INSTITUTIONAL ADVISORY & SOLUTIONS

THE DIVERSITY OF REAL ASSETS: PORTFOLIO CONSTRUCTION FOR INSTITUTIONAL INVESTORS

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AUTHORS

Harsh Parikh, PhD
harsh.parikh@pgim.com
(973) 802-3088

Wenbo Zhang
wenbo.zhang@pgim.com
(973) 367-7871

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What is the role of real assets in institutional portfolios? To answer, we first identify the major real asset classes, both public and private, review their salient features, and measure their performance since 1996.

We focus on estimating real asset sensitivities to both macroeconomic variables (*e.g.*, growth and inflation) and traditional financial market performance (*e.g.*, stock and bond returns). We present a regression framework that addresses the low reporting frequency issues when estimating these sensitivities, especially for private real assets. While our analysis is US-centric, due to greater data availability, our methodology is applicable for non-US investors.

We find that real assets are heterogeneous in their macroeconomic and financial market sensitivities. In addition, we find that the estimated sensitivities are time varying. These findings support a diversified portfolio approach to real asset investing or active management of real asset portfolios.

Using the estimated sensitivities, we construct three real asset strategies – Diversification, Inflation-Protection and Stagnation-Protection. We show that the strategies' sensitivities to macroeconomic variables and financial market are more stable. We then show how these strategies perform in different economic environments: ideal, overheating, stagflation and stagnation.

Finally, we evaluate how these three real asset strategies might fit within a US pension plan. We show that these strategies can help improve funded ratios or lower surplus risk, especially in economic environments such as stagnation or stagflation that are of concern to plan sponsors. This analysis can also be applied to non-US plans.

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What is the investment role of real assets? A real asset has a total return sensitivity to inflation and/or economic growth that differs from those of traditional financial market assets (*e.g.*, stocks and bonds). Consequently, real assets may offer useful inflation protection, stagnation protection and portfolio diversification properties unavailable from traditional assets.

Investors often lump together assets like real estate, infrastructure and timberland into a "real assets" category. However, we show that there is significant diversity across real assets in terms of their sensitivities to macroeconomic factors and to traditional asset performance. Identifying and measuring these sensitivity differences is key to successfully incorporating real assets into an overall portfolio.

We estimate the exposure of various real assets to the inflation rate (CPI) and inflation surprises (*i.e.*, unexpected inflation).[1] If actual inflation matches expected inflation, assets such as nominal bonds, whose prices reflect expected inflation, should adequately compensate for inflation. However, if actual inflation deviates from expected inflation only real assets, whose performance tracks actual, not expected inflation, may provide inflation protection.

We also evaluate the exposures of real assets to the real growth rate (*i.e.*, real GDP) and growth surprises (*i.e.*, unexpected growth). Investors may look to real assets for stagnation protection (*i.e.*, provide robust performance in low growth environments).

Finally, we measure the sensitivity of real assets to financial market returns, such as stocks and bonds.

Given the diverse sensitivities of various real assets to inflation and growth, stocks and bonds, investors may wish to develop a strategy that combines real assets to best match their investment objectives. We design three real asset strategy portfolios to help investors meet a specific investment objective such as greater portfolio diversification, inflation protection, or stagnation protection. We conduct scenario analysis, assuming a three-year investment horizon, to examine how an allocation to real asset strategies would have affected the performance outcomes (*e.g.*, funded ratio and surplus risk) of a typical US pension plan across different economic scenarios.

This report proceeds as follows: In Section 1 we discuss the various types of real assets and some of their key features. This section may be skipped without loss of continuity by those familiar with the universe of real assets. Section 2 provides details on data and our estimation methodology. While our analysis is US-centric, the methodology can be extended to other countries and regions. Section 3 reports historical real asset performance. In Section 4 we estimate real asset exposures to market and macroeconomic factors. Using these exposures, in Section 5 we construct real asset strategy portfolios to meet different investment objectives. We then simulate 3y economic environments and measure strategy portfolio performance to validate our real asset portfolio construction methodology. Finally, in Section 6 we show how a real asset allocation might impact a pension plan's outcomes in various economic environments.

1. Types of Real Assets

Some real assets (*e.g.*, real estate) have long found a place in institutional portfolios and their payoffs and risks are well understood. However, other real assets (*e.g.*, farmland) are relatively new to investors and have limited performance data.[2] Recognizing that US inflation has been relatively tame since the early 1980s, we discuss the fundamentals of real asset returns to build intuition for how these assets might perform across various economic scenarios including high inflationary environments.

Farmland

Farmland typically includes leased, fixed-rent annual crops (*e.g.*, wheat, corn, and soybeans) and owner-operated permanent crops (*e.g.*, pistachios, grapes, and oranges). Unlike annual crops, economic exposure to permanent crops is not widely available to institutional investors via the futures markets.

Investor-owned annual crop returns comprise land appreciation and rental income.[3] Land price appreciation is a major contributor as farmland has experienced inflation-adjusted price appreciation since late 1980s, perhaps due to falling interest rates and favorable governmental policies (Figure 1).[4]

1 For inflation we use the All Items Consumer Price Index for All Urban Consumers (CPI-U), also referred to as headline inflation (CPI). The composition of this price index includes the volatile food and energy components. Federal Reserve policy makers emphasize "core" inflation measures such as the personal consumption expenditure (PCE) measure that exclude these components. While there are compositional differences between CPI and PCE, they track each other closely. Our analysis can be adopted and applied using any inflation index preferred by an investor.

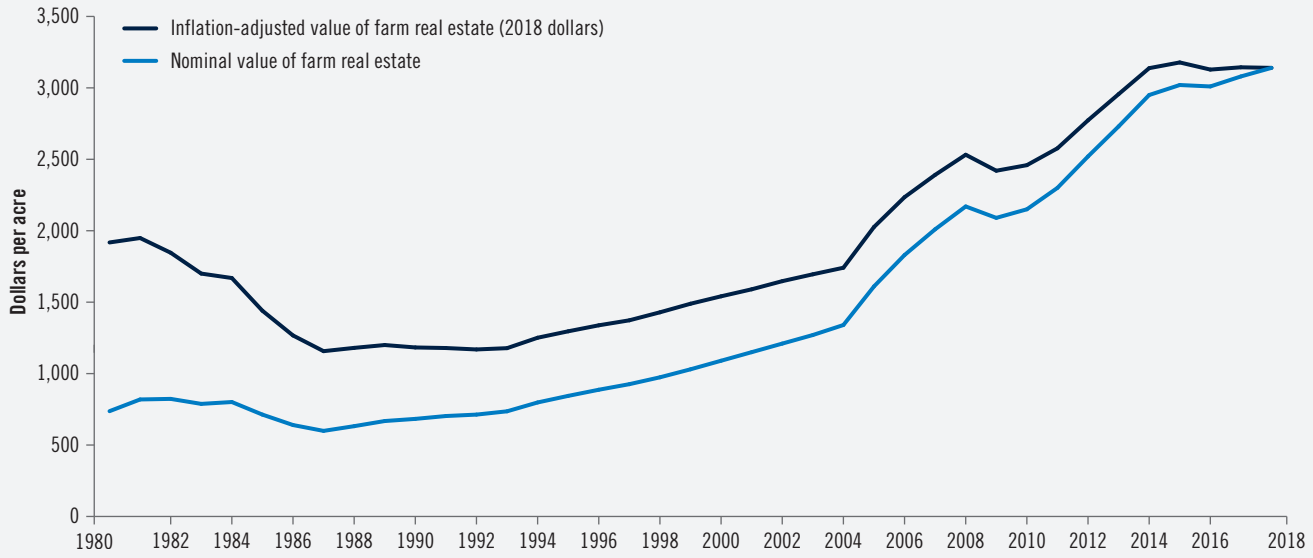
2 Real assets are accessible via many investment vehicles, both public securities (*e.g.*, REITs) and private investments (*e.g.*, limited partnerships). Considering that investors have different liquidity preferences depending on their investment horizon, we include both liquid and illiquid assets for our analysis. This paper does not account for liquidity-related constraints when constructing real asset strategies. See J. Shen, F. Farazmand, and M. Teng, "The Tradeoff between Liquidity and Performance: The Role of Private Assets" *PGIM,* January 2019.

3 Besides the popular fixed cash rent lease, leases could also be flexible like crop share in which the owner receives a share of the crop income. Returns from owner operated permanent crops would include land price appreciation and income from crop sales.

4 B. Christopher, N. Key, S. Tulman, A. Borchers, and J Weber, "Farmland Values, Land Ownership, and Returns to Farmland, 2000-2016" *ERR-245, U.S. Department of Agriculture, Economic Research Service,* February 2018.

Figure 1: Inflation-Adjusted Farm Real Estate Value

Average per-acre US farm real estate values, 1980-2018, in 2018 dollars



Note: Farm real estate includes land and buildings. Data reflect values as of June 1 of each year. The annual GDP implicit price deflator is used to convert nominal values to 2018 US dollars (Department of Commerce, Bureau of Economic Analysis). For 2018, the average of the first and second quarter price deflators is used. Data exclude Alaska and Hawaii.
Source: USDA-ERS Report: Farmland Value https://www.ers.usda.gov/topics/farm-economy/land-use-land-value-tenure/farmland-value/.

Lease terms for annual crops are typically 2-3y after which investors renew leases. Although rents are fixed for that period, they fluctuate with commodity cycles. Investors also bear the risk that farmers miss rental payments and the need for periodic capital expenditures (drainage, soil enrichment and irrigation).

Compared to annual crops, permanent crops are less sensitive to commodity cycles but they have other risks. It can take 5y or longer for a plant to be productive (*e.g.*, fruit bearing), so the land may be "in development". Such development risks, with limited opportunity for crop rotation, makes permanent crops riskier compared to annual crops. While permanent crop yields are usually higher than annual crops, yields depend on plant maturity and are more variable. In addition, a greater share of permanent crop returns is from operating income which has a "J-curve" profile due to upfront development costs. Therefore, active farm management – applying technology, managerial skill, and potential land repurposing for higher and better use (*i.e.*, rezoning) – are key for profitability. Investors looking for an active farmland investment might consider permanent crops, while investors looking for more passive participation or steady income might prefer annual crops.

Aggregate farmland returns have been resilient during economic downturns. In fact, farmland was one of the few asset classes to have positive total returns in 2008 (15.8%). Even during recessions demand for most agricultural products is relatively inelastic suggesting that the farming economy can ebb and flow independently of traditional financial markets.[5] For example, while the US economy improved after the recent financial crisis, farming suffered when ethanol demand stagnated and corn prices declined.[6] Since 1991, annual crops have not had a single negative year and permanent crops have had only one negative year (that one negative year was down 1%). Investors seeking diversification and countercyclical performance may wish to consider farmland.

