Φ_t^f show how much the cross-section is 'loading' on a particular macroeconomic risk, f, controlling for all other macroeconomic risks. These can be interpreted as a measure of how much the market has implicitly changed its view of factor f (on day t). Note that, in contrast to the time series model in Equation A2, where changes in the actual macroeconomic risk factors (ΔF_t^f) were the independent variables and the exposures (β_f^n), were estimated, in the cross-sectional model, the exposures (β_f^n) are the independent variables and implied changes in risk factors are now the estimated parameters (Φ_t^f). Thus, in this context, the parameters Φ_t^f are an estimated and implicit view of shifting macro risks, taking the place of actual shifts in macro risk factors, ΔF_t^f from Equation A2 above.

Although beyond the scope of this paper, the intercept term (γ_t) , which is estimated separately at each time t, is also an interesting parameter. Arithmetically, it is a version of the average return of all the assets in a given market at a point in time, above and beyond macroeconomic differences. It can be thought of as a measure of (macroeconomic-independent) common risk appetite at a point in time. Similarly, the R-squared from these regressions represents the degree to which a market is 'focused' on macroeconomic risks at a point in time.

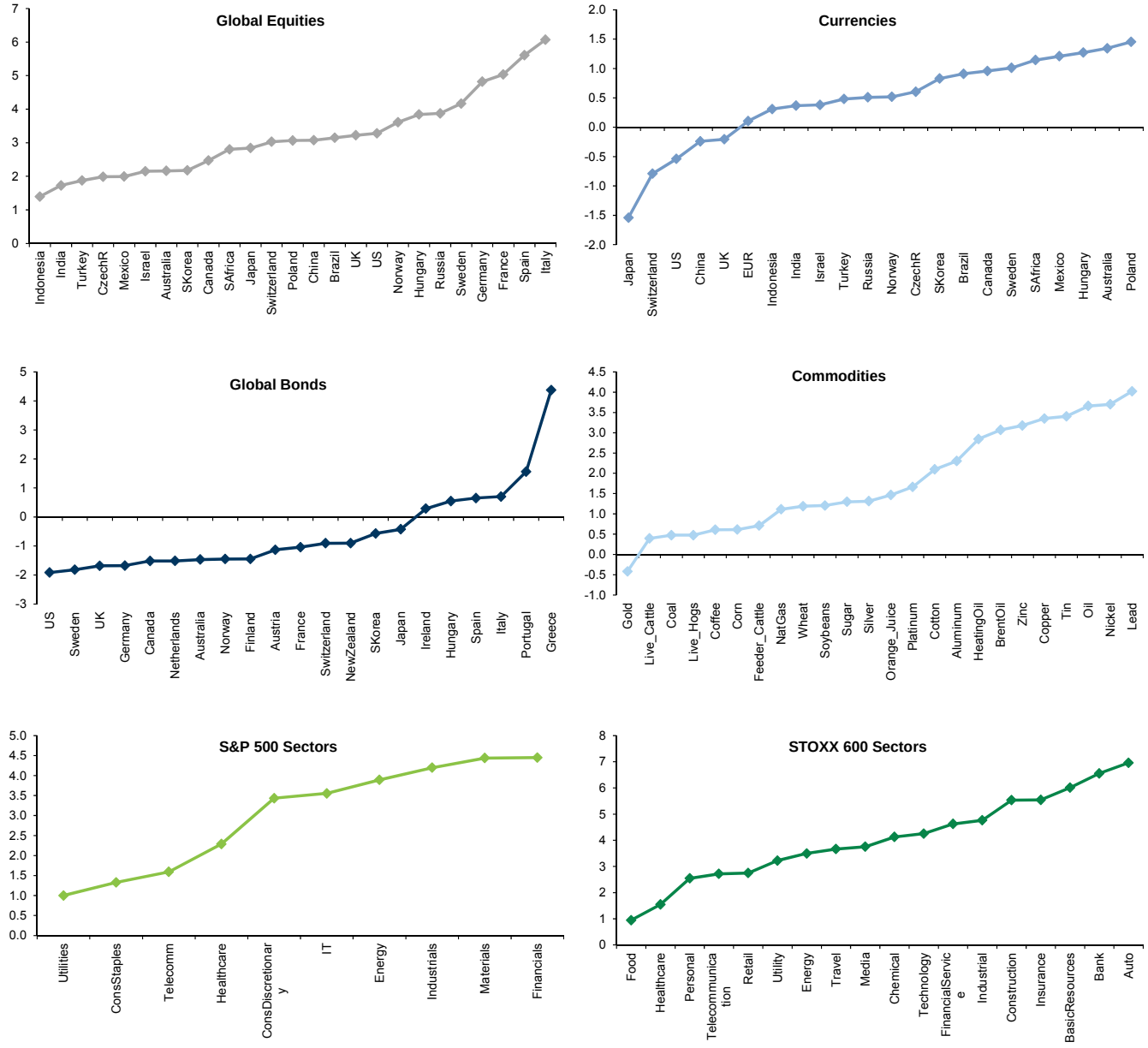
Appendix 6: Market exposures

Exposure to market-based US Growth Risk Factor



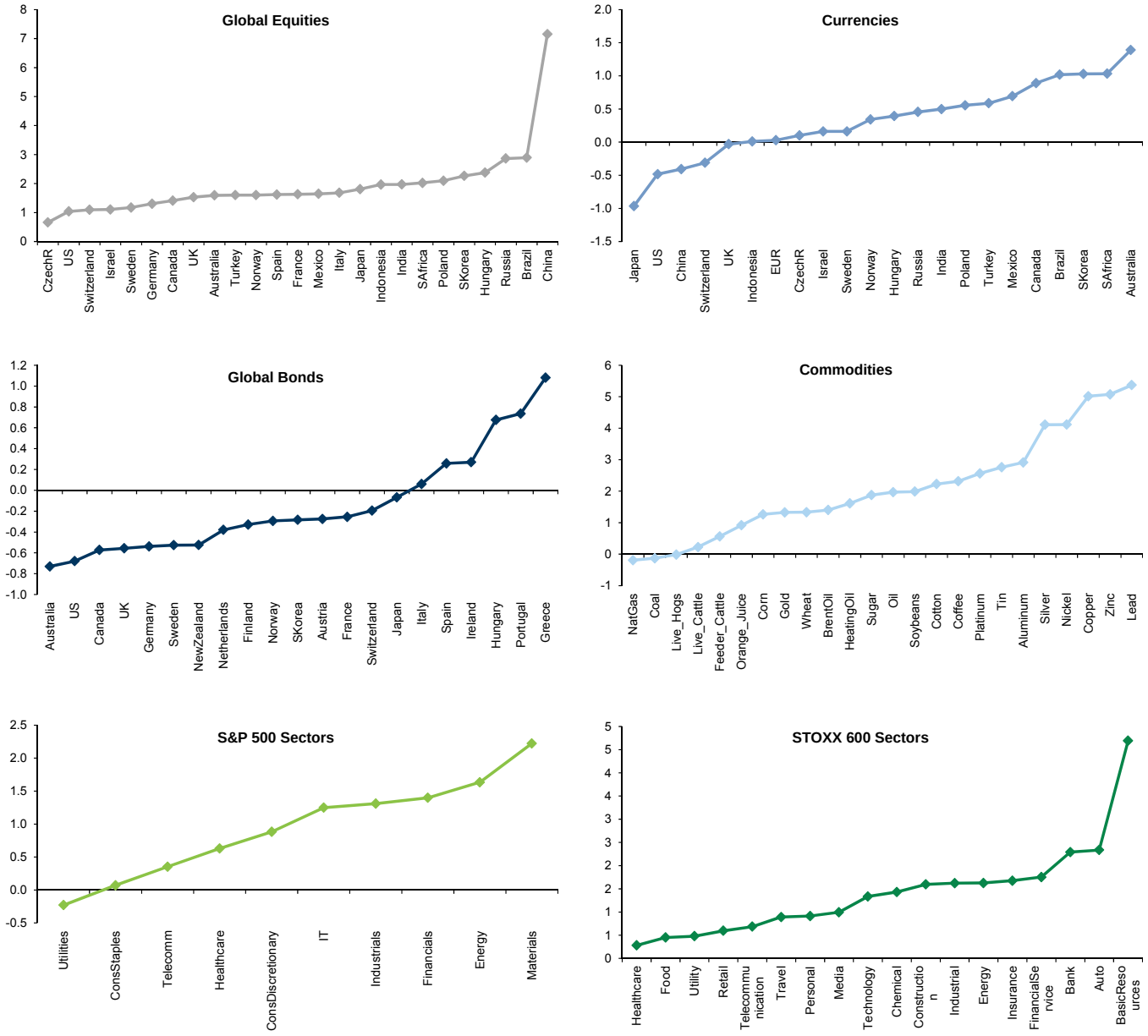
Source: Goldman Sachs Global Investment Research.