While crop price appreciation benefits farmland investors, input cost inflation (energy and wages – food is 13% of the CPI) may offset this benefit. However, sector total factor productivity improvement has limited growth in input requirements so farmland may have mixed sensitivity to inflation.[7]

The NCREIF Farmland Property index represents $8.5b (as of 2017; less than $1b in 1996) in farmland properties.[8] The index includes only income-producing agricultural properties held in fiduciary capacity. Of the properties tracked by NCREIF, 44% (by market value) are permanent crops and 56% are annual crops. The index reports performance on an all-cash, unleveraged

5 Some performance may have been due to demand for ethanol and biofuel production supported by government subsidies.
6 Trade policy additionally affects the agricultural sector.
7 L. S. Wang, P. Heisey, D. Schimmelpfenning, and E. Ball, "Agricultural Productivity Growth in the United States: Measurement, Trends, and Drivers" *USDA,* July 2015.
8 National Council of Real Estate Investment Fiduciaries, NCREIF, also see "Land Values 2018 Summary", USDA. The value of farmland and buildings is estimated at $2.7t. http://usda.mannlib.cornell.edu/usda/nass/AgriLandVa//2010s/2018/AgriLandVa-08-02-2018.pdf

basis, based on self-reported data from contributing members (fiduciaries on behalf of tax-exempt investors).[9] Consequently, index composition changes as membership and member portfolios change. For our analysis we use quarterly index total returns. Since the price return component equals property appreciation adjusted for capital expenditures and partial sales, returns may exhibit appraisal smoothing. Returns may also have self-reporting bias.[10]

Timberland

The three sources of timberland returns are: timber prices, land values and timber growth. Timber prices have been volatile without a long-term trend (Figure 2). Although not shown, this is also the case for inflation-adjusted land values (unlike farmland). The main contributor to timberland returns has been timber growth which affects both size and quality. The stumpage price (price offered for a standing tree) increases with tree size. In addition, as the tree ages its wood can be used for higher-value purposes. For example, younger pine trees (10y old, 10" diameter) are used for lower-value pulpwood while older trees (20y+ old, 14" diameter) are used for higher-value sawtimber like veneer logs. Usage varies with the type of wood – hardwood (*e.g.*, maple, cherry, oak and eucalyptus) or softwood (*e.g.*, spruce, pine and fir). Harvest levels, production costs and weather also affect returns.

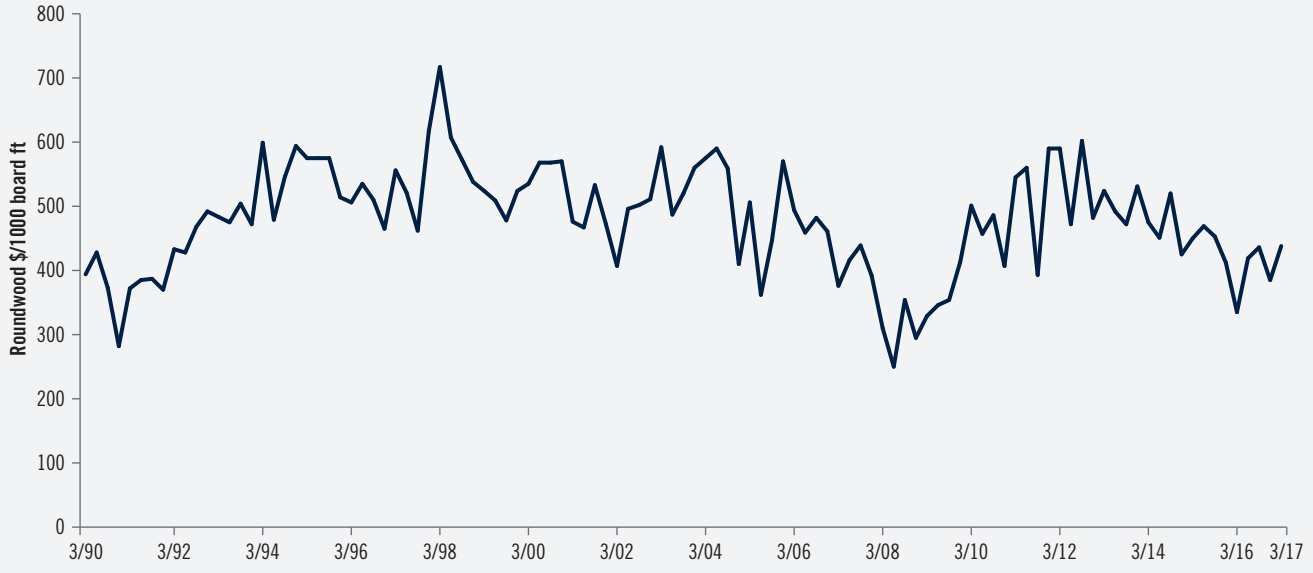
Construction demand for timber has remained strong. US demand for roundwood (*i.e.*, uncut logs used for industrial purposes) and sawn wood (*i.e.*, lumber) has grown steadily. While newsprint demand for pulpwood has fallen (due to online media and recycling), packaging demand remains strong (also due, in part, to online shopping).

Short-term fluctuations in timber demand and supply produce variation in timber prices. For example, a construction boom tends to put temporary upward pressure on timber prices. However, we might expect long-term timber prices to track long-term inflation since a key cost of timber is the waiting time for the tree to grow, and the opportunity cost of waiting is the interest rate which is tied to inflation.

In terms of timberland's sensitivity to growth, sawn wood production and consumption declined during the financial crisis (led by housing) suggesting a positive relationship.[11] However, pulpwood prices remained stable during the crisis.[12] Depending on the mix of tree types, timberland may provide stable returns during market downturns.

Timber property management contributes to investment returns as rotation, harvest timing and seedling plantation decisions affect yields, and taking advantage of higher and better use land opportunities can improve land values.

Figure 2: Roundwood Prices ($/1000 board ft)
(March 1990 – March 2017)



Source: Pennsylvania State University, School of Forest Resources and PGIM IAS.

9 Total returns comprise capital appreciation (the change in market value adjusted for partial sales and any capital improvements) and income returns (net operating income (NOI) divided by average investment for the quarter).

10 See https://www.ncreif.org/data-products/farmland/ for details on performance calculation methodology. Index data start in 1990Q4.

11 "US Pension Fund Suffers Big Losses on Forest Land", https://www.ft.com/content/2ef6229a-8f54-11e8-b639-7680cedcc421

12 P. Stewart, 2015. "Wood Supply Market Trends in the US South" *U.S. Industrial Pellet Association*. Discusses interaction of pulpwood and sawtimber forest inventory.

Investments in timber could have significant idiosyncratic risk stemming from a lack of sector or geographic diversification, weather, title disputes, local regulatory changes and environmental issues.[13]

The NCREIF Timberland Property index represents more than $25b (as of 2017; $2.5b in 1996) in US timberland properties, of which 80% or more are fee simple (directly owned) and held in fiduciary capacity.[14] We use quarterly index total returns which begin in 1987. The reported performance is on an all-cash, unleveraged basis. As with farmland, quarterly price returns may exhibit appraisal smoothing and may have self-reporting bias.[15]

Infrastructure

Infrastructure: Private Equity

Infrastructure is a diverse real asset category comprising airports, toll roads, freight rails, seaports, pipelines, telecom and power generation (hydro, wind, and natural gas) assets. These assets are typically long-lived which may suit investors with long-dated liabilities.

Infrastructure investment risk varies depending on the development stage: brownfield (*i.e.*, operational) assets have lower, bond-like risk while greenfield (*i.e.*, in development) assets tend to have more equity-like risk. Infrastructure investors may wish to diversify across development stage, sectors and regions to manage regulatory, leasing, construction and development risks.

Social infrastructure assets like schools and hospitals may have a positive social impact as well as good investment returns but require specialized management ability and operational skill.

Infrastructure assets vary in their sensitivity to economic growth. For example, economic downturns affect utility consumption and auto traffic less than airport and seaport traffic. Even within the seaport category, demand and prices for tanker, dry bulk, and containerized cargo may respond differently to changes in economic conditions. For example, Figure 3 shows historical prices for both the Baltic dry bulk and dirty tanker indexes. For the months when oil prices fell more than one standard deviation (-7.9%, on average), Baltic dry bulk prices also fell (-5.8%, on average) whereas Baltic dirty tanker prices rose (2.1%, on average).

Infrastructure assets may offer inflation surprise protection as revenues may be contractually linked to general realized inflation or operating expense inflation, or both. Social infrastructure asset types may be vulnerable to wage inflation and other rising costs in education and healthcare, but they are less sensitive to economic downturns.

Overall, an investor's exposure to inflation and growth depends on the portfolio's infrastructure asset mix.

Investors often obtain exposure to infrastructure via private limited partnerships (LPs). Private infrastructure assets under management are estimated at $418b.[16] In 1996 reported performance was based on only 3 funds, but as more data became available, 2017 performance was based on 134 funds and $208b in LP assets. For our analysis, we use quarterly pooled time-weighted rates of return (TWRR), net of fees, of all outstanding vintages.[17] Investors typically hold only a handful of vintages and managers (GPs), so an investor's realized performance is likely to differ from pooled returns.

Infrastructure: Midstream Energy

Investing in midstream energy infrastructure is typically achieved via a Master Limited Partnership (MLP). While MLPs are primarily a vehicle for US retail investors, US institutional investors (*e.g.*, public plan sponsors) also invest. MLPs are publicly-traded passthrough partnerships with a GP-LP type structure which provides tax efficiency as unitholders pay taxes at their individual rate.[18] Most MLPs operate assets like pipelines (natural gas, crude oil or refined products) and typically pay large periodic cash distributions to unitholders.

Tariff rates for crude and product pipelines may be linked regulatorily to inflation, providing investors with some protection against inflation surprises. However, this introduces regulatory risk.[19] MLP investment performance is also sensitive to oil prices (inflation) and pipeline volume (growth) which, in turn, depends on energy demand, oil prices and available infrastructure capacity.

The publicly-listed market for midstream MLPs is relatively liquid with more than $300b in market capitalization in 2017 ($5.6b in 1995).[20] The composition of the MLP universe has changed significantly over time. For example, Kinder Morgan

13 See: https://www.bloomberg.com/news/articles/2018-03-01/harvard-blew-1-billion-in-bet-on-tomatoes-sugar-and-eucalyptus.

14 This figure significantly underestimates investment capacity. Private corporate and non-corporate ownership of timberland is estimated at 360m acres. At $1,808/acre this amounts to a capacity of $650b. See S. N. Oswalt, and W. B. Smith, "U.S. Forest Resource Facts and Historical Trends" *USDA,* August 2014.

15 See https://www.ncreif.org/data-products/timberland/ for details on the performance calculation methodology.

16 Source Preqin, June 2017.

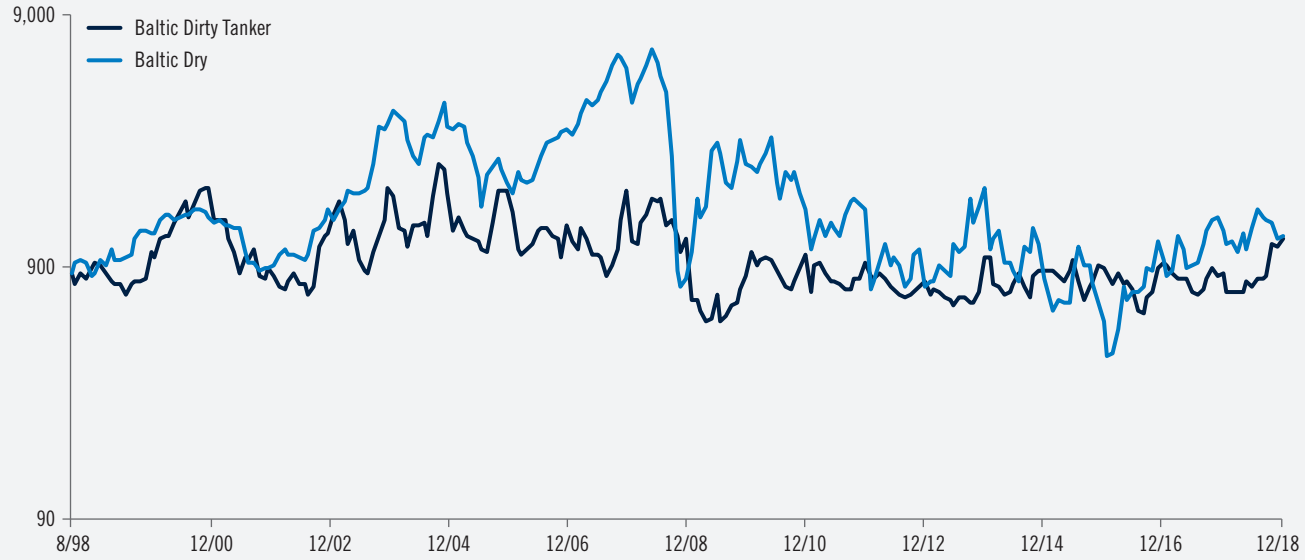
17 Time-weighted rates of return use the modified Dietz methodology which considers the timing of cash flows. We also use the TWRR for private natural resources and private value-add and opportunistic real estate.

18 More recently, there have been several reorganizations merging related GP and LP entities for reasons including simplifying the structure and improving the cost of capital. https://www.alerian.com/mlp-structural-simplifications-part-1-reorganizations/

19 More recently in March 2018 Federal Energy Regulatory Commission (FERC) announced new rules preventing MLPs from recovering income tax allowance (ITA) as part of operating expense, as MLPs do not pay any federal tax. Some MLPs were more affected than others depending on whether the tariff rates are FERC regulated cost-of-service rates. Indeed, political risk is a key concern for MLPs.

20 Source: Alerian MLP Index, Alerian, as of 2017.

Figure 3: Baltic Dry Index vs. Dirty Tanker Index
(August 1998 – December 2018)



Note: The chart is in log scale. The Baltic Dry Index is an index of shipping rates which are based on 20 key dry bulk routes measured on a time charter basis and covers Handysize, Supramax, Panamax and Capesize dry bulk carriers which carry commodities such as coal, iron ore and grain. The Baltic Dirty Tanker Index is an index of charter rates for crude oil tankers on selected routes published by the Baltic Exchange. Dirty tankers generally carry heavy fuel oils or crude oil.
Source: Datastream and PGIM IAS.

Energy Partners (KMP) had a 20% weight in the index in 2000. With the 2001 listing of Kinder Morgan Management LLC the combined weight to Kinder Morgan grew to 25%. Later, in 2014, the three Kinder Morgan MLPs were de-listed when they were repurchased by Kinder Morgan Inc. (KMI).[21]

Infrastructure: Private Debt

Another infrastructure investment option is fixed income debt backed by infrastructure projects. Unlike traditional unsecured corporate debt, infrastructure debt is often directly tied to the cash flow generated by the underlying long-lived assets. This cash flow is, in turn, generally tied, sometimes contractually and regulatorily, to inflation (*i.e.*, operating costs) and growth (*i.e.*, asset usage) providing a source of credit support during adverse economic conditions that is not available in other debt markets.

Infrastructure debt may have either fixed or floating rate coupon with a benchmark rate and credit spread. Although infrastructure debt typically has a good credit rating, debt related to greenfield projects may have a low initial rating as projects often commence with high operating leverage. Nevertheless, infrastructure debt does have credit risk as a project could fail or regulatory support may weaken. In addition, investor appetite for credit-risky debt fluctuates with the macroeconomic credit cycle which affects interim infrastructure debt returns.[22]

Energy is a major sector within infrastructure debt. After the financial crisis, as investors searched for yield and security, and the need for financing of innovative oil production techniques grew, there was a wave of infrastructure debt issues in oil and natural gas infrastructure (24% of project finance debt globally).[23] The growing financing need for emerging renewable resource projects accounted for 12% ($9b) of infrastructure fundraising in 2017. The ability to service private energy-related infrastructure debt depends on energy prices which, in turn, will likely make the performance of this debt sensitive to inflation and growth.

Since 2008 more than $40b of funds has been raised in private infrastructure debt funds.[24] Due to currently limited available historical data we exclude private infrastructure debt in this study.

21 Individual stock discussion is for illustration purposes only and does not constitute a recommendation to buy, sell or hold any particular security.
22 See F. Blanc-Brude, and O. R.H.Ismail, "Who is afraid of construction risk?" *EDHEC-Risk Institute,* July 2013.
23 https://www.windpowerengineering.com/construction/financing/analyzing-size-structure-2016-global-project-finance-debt-q3-q4/
24 Source: Preqin, June 2017.

Natural Resources (Energy & Metals)

Natural Resources: Private Equity

Natural resource investments are typically upstream energy (oil and gas exploration & production) and mining assets. Since commodities are a driver of supply-led inflation, these investments should provide inflation protection. Moreover, since demand for industrial commodities tracks the business cycle, these investments are growth sensitive. However, mining has very specific risks such as project delays and shutdowns due to environmental litigation. Additionally, there are operational and productivity concerns regarding production costs and metal quality.

Demand for some metals can be elastic as metals substitute for each other. For example, iron ore demand fluctuates as an input for steel production as scrap prices fluctuate (scrap is used to produce 60% of US steel). Secular trends like electric vehicles may increase demand for lithium, cobalt, nickel and rare earth metals.[25] Most of these metals are mined outside the US (*e.g.*, 60% of the world's cobalt supply is mined in the Congo).

Natural resources funds' assets under management are estimated at $533b, with performance in 2017 based on 124 funds and $106b in LP assets.[26] (1996 reported performance is based on 7 funds with $700m in assets.)

Natural Resources: Public Equity

Some publicly-traded energy and materials equities can be considered real assets. Within this category there are differences at the industry level. Upstream, midstream and downstream industries have different economic and commodity price sensitivity. Being publicly-traded their returns are correlated to movements in the entire equity market, but they also reflect commodity price movements and, therefore, have sensitivity to inflation.[27] The combined market capitalization for the energy and materials sectors is greater than $2.0t.[28]

Real Estate

Real Estate: Private Equity – Core, Value-Add, Opportunistic

Managed private real estate assets reached a record $811b in June 2017.[29] The NCREIF Property Index (NPI) measures unleveraged performance of more than 7,000 operating properties worth $550b (2017).[30] NPI comprises five property sectors – apartment, hotel, industrial, office and retail. Office is the largest sector (more than 35% in the NPI) and hotel is the smallest (less than 1%). The NCREIF Open End Diversified Core Equity (ODCE) Index also includes properties like senior housing, student housing, etc. NPI reports returns excluding leverage while ODCE reports returns including leverage. Burgiss reports performance of value-add and opportunistic real estate LP funds.

Many institutional investors have real estate allocations greater than 5%. While most investors invest in core funds, half also invest in value-add and opportunistic funds.[31] One difference across these three strategies is the amount of leverage applied. Opportunistic funds typically apply high leverage with loan-to-value ratios greater than 65%. Loan-to-value ratios for value-add typically would be greater than 50%, while leverage for core funds would be below 50%. Consequently, rising borrowing costs may adversely affect real estate investment performance. Besides leverage, value-add and opportunistic real estate funds may have higher exposure to development properties.

Real estate income returns are relatively stable and may cushion adverse real estate price movements. Real estate fundamentals like rental income, vacancy and supply are linked to the business cycle. There are also linkages between the financial health of mortgage finance providers (*e.g.*, banks) and real estate performance. Despite these systemic linkages, real estate may still offer diversification benefits relative to stock and bond returns and macroeconomic factors. Parikh and Cheng [2017] show that real estate has been a better diversifier to traditional asset classes compared to alternatives like hedge funds and private equity buyout funds.[32]

Since long-term leases are negotiated with expected inflation in mind, real estate property prices may generally track inflation. In fact, inflation-adjusted real estate prices were flat from the late 1970s through the 1990s.[33] However, in the short-term, prices may respond more quickly to market fundamentals like vacancy and rental rates. Inflation and interest rate sensitivities vary for different sectors due to differences in cashflow horizons, covenants and regulations. Apartments with annual leases (sometimes with rent ceilings) may not respond to inflation surprises as quickly as retail real estate due to rent escalation clauses tied to consumer

25 "The Technology Frontier: Investment Implications of Disruptive Change" *PGIM,* Fall 2018.
26 Source Preqin, as of June 2017. Preqin classification also includes funds like midstream energy infrastructure funds.
27 See Appendix A4.3 for details.
28 Source S&P and Datastream, as of 2017.
29 B. Teuben, S. Shah, and G. G. Hariharan, "Real Estate Market Size 2016" *MSCI,* June 2017. https://www.msci.com/documents/10199/8ca227ce-bb56-45e3-985e-650d81f98965
30 https://www.ncreif.org/data-products/property/
31 C. Wood, "Pension Funds Investing in Real Estate", *Real Estate Spotlight - Preqin,* September 2016.
32 H. Parikh, and T. Cheng, 2017. "Revisiting the Role of Alternatives in Asset Allocation" *Alternative Investment Analyst Review,* Vol. 6(2). Also available via pgim.com/ias website.
33 S&P/Case-Shiller U.S. National Home Price Index adjusted for inflation (CPI-U), St. Louis FRED, BLS.

prices. Also, retail (and office) tenant leases are often net leases which help protect against inflation surprises. Value-add and opportunistic real estate (with their embedded leverage) may have accentuated growth and inflation sensitivities.

For core real estate performance, we use the ODCE index which measures the performance of open-end funds and is a cap-weighted, gross-of-fees, time-weighted return index. The index comprises 36 open-end commingled funds with more than 2,000 properties and $190b in assets (2017). In 2017, Burgiss reported value-add LP fund performance is based on more than 200 funds and $121b in assets. Opportunistic LP fund performance is based on more than 100 funds and $92b in assets.

Real Estate: Private Debt

First lien senior mortgages on high-grade properties have been relatively safe investments during recessions. Private real estate debt assets have grown to $638b in 2017 from $200b in 2007.[34] Recently, investors have expressed interest in riskier real estate debt investments (*e.g.*, mezzanine debt).

For private real estate debt performance we use the Giliberto-Levy Commercial Mortgage Performance Index. This index tracks the performance of fixed-rate, fixed-term senior commercial real estate loans originated by life insurance companies and pension funds and held in their investment portfolios. Currently the index tracks approximately 14,000 loans with $190b in current principal balance (2016). While the index's performance is marked-to-market, credit losses are estimated using public market commercial real estate loans data which may not be ideal.[35] Despite this limitation, this is the most representative index available.

Real Estate: Publicly-listed REITs

Publicly-listed equity REITs, with more than $1t in market capitalization, comprise hotels, residential, retail, industrial, office and specialty sectors.[36] Over short periods, REITs have a much higher equity market beta compared to private real estate. However, over long holding periods REITs closely track private real estate performance.