Exposure to market-based European Growth Risk Factor



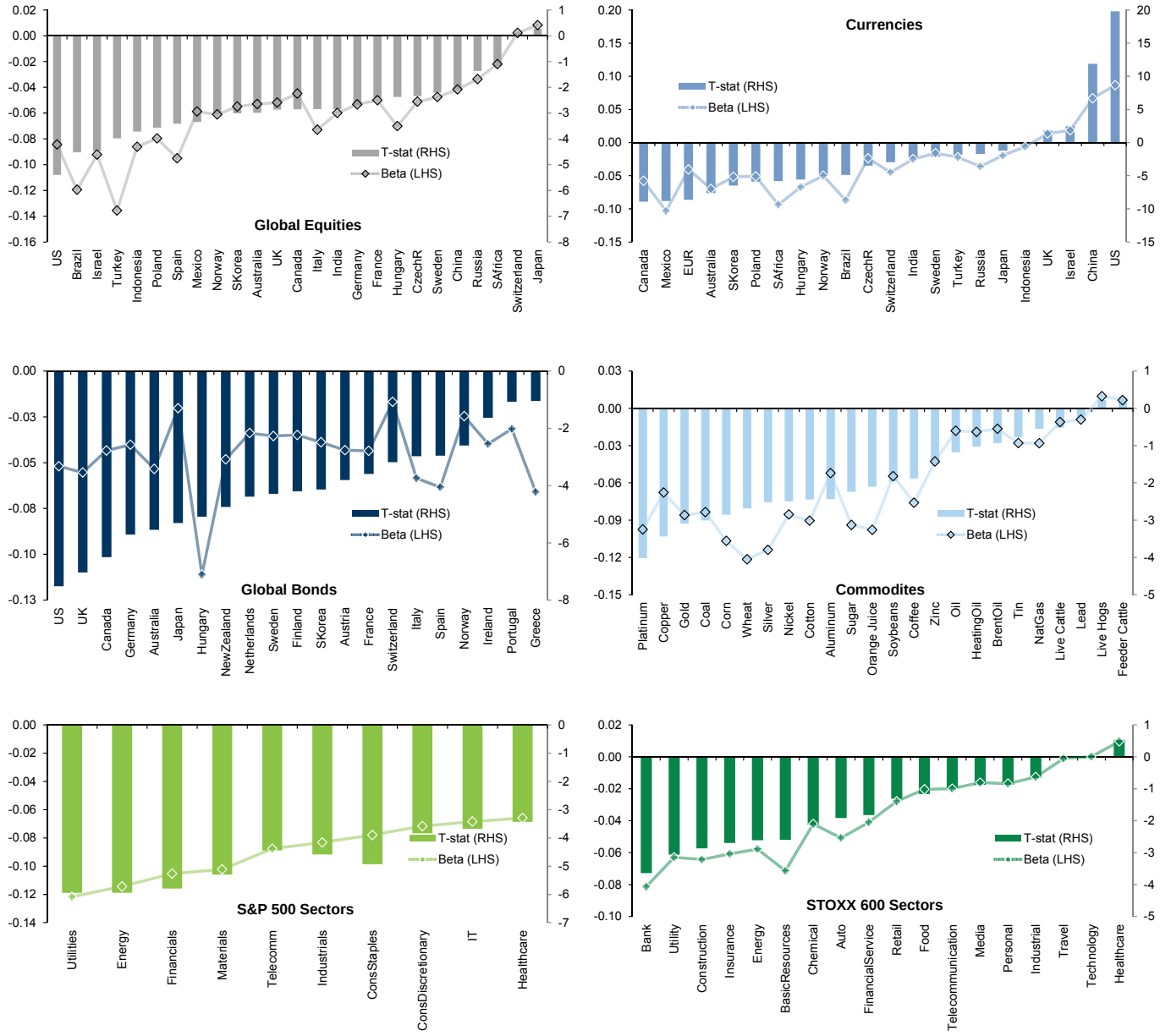
Source: Goldman Sachs Global Investment Research.

Exposure to market-based China Growth Risk Factor



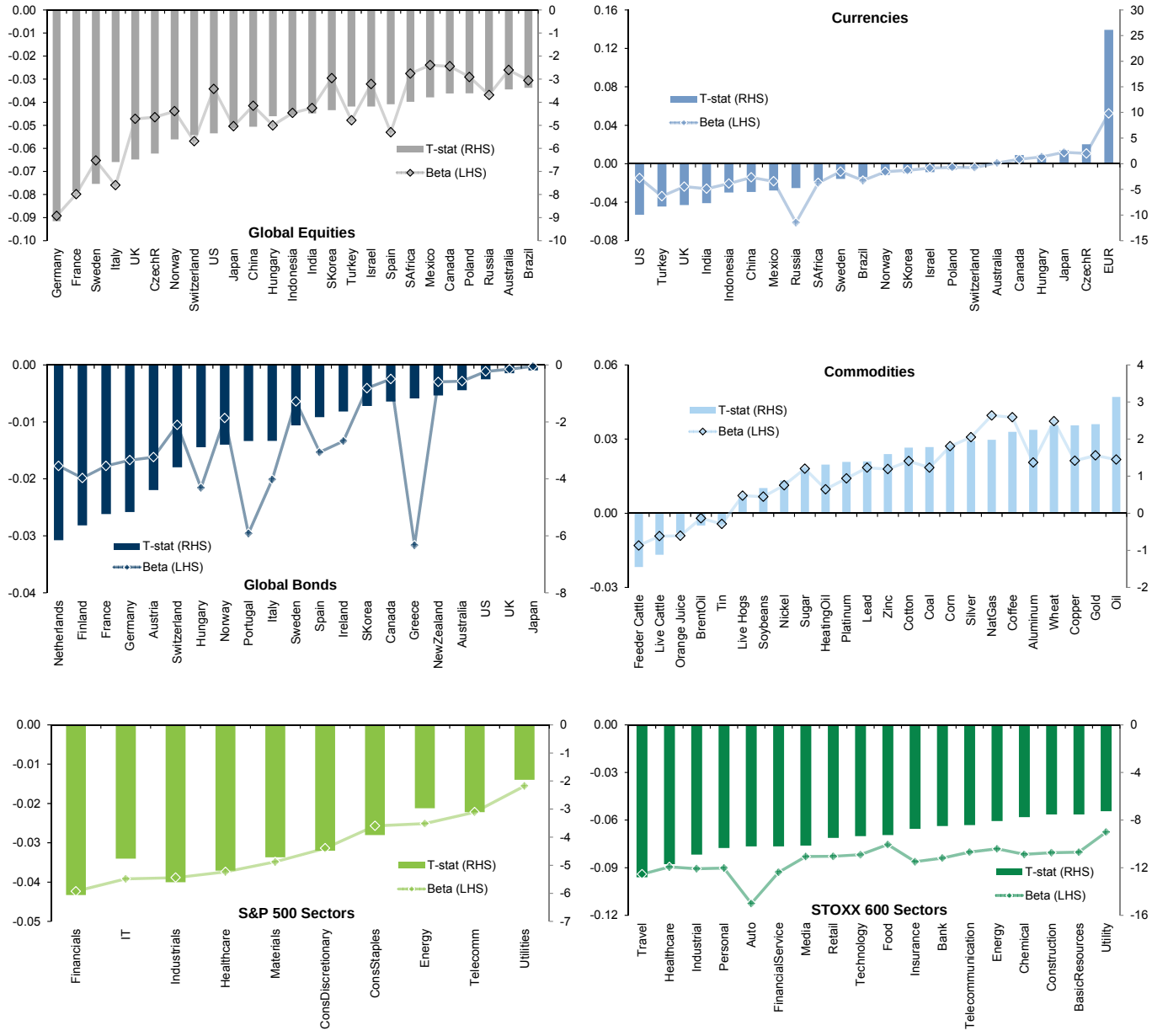
Source: Goldman Sachs Global Investment Research.