There are significant sector differences between REITs and the overall real estate market. Approximately 40% of the REIT market consists of non-major sectors like data centers, specialty (*e.g.*, private prisons), healthcare (senior living), and infrastructure (cell towers), a much higher percentage than the overall real estate market. While these sectors can provide stable income with long lease terms and contractual rental rate increases, they can become obsolete with high loss severities.[37] Investors seeking diversification and access to the "new age" economy may benefit from allocating to both REITs and private real estate.

TIPS (Treasury Inflation Protected Securities)

US TIPS adjust the riskless principal amount for realized CPI inflation. If held to maturity, this makes TIPS a natural real asset. TIPS are also one of the newer real assets (launched in February 1997). By 2017 the TIPS market had grown to $1.1t.

On a mark-to-market basis, however, there can be price volatility arising from changes in real yields, especially for long maturity bonds. If real yields rise with inflation, which has been the case in the past, this may render TIPS less effective as an inflation hedge on an interim basis.

For our analysis we use the Bloomberg Barclays US TIPS All Maturity Index. For performance prior to 1997 we use performance based on a real yield model developed by Pond and Mirani [2009].[38] Since the performance prior to 1997 is modeled, we do not know how TIPS actually performed in periods of high inflation like the 1970s.

Commodities

A widely-adopted measure of commodity performance is the S&P Goldman Sachs Commodity Index (GSCI) which tracks the performance of a fully-funded basket of commodity futures contracts which are periodically rolled. The index's total return performance includes the return on cash not used for margin purposes. The GSCI is heavily weighted to energy-complex futures (59% recently).

Historically, commodities have produced poor long-term returns with significant volatility. Returns on commodity futures depends on whether the futures market is in backwardation (spot price is higher than the futures price) or in contango (spot price less than futures price). In backwardation (contango) the roll yield, the return generated as the futures price converges to the spot price before the contract is rolled, is positive (negative). Due to high price volatility and recent negative roll yields, investors have questioned role of commodities in investment portfolios despite their diversification and inflation protection benefits.

34 Source: Preqin, 2017.
35 M. Giliberto, 2012. "The Giliberto-Levy Commercial Mortgage Performance Index."
36 A small fraction (6%) of US REITs are mortgage REITS.
37 R. Carr, "Money in the Cloud: CRE Investors Continue Pursuit of Data Centers" *National Real Estate Investor,* October 2013.
38 M. Pond, and C. Mirani, "TIPS: Predicting History" *Interest Rates Research, Barclays Capital,* March 2009.

Investors may adopt a more diversified commodity index such as the rules-based S&P GSCI risk weight index that limits the risk contribution of any commodity sector.[39] Diversification in commodities is necessary due to the large cross-sectional dispersion in returns (*e.g.*, when the energy sector was down -41% for six-months in 2016, the precious metal sector was up 8%). Even intra-sector differences in returns can be large. For example, even though commodities like heating oil and WTI crude oil are highly correlated (0.91), 3y annual return differences have ranged from -10.0% to 15.7%. A rule-based index can also systematically reduce the allocation to commodities in contango.

Globally, the notional value of open interest in commodity futures is estimated at $1.2t across the top 10 commodity futures exchanges (2014) with energy futures the dominant segment.[40]

Foreign Currencies

Some foreign currencies have behaved as a real asset: providing inflation protection to US investors. Some currencies may be backed by central banks with credible anti-inflation views or an economy with strong ties to commodity prices. Holding a basket of such currencies might be a good domestic inflation hedge, especially against inflation surprises.

However, in practice, currency returns are highly volatile and have a negative skew. Central banks can also intervene unexpectedly, such as when the Swiss franc, which had been pegged to the euro since 2011, was suddenly unpegged in 2015 causing the currency to jump more than 25% against the dollar. Additionally, as non-US assets (*e.g.*, foreign bonds) are usually unhedged in US portfolios, investors may already have foreign currency exposure. For this reason, while we estimate foreign currency return sensitivities we do not include currencies in our real asset strategies.

Figure 4: Summary of Real Asset Attributes

Asset	Growth Sensitivity	Inflation Sensitivity	Accessibility	Data Availability & Quality	Specific Risks	Sector Differences
Real Estate Core	mid	mid	high	high	mid	mid
Real Estate Value-Add	high	mid	mid	mid	mid	mid
Real Estate Opportunistic	high	mid	mid	mid	mid	mid
Real Estate Debt	low	low	mid	low	low	mid
REIT	high	mid	high	high	low	high
Natural Resource	high	high	mid	mid	high	high
Energy Equity	high	high	high	high	low	high
Infrastructure Brownfield	mid	mid	mid	low	mid	mid
Infrastructure Greenfield	mid	low	low	low	high	high
MLP	high	mid	mid	mid	low	low
Timberland	mid	mid	mid	mid	high	mid
Farmland Annual Crops	mid	high	mid	mid	mid	mid
Farmland Permanent Crops	low	mid	low	mid	high	high
TIPS	low	high	high	high	low	low
Commodity	high	high	high	high	low	high
Gold	low	high	high	high	low	low
Currency	low	mid	high	high	mid	mid

Note: Accessibility implies ease of investment and availability of open-end funds. Specific risks imply risks associated with the asset such as geography, legal, etc. Sector differences imply how varied the performance and macroeconomic sensitivities can be within the asset class. Assets in bold are private assets with limited liquidity.
Source: PGIM IAS.

39 The S&P GSCI Risk Weight Index computes weights applying a risk parity concept, then limits the maximum sector weight to 33%.
40 CFA Level III program curriculum, 2018.

Gold

We treat gold as a separate real asset type due to its well-accepted role as a store of value. Gold enjoyed more than a 10-fold price increase from the 1970s through its peak reflecting a period of rapid inflation. During periods of inflation uncertainty, investors seek gold as an inflation hedge.[41] Similarly, gold may be a good recession hedge. In 2007-2008, while the S&P 500 was down -18.5% gold was up 16.6%, and in 2001-2002, while the S&P 500 was down -17.2% gold was up 12.1%.

Investors can invest in physical gold but that incurs storage and insurance costs. Investors can also invest in COMEX gold futures (which trades the gold equivalent of 27m ounces per day). The roll yield on gold futures has been only slightly negative (-0.2% from 1996 to 2017). Investors may also invest in gold mining stocks and can enter into gold royalty agreements. Although gold is an under-owned institutional asset, some institutional investors such as government pension funds have target allocations to gold-related assets (including derivatives).[42]

Summary of Real Asset Types

Figure 4 ranks the various real assets based on our initial views of their macroeconomic sensitivities, data quality and investment capacity. As discussed, for many assets we cannot be certain as to their inflation and growth sensitivities. Ultimately, it is an empirical question addressed in the next section.

2. Data and Methodology

To measure the macroeconomic and market sensitivities of real assets we conduct regression analysis for every real asset class, both from their own inception date as well as for a period common to all assets (January 1996 – June 2017). We use quarterly data which is the available reporting frequency for many real assets.[43] For many public assets, data are available since April 1973 which includes the inflationary 1970s. For robustness we also conduct subsample regressions, separately for January 1996 – December 2007 and for January 2008 – June 2017.

First, we measure macroeconomic exposures. Besides measuring sensitivity to actual inflation, we also measure exposure to inflation surprises (unexpected inflation) measured as the difference for a given quarter in actual inflation and expected inflation using the mean economist forecast provided by the Survey of Professional Forecasters (SPF). Similarly, we measure sensitivity to the real growth rate (GDP) and growth surprise measured as the difference in first-reported, quarter-over-quarter GDP and the mean growth forecast provided by SPF.

Second, we measure the sensitivity of real asset returns to stock and bond market returns. To evaluate the diversification benefit of real assets we examine the regression goodness-of-fit (R^2) measure: a high R^2 suggests that a real asset is not a diversifying asset as its returns are well explained by stock and bond returns.

Given the availability of longer US historical data series, our analysis uses USD-denominated assets and US macroeconomic data. Depending on data availability, a non-US investor could apply our methodology to their own investment opportunity set and macroeconomic data. We believe that many of the results reported below are broadly relevant to non-US investors.

Many private real assets are thinly traded and their reported returns may be serially correlated as are some macroeconomic and financial market variables. This makes estimation of real asset sensitivities problematic. To address this issue, Dimson [1979] used a combination of leading and lagging market returns as independent variables when estimating a stock's sensitivity to the market. The sum of the estimated coefficients, popularly known as the "Dimson beta", is the stock's estimated beta.[44] Similarly, Nelson [1976], recognizing the reporting lags in inflation, used leading and lagging actual and inflation surprises to study inflation's impact on stock market returns. Nelson found that the equity returns were negatively related to inflation as the sum of the estimated coefficients was both negative and significant.[45] We adopt these approaches and estimate real asset Dimson betas which can be intuitively interpreted as the response of a real asset's return to changes in market returns or macroeconomic variables over a horizon that spans their leads and lags.

For regressions with macroeconomic independent variables, we regress current quarterly real asset returns on independent variables with one leading quarter value, current value and one lagging value.[46] We regress real asset returns on inflation and growth levels in one regression, and regress real asset returns on inflation and growth surprises in another. For regressions

41 As Fed monetary policy became more credible, gold prices declined in real terms as inflation uncertainty diminished. While gold may hedge realized inflation over long periods, over shorter periods gold will fluctuate with the inflation uncertainty premium.

42 See, C. B. Erb, and C. R. Harvey, 2012. "The Golden Dilemma" *Financial Analysts Journal,* 69, 10-42; A. Ang, "Real Assets" *Asset Management,* Chapter 11. B, 2014; Ottawa, "Swaps, swapped: Switzerland's AHV moves into physical gold" *IPE,* 2018 and "Institutional Gold!" *PGIM IAS* forthcoming.

43 See Appendix A1 for details on indices and sources we use to proxy various real asset classes for empirical analysis.

44 See, E. Dimson, 1979. "Risk measurement when shares are subject to infrequent trading" *Journal of Financial Economics, 7,* 197-226.

45 See, C. R. Nelson, 1976. "Inflation and Rates of Return on Common Stocks" *Journal of Finance*, 31(2), 471-483.

46 See, K. J. M. Cremers, "The Performance of Direct Investments in Real Assets" *Global Financial Institute, Deutsche Bank,* June 2013. and C. Spaenjers, "The Long-Term Returns to Durable Assets" *CFA Institute Research Foundation,* December 2016.

with market variables, we regress using independent variables with 2 lagging and current quarterly returns (*i.e.,* S&P 500 and Datastream US 10y Government total returns). We use Newey-West standard errors to adjust for both autocorrelation and heteroskedasticity. We also winsorize the data at the 1% and 99% percentage levels (*i.e.*, observations below the 1st or above the 99th percentile are set to the 1st or 99th percentile value, respectively) to reduce the influence of extreme outliers on the results.

Using the estimated sensitivities to the macroeconomic and financial market variables we construct three real asset strategies – "diversification", "inflation-protection", and "stagnation-protection" – described in Section 4. Before doing so, we first examine the risk and return performance of the various real asset classes.

3. Real Asset Investment Performance

From January 1996 to June 2017, the performance across real assets varied widely (Figure 5). Annual returns ranged from -1.2%/y to 15.9%/y, and volatilities were also very different. Even after calculating volatility using annual returns to adjust for possible smoothing in price returns we find most real assets had lower risk than stocks. In fact, volatilities for real estate debt, timberland and farmland returns were lower than for 10y Treasuries. Over the long run commodity and currency assets had negative returns, and commodities had the highest risk.

Income return is an important metric for investors. For some real assets, income is greater than traditional bonds, making them attractive for investors seeking income to pay near-term liabilities. Figure 6 shows trailing twelve-month cash income for some real assets. MLP had both the highest income and performance (among public assets).

Figure 5: Real Asset Class Performance
(January 1996 – June 2017)

Asset	Returns (Annual)	Risk		Sharpe Ratio (Annual)
		(Quarterly)	(Annual)	
Real Estate Core	8.3%	6.3%	11.0%	0.55
Real Estate Debt	6.3%	4.2%	4.8%	0.85
REIT	10.7%	20.2%	19.8%	0.43
Natural Resource	15.9%	16.4%	23.8%	0.58
Energy Equity	9.0%	19.2%	19.7%	0.35
Infrastructure	4.0%	9.4%	12.7%	0.14
MLP	12.6%	17.1%	26.2%	0.39
Timberland	7.3%	5.2%	6.9%	0.74
Farmland	12.2%	6.7%	7.3%	1.37
TIPS	5.2%	4.9%	6.0%	0.50
Commodity	–0.9%	24.6%	28.2%	–0.11
Gold	5.6%	14.0%	16.2%	0.21
Currency	–1.2%	8.3%	8.5%	–0.40
US Cash	2.2%	1.1%	2.2%	—
US 10y Treasury	5.2%	8.3%	8.6%	0.35
US Equity (S&P 500)	8.6%	16.3%	18.3%	0.35

Note: Assets in bold are private and assets in italics are for reference purposes only. Past performance is not a guarantee or a reliable indicator of future results.
Source: Alerian, NCREIF, Burgiss, John B. Levy & Co., Global Financial Data, Bloomberg, S&P, Datastream and PGIM IAS.

Figure 6: Real Asset Current Income
(12m income returns ending December 2017)

Asset	Income Returns
Real Estate Core	4.7%
Real Estate Debt	4.5%
REIT	3.6%
Farmland	—
Annual crops	4.0%
Permanent crops	6.2%
Timberland	3.1%
Infrastructure (Brownfield)*	4.0%
MLP	6.0%
US Aggregate Bond Index	2.8%

Note: Assets in bold are private and assets in italics are for reference purposes only. Reported values are trailing twelve-month income return received by investors as of Q4 2017. *Estimated based on par coupon of S&P Municipal Bond Toll Road Index. US Aggregate (Bloomberg Barclays US Aggregate Index). Past performance is not a guarantee or a reliable indicator of future results.
Source: PGIM IAS, Datastream, S&P, Alerian, Burgiss, NCREIF, Bloomberg, John B. Levy & Co., and Global Financial Data.

4. Real Asset Macroeconomic and Financial Market Exposures

Macroeconomic Exposures – Inflation & Growth (Level and Surprise) Sensitivities

We estimate the sensitivities of real assets to inflation and growth. Figure 7 shows that inflation and growth sensitivities varied between the subsample periods. In fact, for some assets the subperiod betas flipped signs, suggesting that many real assets have time-varying exposures to inflation and growth. The fact that a given real asset may not have stable return sensitivities to inflation and growth poses a problem for investors. We address this issue by defining real assets that provide either inflation or stagnation protection not only for the full period but generally for both subperiods as well.

Are these exposures different from what stocks and bonds have exhibited? Figure 7 also shows that stocks and bonds have sensitivities to inflation and growth that differ from those of many real assets.

Inflation Protection

Figure 7 shows that cash had a significant inflation beta of 0.73. In other words over 1996 – 2017, nominal short rates largely kept up with inflation. Stocks had a negative inflation beta (although not statistically significant) suggesting stocks tended to have lower returns when inflation was higher. Bonds had no significant exposure to inflation. In contrast, many real assets had large positive inflation betas.

We define a real asset as offering "inflation protection" if its full-period estimated inflation and inflation surprise betas are both significant and greater than zero. Overall, we find that commodity, currency, energy equity, gold, infrastructure, TIPS and natural resource real assets provided inflation protection, not only for the full period but generally (except for gold and currency) for both subperiods as well.

Stagnation Protection

Over 1996 – 2017, cash had a significant real GDP (growth) beta of 0.46 (Figure 7). Stocks had a significant growth beta of 5.99. In contrast, farmland, gold, real estate debt, TIPS, and currency had betas that were not significant, with a magnitude lower than that for cash. The growth surprise betas for gold, real estate debt, currency, real estate, timberland, and infrastructure were also low and statistically insignificant. The growth surprise beta for farmland was negative and statistically significant.

We define a real asset as offering "stagnation protection" if its full-period estimated growth and growth surprise betas were approximately equal to or less than the corresponding growth betas for cash. Therefore, farmland, currency, gold, real estate debt, and TIPS provided stagnation protection for the full period and often for both subperiods.[47]

47 Appendix A4 contains estimated inflation and growth sensitivities at the real asset subsector level.

Figure 7: Exposures to Inflation and Real GDP, Level and Surprise; Estimated Dimson Betas
(1996–2017; and subperiods)

	Inflation Level			Inflation Surprise			Real GDP Level			Real GDP Surprise		
Asset	1996–2017	1996–2007	2008–2017	1996–2017	1996–2007	2008–2017	1996–2017	1996–2007	2008–2017	1996–2017	1996–2007	2008–2017
Real Estate	0.95	0.97	2.07	–0.16	2.17	–2.81	**4.78**	0.30	**8.32**	0.00	–1.28	–3.17
Real Estate Debt	–0.25	–1.58	–0.08	–1.08	**–3.78**	–0.74	0.05	**–0.91**	0.47	1.16	–1.08	3.29
REIT	2.70	–0.35	5.83	4.13	–7.02	1.06	5.59	–1.28	**11.75**	8.81	–4.08	25.36
Natural Resource	**12.27**	7.08	**13.08**	**18.58**	**10.02**	**16.13**	2.91	–2.27	**5.34**	3.60	–8.36	**12.15**
Energy Equity	**10.26**	4.46	**14.48**	**16.80**	11.17	**13.62**	**5.08**	2.76	**8.08**	**8.44**	1.36	**16.78**
Infrastructure	**4.02**	**11.02**	**2.74**	**7.03**	**14.04**	–0.29	1.62	–1.43	**4.93**	–3.46	–6.45	4.11
MLP	3.76	3.49	3.76	1.88	–4.89	–3.33	1.38	–4.52	**3.88**	4.92	**–9.23**	**24.36**
Timberland	**1.55**	–0.05	0.58	0.51	0.94	–0.30	**0.98**	**1.82**	–0.01	0.64	1.10	0.03
Farmland	0.67	1.36	0.20	0.94	0.21	0.29	–0.50	–0.01	**–0.77**	**–2.67**	–4.13	–0.95
TIPS	**2.35**	1.58	**3.41**	**3.13**	1.40	**3.67**	0.02	**–1.09**	**1.25**	0.63	–0.57	1.58
Commodity	**20.82**	**20.83**	**23.34**	**36.53**	**39.71**	**28.84**	**4.77**	3.54	**8.60**	**9.54**	5.98	**19.01**
Gold	**4.11**	–1.72	**7.70**	**8.40**	–0.67	**10.07**	–1.38	–2.25	1.66	–3.20	**–8.93**	4.74
Currency	**4.03**	0.00	**7.31**	**6.09**	–2.32	**10.07**	0.09	–0.58	**1.42**	0.98	–2.00	0.87
US Cash	**0.73**	0.30	**0.38**	0.31	0.02	**0.61**	**0.46**	0.18	–0.04	**1.12**	0.41	0.13
US Equity (S&P 500)	–1.01	–3.96	1.34	–1.78	0.99	–5.81	**5.99**	**7.87**	**6.70**	**11.36**	**13.76**	**14.06**
US Govt. Bond	0.05	**–1.34**	0.68	–0.70	–3.14	1.10	–0.18	–0.68	0.01	–0.10	–1.23	–1.25

Note: Returns for each are regressed on inflation and real GDP levels (QoQ). We also regress asset returns on inflation and GDP surprises. The beta is a sum of lead, current, and lag betas (*i.e.*, Dimson beta). Betas in bold suggests significance at a 90% confidence level. Assets in bold are private and assets in italics are for reference purposes only. For real estate, we allocate 60% to Core and 20% each to Opportunistic and Value-Add.
Source: PGIM IAS.

In Section 5 we show that the time-varying nature of the estimated sensitivities can be controlled by constructing portfolios of real assets. Since not all real assets will vary their sensitivities simultaneously, a portfolio of real assets selected by their full-period sensitivities may be expected to have more stable inflation and growth sensitivities. We test the robustness of this assertion by comparing the in-sample and out-of-sample estimated sensitivities of real asset portfolios (Appendix A5).

Market Exposures – Stocks & Bonds

How much diversification benefit might real assets provide to a stock and bond portfolio? To answer we use regression to identify those real assets whose returns are not highly correlated with stock and bond returns.

Figure 8 reveals that for the full data period energy equity, MLP, REIT and real estate had positive and statistically significant betas to equity returns, while real estate debt and TIPS had positive and significant betas to bond returns.

We find that the relevant betas to stocks and bonds are generally as expected, but time-varying. For example, gold had a negative beta to both stocks and bonds in the first subsample period, but a positive beta to both in the second period.

Diversification

We identify a real asset as "diversifying" if the R^2 from its regression on stock and bond returns was low (*i.e.*, 0.4 or less) in both subperiods (Figure 9). Based on this criterion, we classify currency, farmland, gold, natural resource, real estate and timberland as diversifying real assets. While the R^2s for infrastructure, MLP, real estate debt and TIPS were low over the entire period, in the subsample regressions we find that their returns were meaningfully explained by stock and bond returns. For example, TIPS had a $R^2 = 0.61$ in the first subsample period while its overall R^2 was only 0.31. Consequently, TIPS were not classified as diversifying.