Exposure to US Financial Conditions Factor



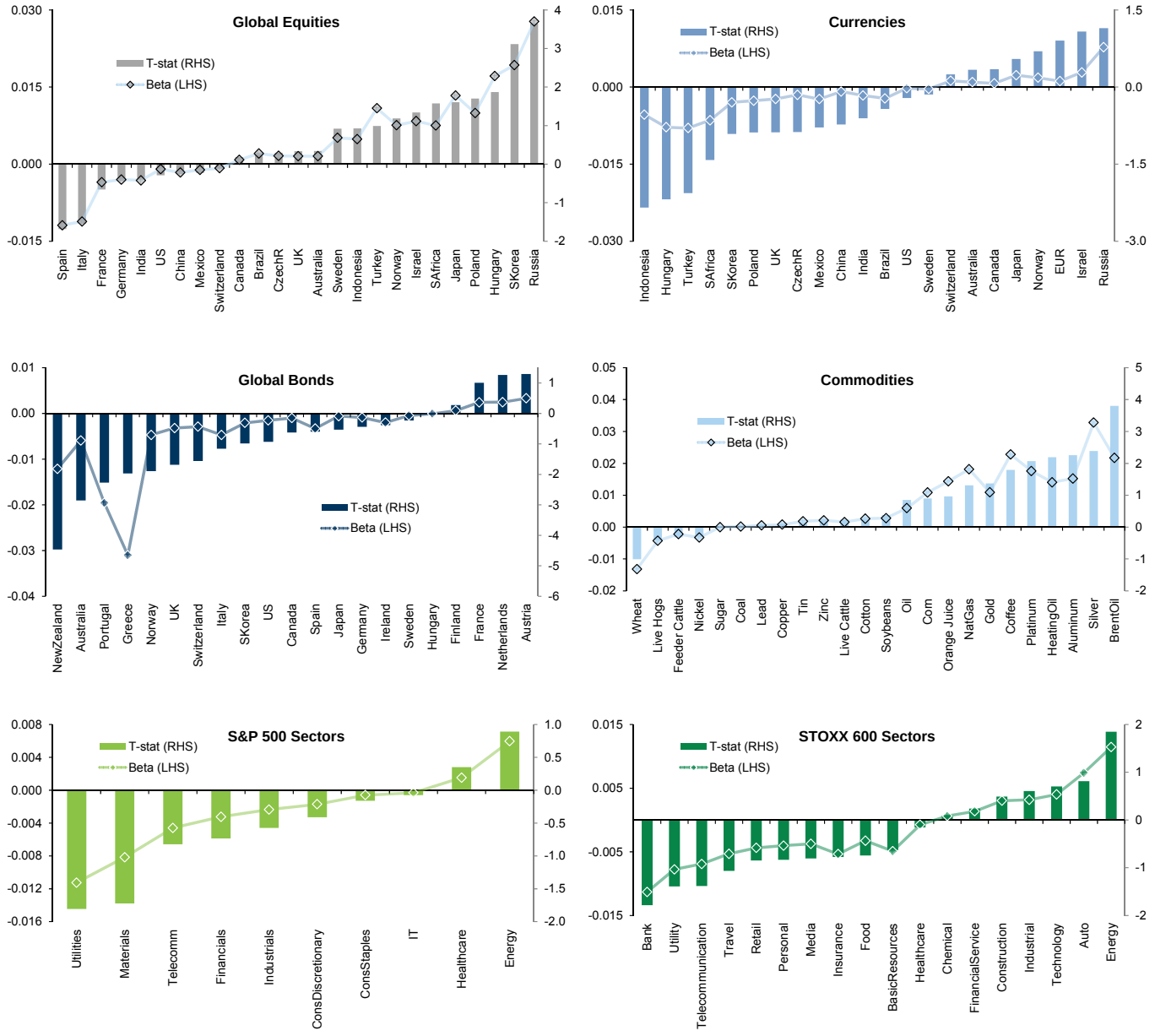
Source: Goldman Sachs Global Investment Research.