Figure 8: Exposures to Stocks and Bonds; Estimated Dimson Betas
(1996 – 2017; and subperiods)

	Stocks (S&P 500)			Bonds (US 10y Treasury)		
Asset	**1996–2017**	**1996–2007**	**2008–2017**	**1996–2017**	**1996–2007**	**2008–2017**
Real Estate	**0.41**	**0.17**	**0.6**7	0.42	**0.20**	0.69
Real Estate Debt	0.01	–0.04	0.06	**0.23**	**0.44**	0.06
REIT	**0.70**	0.27	**1.45**	–0.20	–0.81	**0.98**
Natural Resource	0.21	–0.05	**0.69**	–0.31	**–1.46**	**0.70**
Energy Equity	**0.87**	**0.53**	**1.45**	0.00	–0.86	**0.95**
Infrastructure	0.14	–0.06	**0.51**	–0.60	**–1.29**	0.27
MLP	**0.42**	0.01	**1.08**	0.33	0.46	0.37
Timberland	0.10	**0.20**	–0.04	0.19	0.09	0.02
Farmland	0.02	0.07	0.00	–0.01	–0.12	0.10
TIPS	0.01	**–0.11**	**0.20**	**0.40**	**0.22**	**0.66**
Commodity	0.34	–0.15	**1.36**	–0.11	**–1.59**	1.47
Gold	–0.10	**–0.33**	**0.43**	0.03	**–0.94**	**1.46**
Currency	0.01	–0.10	0.20	–0.10	–0.21	0.10
US Cash	0.02	0.03	**–0.01**	0.05	0.04	0.01
US Equity (S&P 500)	**1.00**	**1.00**	**1.00**	0.00	0.00	0.00
US Govt. Bond	–0.01	–0.02	0.00	**0.53**	**0.58**	**0.47**

Note: The beta is a sum of current beta, and two lag betas. Betas in bold are estimated at a 90% confidence level. Assets in bold are private and assets in italics are for reference purposes only. For real estate, we allocate 60% to Core and 20% each to Opportunistic and Value-Add.
Source: PGIM IAS.

5. Real Asset Strategy Portfolios

We design three real asset strategy portfolios to help investors meet a specific investment objective such as greater portfolio diversification, inflation protection, or stagnation protection.

The **Diversification** strategy is a portfolio of real assets that is expected to have performance uncorrelated with traditional stock and bond returns. This ensures a diversification benefit regardless of the market cycle. For this strategy we select the diversifying real assets whose performance is least correlated to stock and bond returns (*i.e.*, low R^2s for both subsample regressions): farmland, gold, natural resource, real estate and timberland.[48]

The **Inflation-Protection** strategy is designed to have higher returns when inflation and inflation surprise are higher. It is a strategy for investors with inflation-linked liabilities or a concern about overheating (high inflation and high growth) and stagflation (high inflation and low growth) economic scenarios. For this strategy, we select the inflation-protection real assets that have significant and positive exposure to both inflation level and inflation surprise: commodity, energy equity, gold, infrastructure, TIPS and natural resource.

The **Stagnation-Protection** strategy portfolio is expected to perform better than cash in economic environments with below average growth. This is a strategy for investors concerned about stagnation (low inflation and low growth) scenarios. For this strategy we include the stagnation-protection real assets that have a sensitivity to both the real growth level and growth surprise that is lower than corresponding sensitivities for cash: farmland, gold, real estate debt and TIPS.

48 For real estate, we allocate 60% to Core and 20% each to Opportunistic and Value-Add. As discussed, we exclude currencies from the real asset strategies.

Figure 9: Explanatory Power (R^2) of Stocks and Bonds for Real Asset Returns
(1996 – 2017; and subperiods)

Asset	1996–2017	1996–2007	2008–2017
Real Estate	0.23	0.17	0.32
Real Estate Debt	0.33	0.80	0.09
REIT	0.41	0.24	0.67
Natural Resource	0.07	0.26	0.31
Energy Equity	0.48	0.40	0.66
Infrastructure	0.16	0.18	0.53
MLP	0.15	0.05	0.52
Timberland	0.05	0.16	0.06
Farmland	0.05	0.07	0.08
TIPS	0.31	0.61	0.32
Commodity	0.11	0.19	0.41
Gold	0.07	0.15	0.20
Currency	0.07	0.10	0.19

Note: The beta is a sum of current beta, and two lag betas. Betas in bold are estimated at a 90% confidence level. Assets in bold are private and assets in italics are for reference purposes only. For real estate, we allocate 60% to Core and 20% each to Opportunistic and Value-Add.
Source: PGIM IAS.

We use equal weights to construct these three real asset strategy portfolios, rebalanced annually back to equal weights.[49] Figure 10 shows the strategy portfolio compositions and weights for the three strategies and Figure 11 shows their in-sample cumulative performance from January 1996 to December 2017.

Each real asset strategy portfolio has a different mix of public and private real assets. The **Diversification** strategy has more than an 80% allocation to private real assets. Even after adjusting returns for appraisal smoothing (by including lags in the regressions), we still find several private assets as diversifying. The **Stagnation-Protection** strategy has a 50% allocation to private assets. These assets are both income-oriented and have low estimated exposure to real growth. The **Inflation-Protection** strategy has a one-third allocation to private real assets.

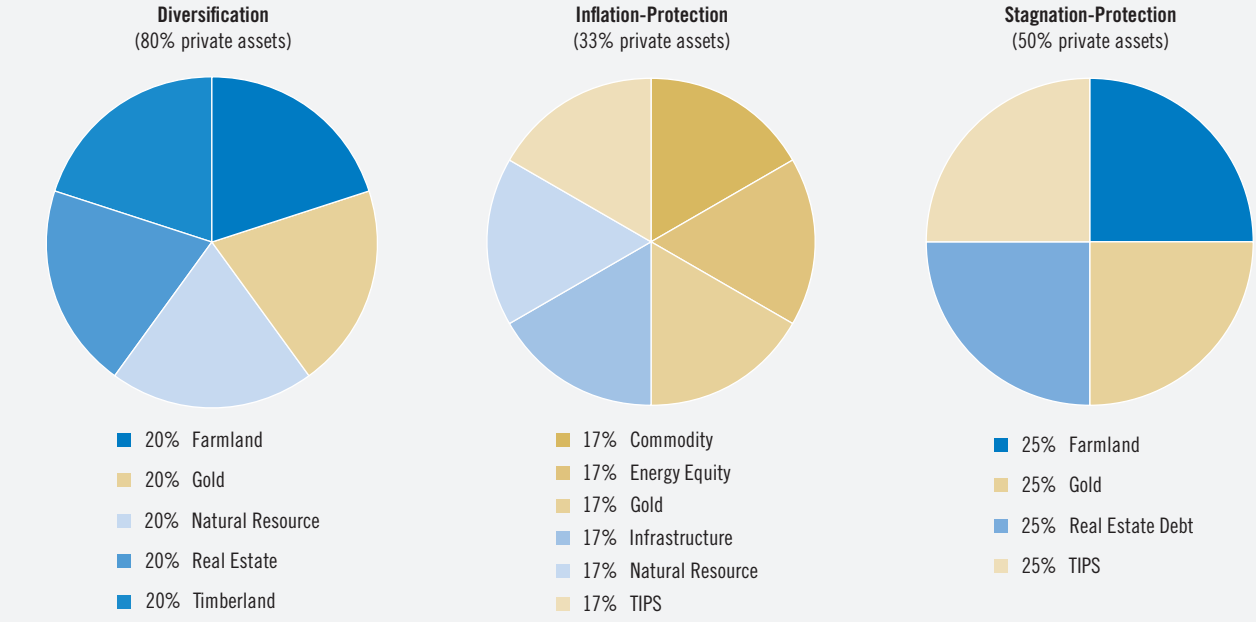
Figures 12 shows the long-term performance of the three real asset strategy portfolios compared to stock and bond performance. The **Diversification** strategy produced the highest return (10.4%), with moderate risk (8.6%), and clearly outperformed the 60/40 stock (60%) and bond (40%) portfolio. The **Stagnation-Protection** strategy offered similar absolute performance as the 60/40 portfolio, but due to its lower volatility produced much better risk-adjusted performance (Sharpe ratio 0.96 vs 0.55). The **Inflation-Protection** strategy underperformed the 60/40 portfolio but generated a slightly higher Sharpe ratio (0.39) than the S&P 500 (0.35). The **Inflation-Protection** strategy had the highest volatility of all three strategies due to holdings of commodity (17%) and natural resource (17%) which had higher volatilities than stocks.

For the full period, the three real asset strategies had low sensitivities to stocks (Figure 13), although in the latter subperiod we find that all three strategies had positive and statistically significant stock betas. The **Inflation-Protection** strategy tended to have the highest beta to stocks for the full period and the two subperiods, while the **Stagnation-Protection** strategy had the lowest. Notably, the **Stagnation-Protection** portfolio had much lower sensitivity to stocks than the 60/40 portfolio for the full period and the two subperiods.

For the full period, the three strategies had low and statistically insignificant betas to bonds. However, the low sensitivity to bonds for the full period masked the fact that all three strategies had negative bond betas in the first subperiod but positive betas in the second subperiod.

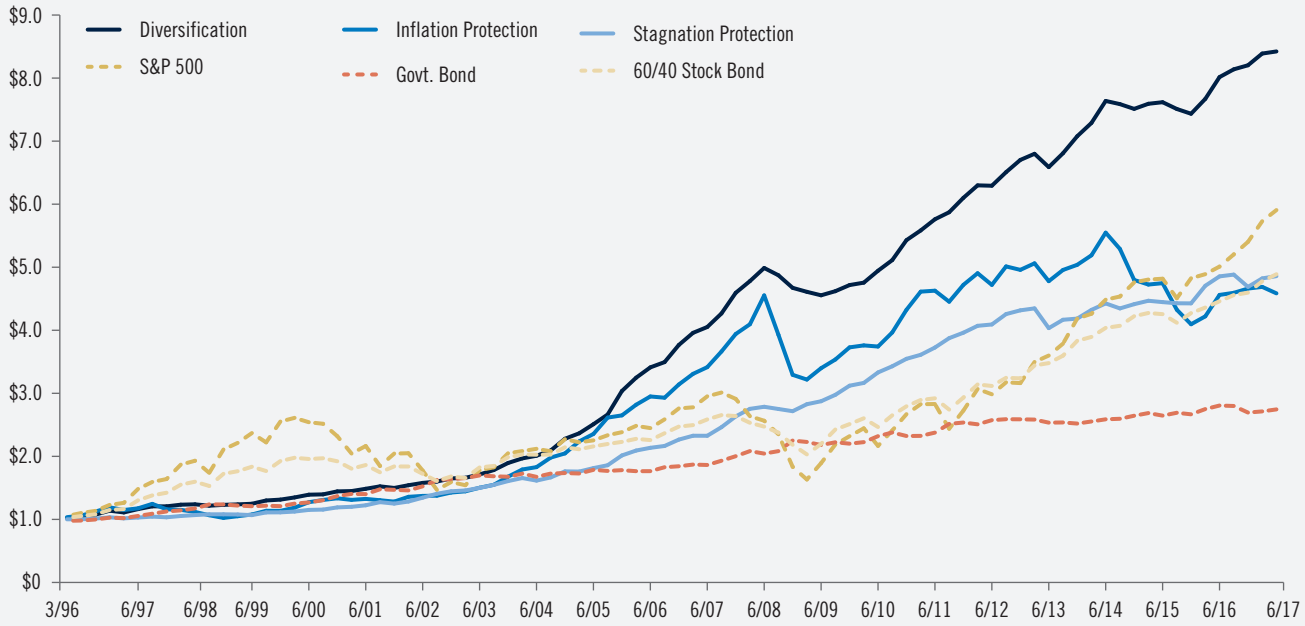
49 The results are not fully replicable as annual rebalancing is not practical for some private assets. Investors may choose to allocate to asset classes based on capital market assumptions and then have budget constraints for target macroeconomic or market sensitivities. Investors can also impose income constraints so certain asset classes (*e.g.*, MLPs) or even subsectors within (*e.g.*, brownfield infrastructure or permanent crops) have an added allocation. Investors may also consider weighting schemes like equal risk contribution (ERC).