Exposure to European Financial Conditions Factor



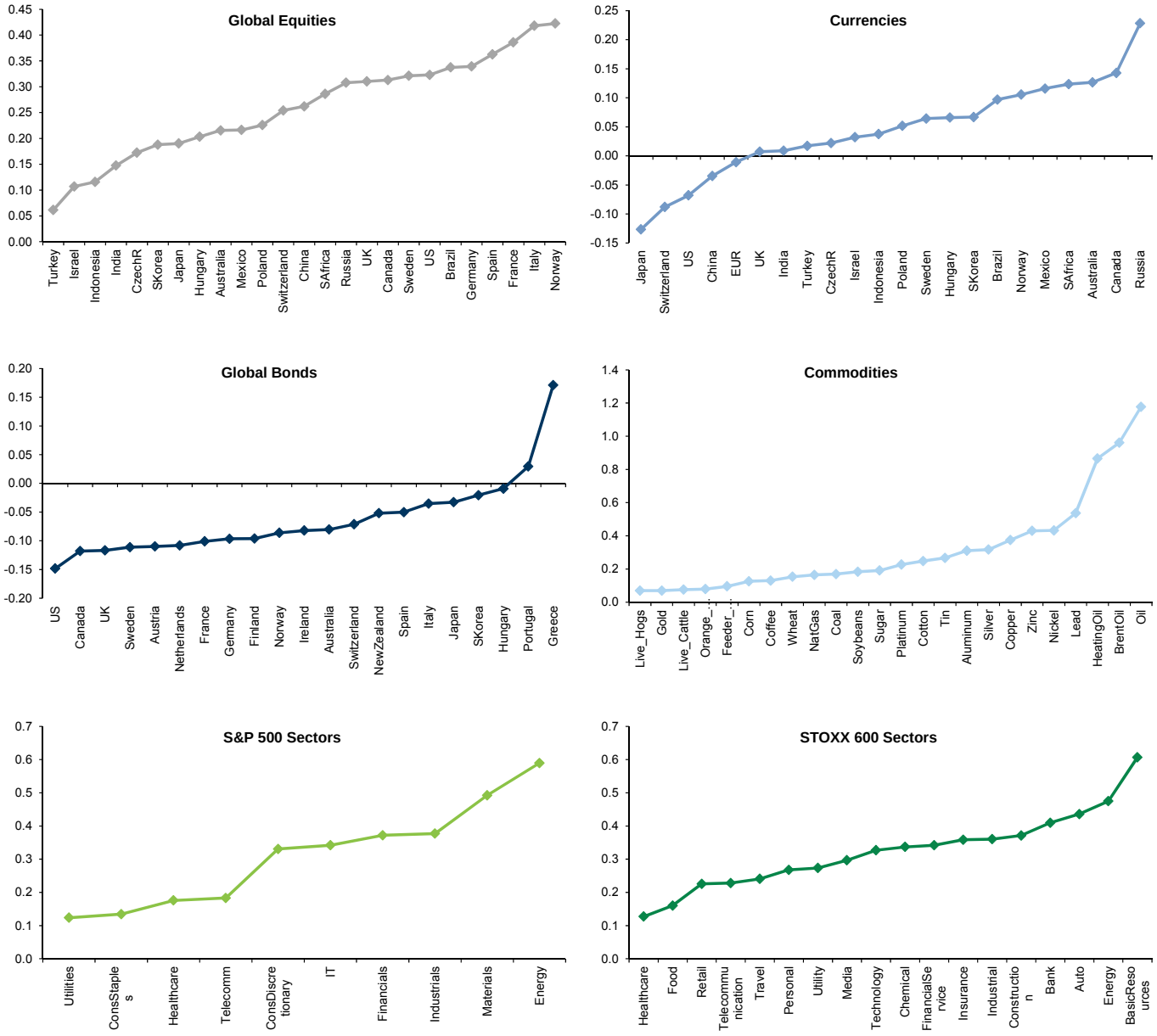
Source: Goldman Sachs Global Investment Research.

Exposure to US Inflation Factor



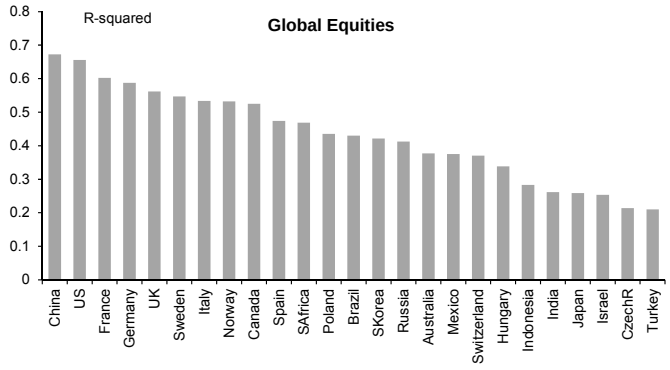
Source: Goldman Sachs Global Investment Research.