Figure 10: Asset Class Weights for the Three Real Asset Strategy Portfolios



Note: Percentages may not add to 100% due to rounding. Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

Figure 11: Real Asset Strategy Portfolios; Growth of $1 Invested since January 1996
(January 1996 – June 2017)



Note: Portfolios are rebalanced annually. Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

Figure 12: Real Asset Strategy Portfolio Performance
(January 1996 – June 2017)

	Diversification	Inflation-Protection	Stagnation-Protection	US Equity (S&P 500)	US Govt. Bond	60/40
Return	10.4%	7.3%	7.6%	8.6%	4.8%	7.7%
Annual Risk	8.6%	13.2%	5.7%	18.3%	4.9%	10.0%
Sharpe Ratio	0.96	0.39	0.96	0.35	0.54	0.55

Note: Due to smoothing in private assets, risk is calculated as volatility of annual returns instead of quarterly returns. US Govt. Bond is the Bloomberg Barclays Government Bond Index. Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

The **Inflation-Protection** and **Diversification** strategies showed positive sensitivity to growth in both the full period and the second subperiod (Figure 14). In contrast, the **Stagnation-Protection** strategy had negative sensitivity to growth for the full period, although not statistically significant. While the **Stagnation-Protection** strategy had positive and statistically significant exposure to growth in the second subperiod, it was still the lowest growth exposure of all three strategies.

All three strategies consistently displayed lower growth exposure compared to stocks suggesting they (especially **Stagnation-Protection** and **Diversification**) may offer investors some protection relative to stocks against economic downturns. To highlight the potential benefit, the **Stagnation-Protection** strategy offered positive exposure to inflation and negative exposure to growth, the opposite exposures for the 60/40 portfolio.

In terms of inflation sensitivity all three strategies had positive and significant betas to inflation for the full period. The **Inflation-Protection**, as desired, showed the highest and statistically significant inflation sensitivity in both the full period and both subperiods (Figure 14) suggesting the strategy may provide inflation protection going forward. Notably, the **Inflation-Protection** strategy had much higher inflation sensitivity than stocks, bonds or the 60/40 portfolio. In contrast, the **Stagnation-Protection** strategy had the lowest sensitivity.

1996 to 2017 was a period of low inflation and moderate growth (although punctuated by the global financial crisis) making it difficult to evaluate the performance of the three strategies in different economic environments (*e.g.*, high inflation and low growth). To see how the strategies might have performed in other economic environments, we randomly sample two consecutive quarters of data from the 1996 – 2017 period. We then randomly pick six of these two-quarter samples and link them together to generate a simulated 3y economic scenario.[50] We repeat this exercise 10,000 times to generate a large sample of hypothetical 3y economic scenarios. We then calculate the annualized inflation and growth rate for each scenario. Figure 15 plots the inflation-growth combinations for each of the 10,000 3y scenarios.

We categorize the scenarios into four inflation-growth environments: ideal (low inflation/high growth); stagnation (low inflation/low growth); stagflation (high inflation/low growth); and overheating (high inflation/high growth). We define an economic environment as muddled for which inflation or growth is neither high nor low.[51]

Figure 16 shows how the three real asset strategies perform in these distinct economic environments. All three strategies perform well when inflation is high. During stagflation the three strategies all have higher average return than stocks or bonds. In overheating environments stocks do well but the **Diversification** and **Inflation-Protection** strategies do even better (12.9% vs. 13.1% and 13.2%).

Performance across the three real asset strategies diverges when inflation is low. In ideal environments stocks do best, followed by the **Diversification** strategy. The performance of the **Inflation-Protection** strategy (4.2%) is worse than both the **Stagnation-Protection** strategy (6.5%) and bonds (4.8%). During periods of stagnation (low inflation/low growth) bonds do well, but so do the **Stagnation-Protection** and **Diversification** strategies. Stocks and the **Inflation-Protection** strategy, as expected, do poorly.

In any economic environment, all three strategies have lower returns dispersion (*i.e.,* standard deviation of the 10,000 3y simulated returns) compared to stocks (Figure 17).

50 We use a size-2 block bootstrap. A one-period (*i.e.,* quarterly) bootstrap has a drawback as it loses any autocorrelation structure which is present in the data. For more details about block bootstrap, refer to H. R. Künsch, 1989. "The jackknife and the bootstrap for general stationary observations" *Annals of Statistics,* 17: 1217–1241.

51 See Appendix A2 for average inflation and real growth rates in each environment.

Figure 13: Real Asset Strategy Exposures to Stocks and Bonds; Estimated Dimson Betas
(1996 – 2017; and subperiods)

	Stocks (S&P 500)			Bonds (US 10y Treasury)		
	1996–2017	1996–2007	2008–2017	1996–2017	1996–2007	2008–2017
Diversification	0.13	0.01	**0.33**	0.08	**–0.46**	**0.59**
Inflation-Protection	0.25	0.00	**0.80**	–0.07	**–0.94**	**0.95**
Stagnation-Protection	–0.01	**–0.12**	**0.19**	0.18	–0.12	**0.57**
US Equity (S&P 500)	**1.00**	**1.00**	**1.00**	0.00	0.00	0.00
US Govt. Bond	–0.01	–0.02	0.00	**0.53**	**0.58**	**0.47**
60/40	**0.59**	**0.60**	**0.61**	**0.21**	**0.26**	**0.17**

Note: Returns for each strategy are regressed on S&P 500 and US 10y Treasury total returns (quarterly frequency). The beta is the sum of the estimated betas on the current and two lagged quarterly returns for each independent variable (*i.e.*, Dimson beta). A beta value in bold suggests significance at a 90% confidence level. US Govt. Bond is the Bloomberg Barclays Government Bond Index. Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

Figure 14: Real Asset Strategy Exposures to Inflation and Real GDP Growth; Estimated Dimson Betas
(1996 – 2017; and subperiods)

	Inflation Level			Real GDP Level		
	1996–2017	1996–2007	2008–2017	1996–2017	1996–2007	2008–2017
Diversification	**4.01**	2.14	**4.83**	1.24	–0.45	**2.64**
Inflation-Protection	**9.13**	**6.92**	**10.89**	**2.24**	–0.18	**5.13**
Stagnation-Protection	**1.79**	0.13	**2.87**	–0.34	**–1.18**	**0.88**
US Equity (S&P 500)	–1.01	–3.96	1.34	**5.99**	**7.87**	**6.70**
US Govt. Bond	0.05	–1.34	0.68	–0.18	–0.68	0.01
60/40	–0.66	–3.2	0.97	**3.53**	**4.7**	**4.15**

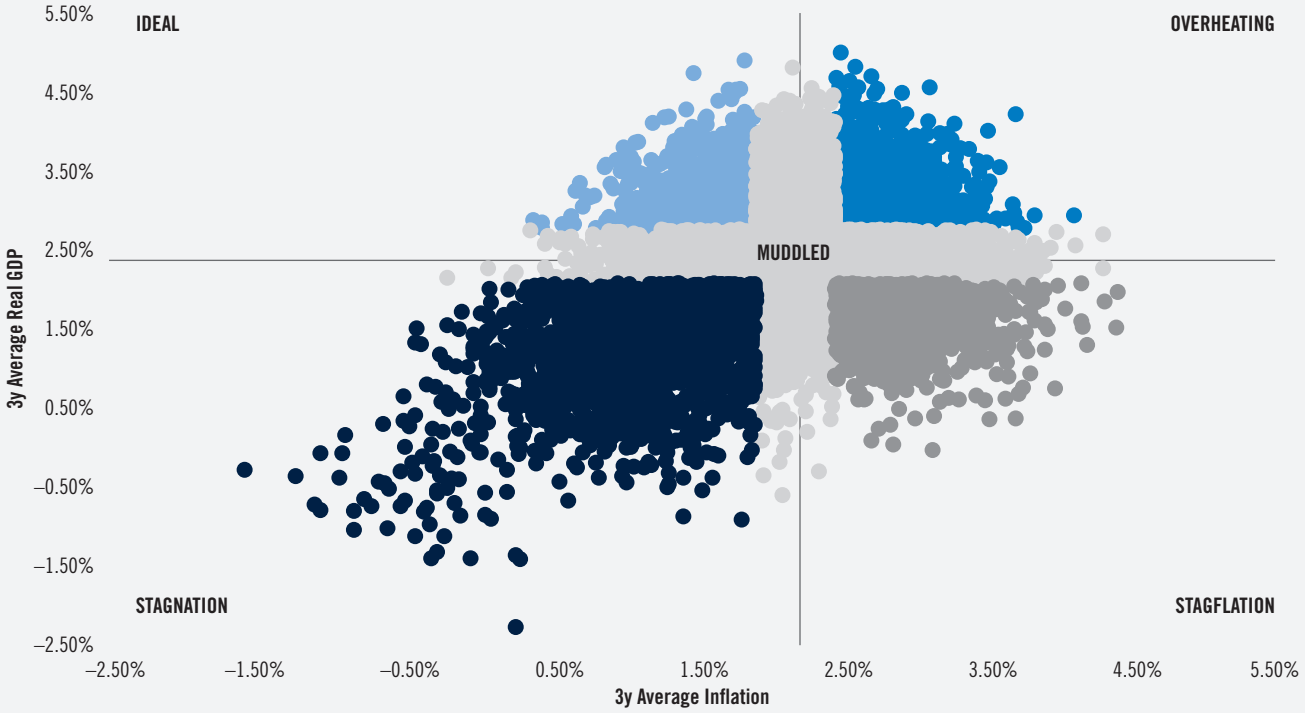
Note: Returns for each strategy is regressed on the inflation and real GDP levels (QoQ). The beta is the sum of the estimated betas on one leading, current and one lagged quarterly returns for each independent variable (*i.e.*, Dimson beta). A beta value in bold indicates statistical significance at a 90% confidence level. US Govt. Bond is the Bloomberg Barclays Government Bond Index. Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

During stagflation, all three strategies have a positive annual average 3y return in the worst 5% of simulation runs (*i.e.*, 95% CVaR – Figure 18) while the S&P 500 has a 95% CVaR of -13.8%. It is notable that there are economic environments where bonds have a negative 95% CVaR, but the **Diversification** and the **Stagnation-Protection** strategies consistently do not.

Figure 19 highlights those strategies or assets that do best in each economic environment.

So far, the regression analysis uses all available data (*i.e.*, full sample, 1996 – 2017). In Appendix A5 we conduct an out-of-sample test to evaluate the performance robustness of the real asset strategies. To do so we divide the full sample (FS) into an in-sample (IS) data period (*i.e.*, January 1996 – June 2010) and an out-of-sample (OOS) data period (July 2010 – June 2017). Using only IS period data we apply our methodology to identify the real assets for each of the three real asset strategies. Then, we check to see if the three real asset strategies maintained their expected sensitivities and performance in the OOS data period. The results show that our methodology is robust.