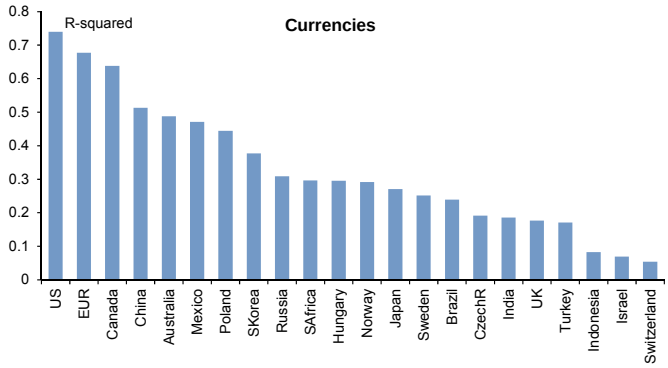
Exposure to Oil Risk

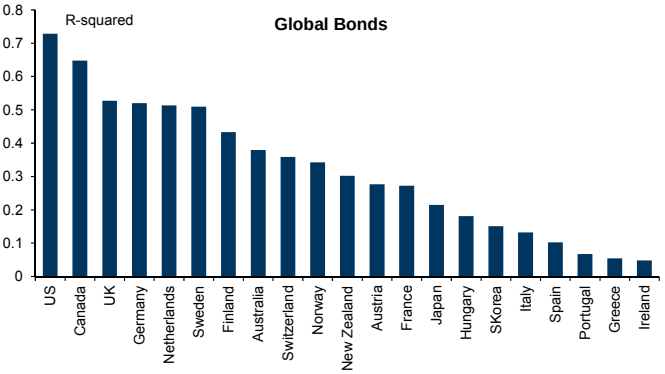


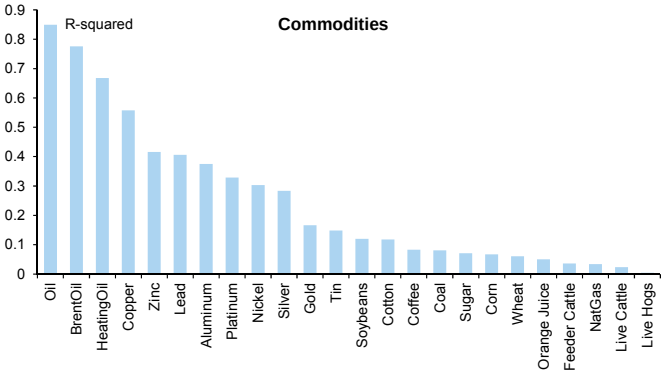
Source: Goldman Sachs Global Investment Research.

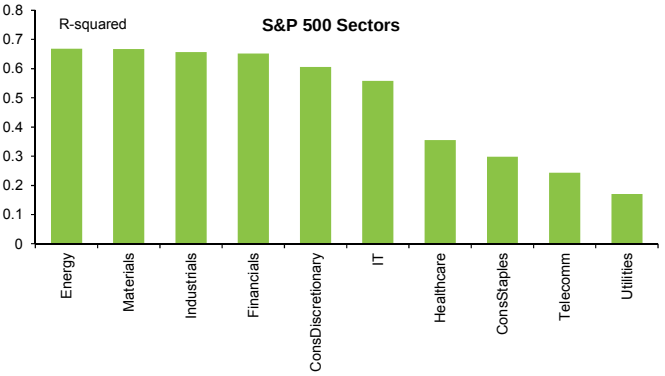
R-squared of macro risk models

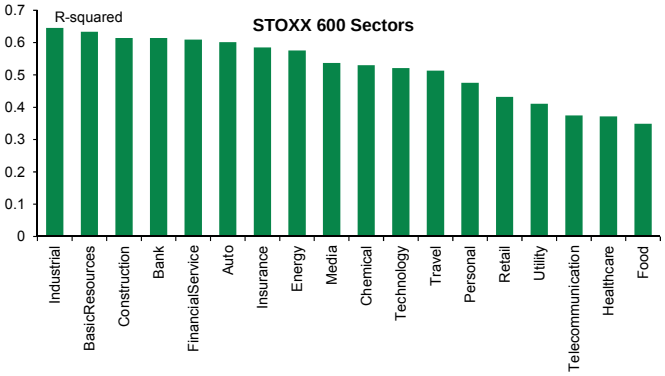








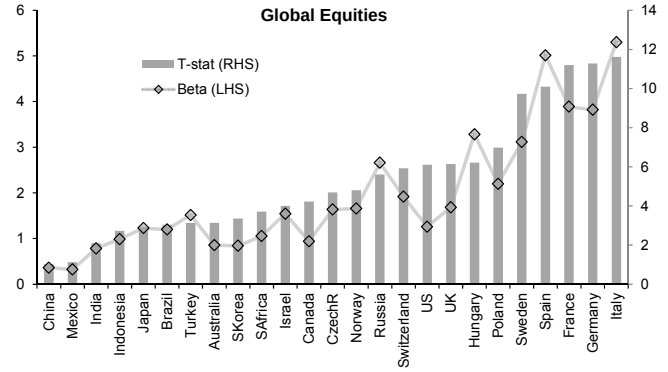


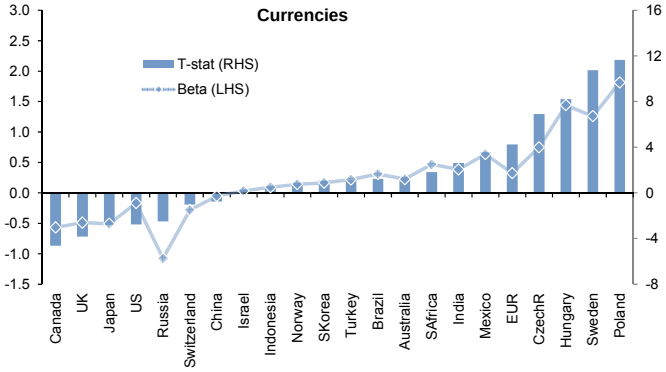


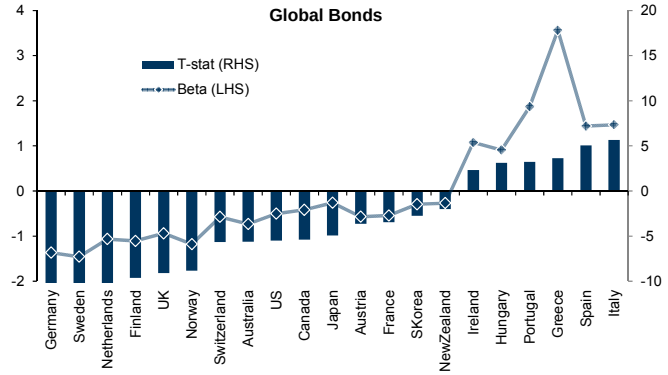
Source: Goldman Sachs Global Investment Research.

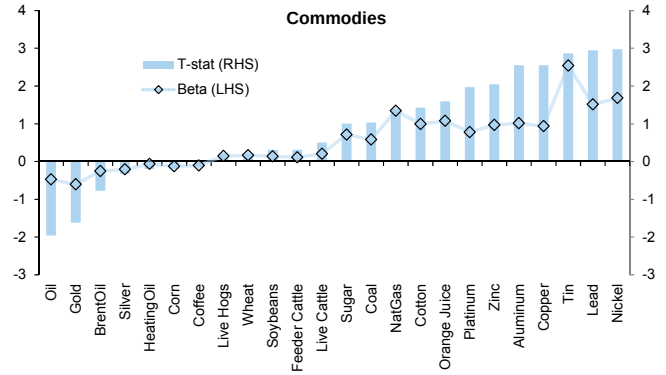
Exposure to European Growth Risk Factor*

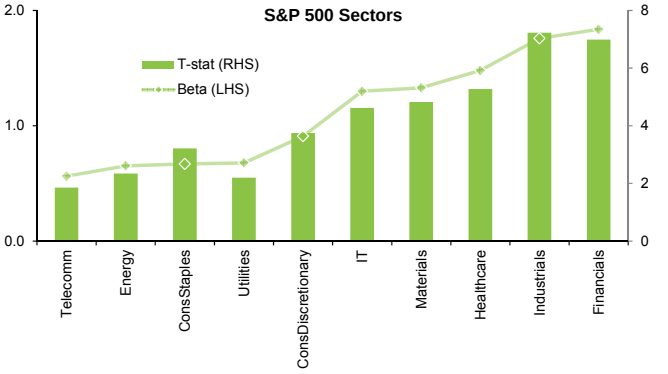
*Net of US Growth Risk

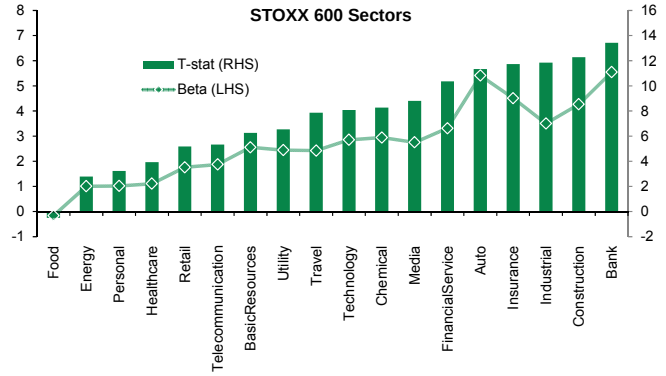








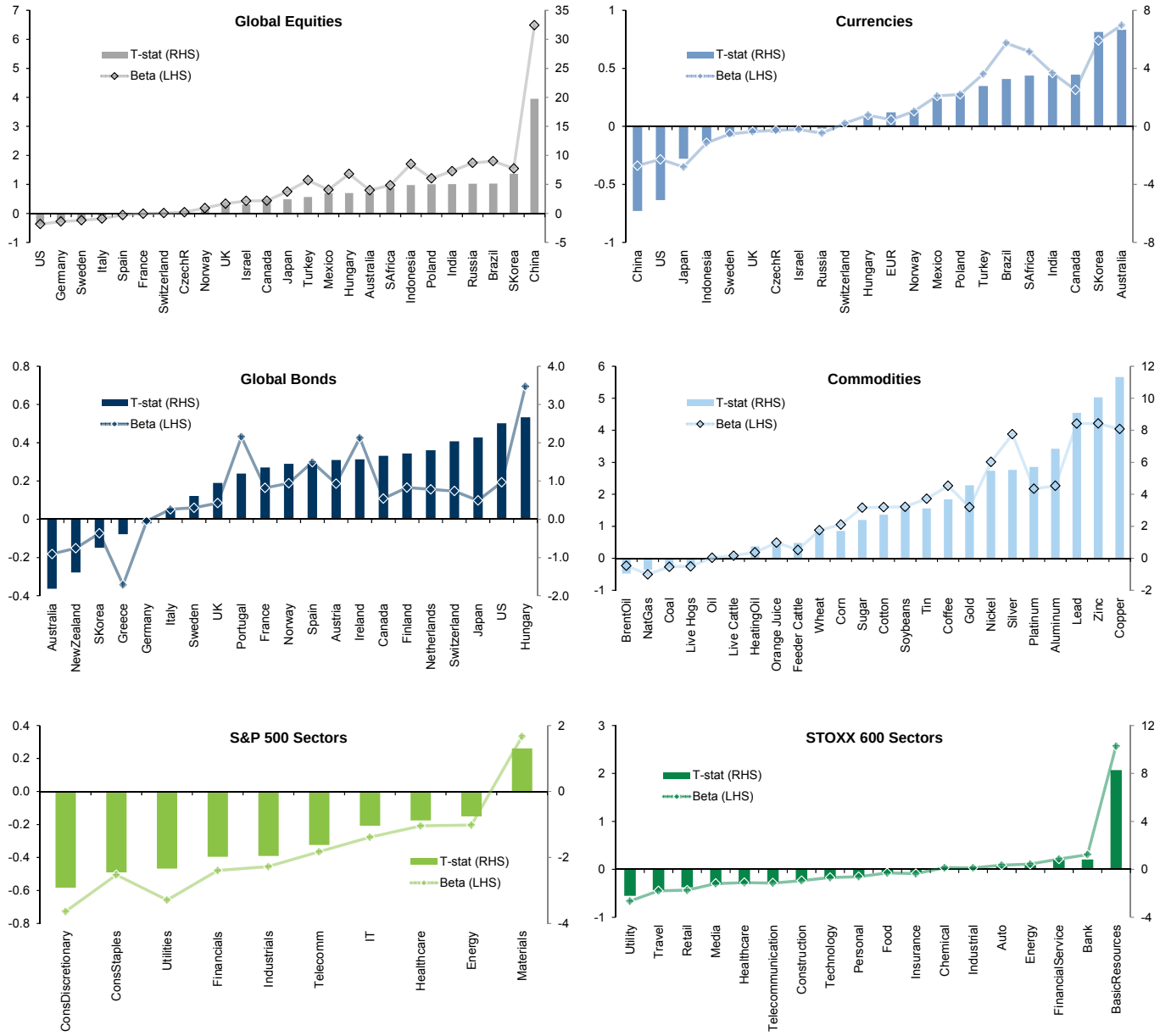




Source: Goldman Sachs Global Investment Research.

Exposure to China Growth Risk Factor*

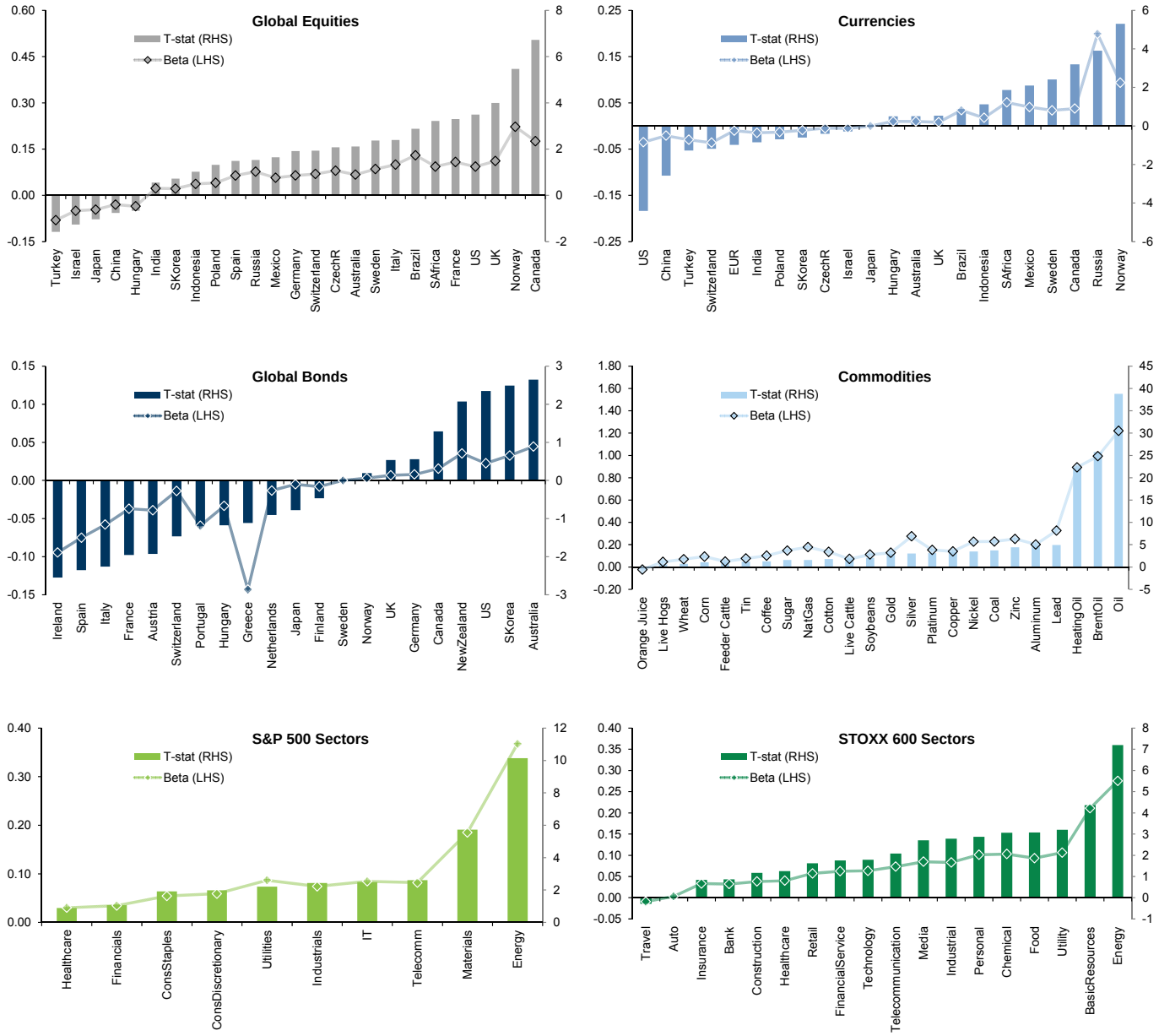
*Net of US Growth Risk



Source: Goldman Sachs Global Investment Research.

Exposure to Oil Risk Factor*

*Net of US Growth Risk



Source: Goldman Sachs Global Investment Research.

Disclosure Appendix

Reg AC

We, Noah Weisberger, Aleksandar Timcenko and Steven Strongin, hereby certify that all of the views expressed in this report accurately reflect our personal views, which have not been influenced by considerations of the firm's business or client relationships.

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