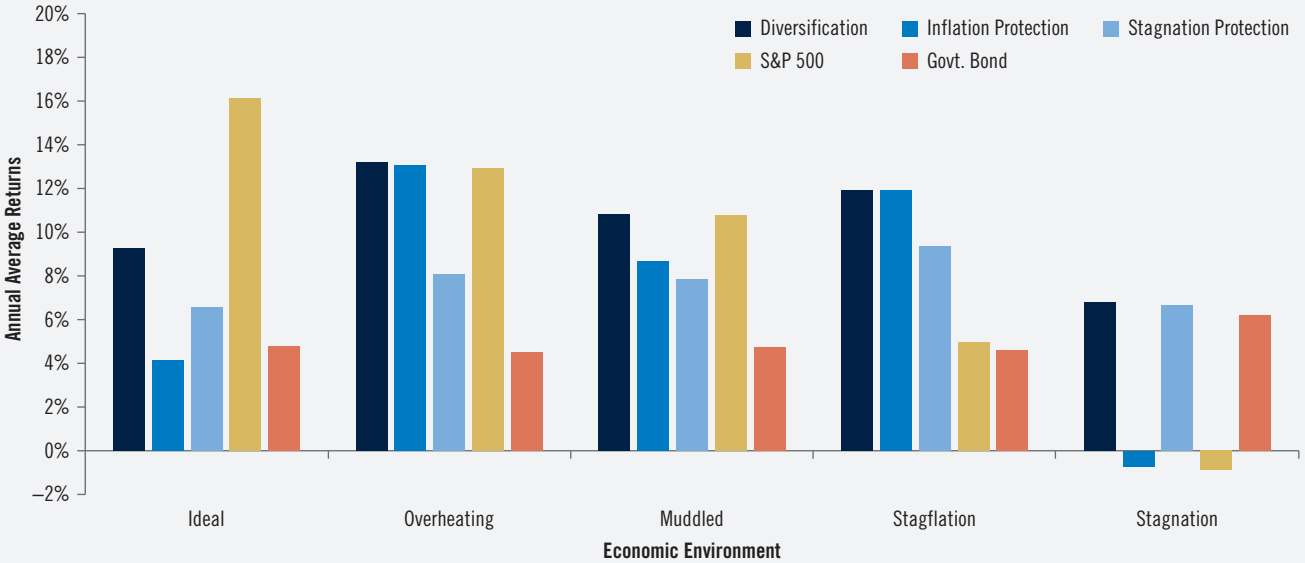
Figure 15: Economic Environments: Annualized Inflation and Growth Combinations for Each of 10,000 3y Scenarios



Note: The figure illustrates the annualized average quarterly inflation and real growth rate for each 3y simulated scenario. The scenarios, categorized as high/low inflation with high/low growth, are sorted in one of the four inflation-growth quadrants. Indeterminate (*i.e.*, "muddled") scenarios are light grey. Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

Figure 16: 3y Annualized Average Returns, across All Scenarios, by Economic Environment

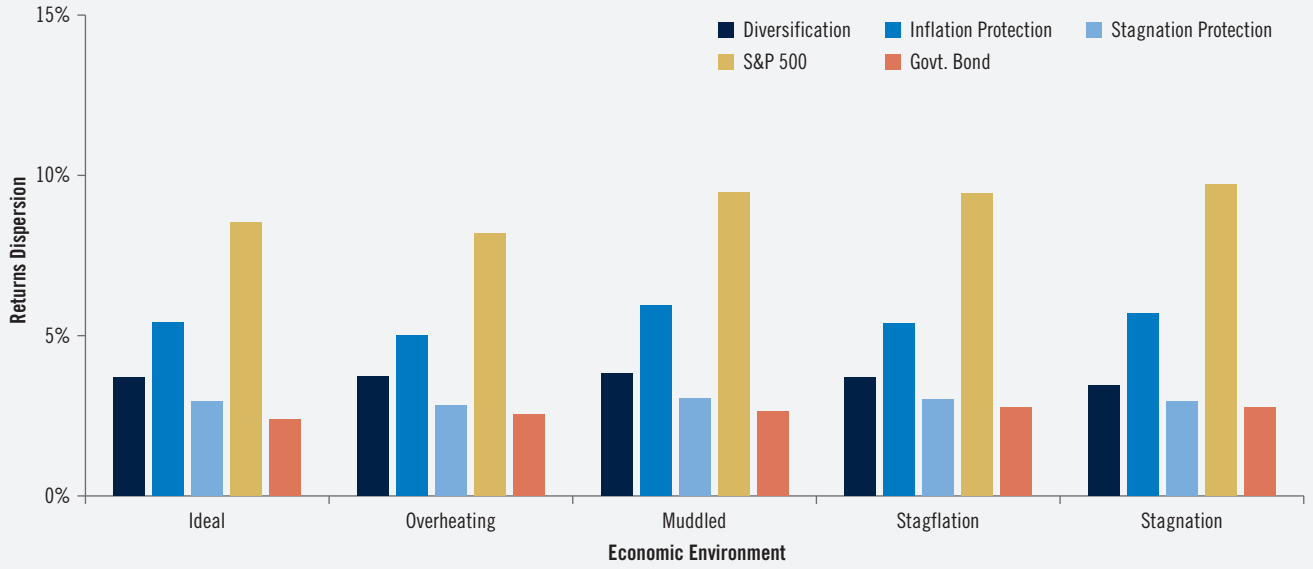
Three Real Asset Strategies



Note: Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

Figure 17: Returns Dispersion: Standard Deviation in 3y Returns, across All Scenarios, by Economic Environment

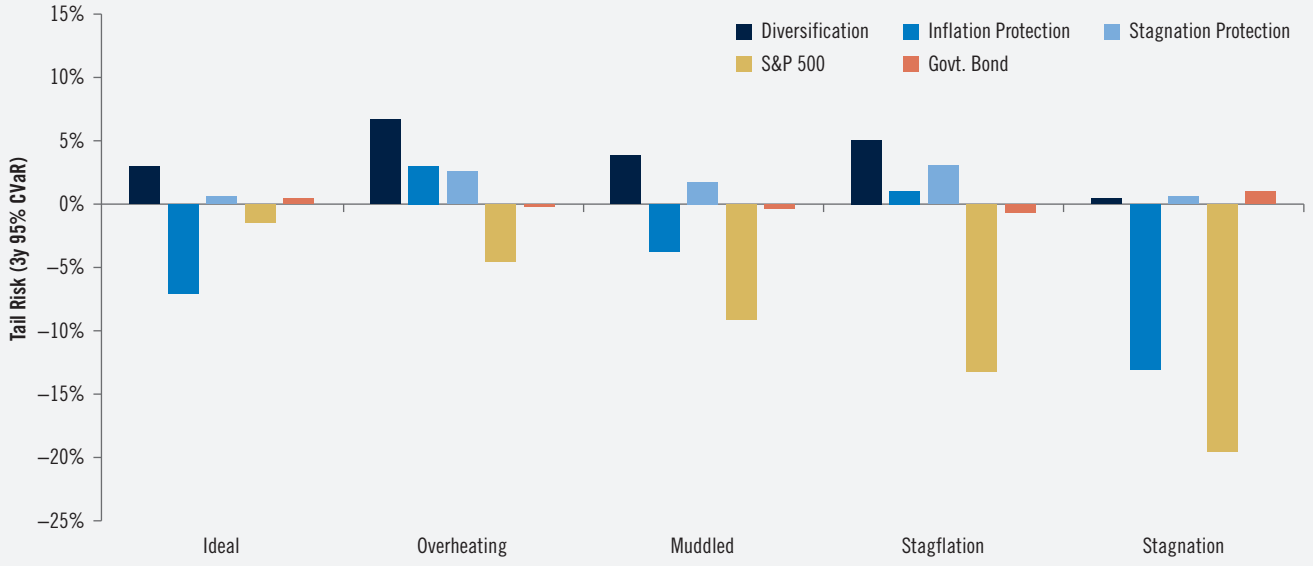
Three Real Asset Strategies



Note: Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

Figure 18: Tail Risk: 95% CVaR of 3y Returns, across All Scenarios, by Economic Environment

Three Real Asset Strategies



Note: Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

6. Real Asset Strategies in Pension Plans

How might corporate and public pension plan sponsors best benefit from real asset strategies? Can a particular real asset strategy help improve a plan's funded ratio or surplus risk? Specifically, can a real asset strategy allocation change a plan's performance in various economic environments?

Funded ratios for US corporate plans have increased in recent years (86%, 2017) as equity markets have rallied and plan liability values have fallen with rising interest rates.[52] Consequently, corporate CIOs may worry about slow growth environments (stagflation and stagnation) when assets price fall or liabilities go up, causing funded ratios to decline. Can an allocation to the **Diversification** or **Stagnation-Protection** strategies, which performed well when growth was slow, help mitigate these adverse outcomes? We analyze this issue from the perspective of a US pension plan, although the methodology can be applied to plans in other countries.

For a corporate plan we assume that the current funded ratio is 85% (projected benefit obligation, PBO, basis) with a 35% allocation to stocks (MSCI ACWI), 45% to fixed income (Bloomberg Barclays Long Government/Credit Index) and 20% to other assets.[53] We proxy the plan's liability using long AA-rated corporate bond index performance and we assume the plan has no further plan contributions and distributions.

In contrast to corporate plans, many public plans have liabilities subject to a cost-of-living adjustment (COLA) tied to inflation. Can an allocation to the **Inflation-Protection** strategy improve outcomes for these plans either by improving the funded ratio or reducing surplus risk?

We assume a typical public plan allocates 23% to fixed income (Bloomberg Barclays US Aggregate Index), 50% to stocks (MSCI ACWI), 6% to real estate (ODCE), 17% to alternatives (equally split between private equity and hedge funds) and 4% to cash.[54] We assume a current funded ratio of 70% (actuarial) and a liability that grows at 8.5%/y, which is the median rate for the past few years. Due to COLA adjustments, we increase the liability growth rate for scenarios with an above average inflation rate (the liability growth rate has a floor of 8.5%/y). We ignore contributions and distributions.

We compare the 3y simulated performance of a representative plan allocation and an alternative allocation which includes a real asset strategy. Even a 10% allocation to a real asset strategy, depending on the investment objective, can lead to a noticeable improvement in both the final funded ratio and the risk of being further under-funded (*i.e.*, surplus risk). We allocate to a real asset strategy proportionally from all the other asset classes in the plan portfolio (Appendix A3). Figure 20 and 21 show the funded ratio and the surplus risk in the different economic environments.

For a corporate plan without real assets, the current funded ratio (85%) improves by 2.2 percentage points on average at a 3y horizon (87.2%). Allocating to the **Diversification** real asset strategy improves the funded ratio by more, an average of 2.8

Figure 19: Top Three Best Performing Strategy/Asset in Each Economic Environment (inflation/growth)

	Ideal	Overheating	Muddled	Stagflation	Stagnation
Inflation &/ Growth	**Low & High**	**High & High**	**Median/Median**	**High & Low**	**Low & Low**
Diversification	✓	✓	✓	✓	✓
Inflation-Protection		✓	✓	✓	
Stagnation-Protection	✓			✓	✓
Stocks	✓	✓	✓		
Govt. Bonds					✓
Scenario Frequency	8.9%	11.4%	53.9%	10.2%	15.8%

Note: A "✓" denotes top 3 assets, based on 3y average total return performance, in each of the economic environments. Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

52 "Corporate Pension Funding Study" http://us.milliman.com/PFS/

53 2017. "Corporate Pension Funding Study" http://www.milliman.com/uploadedFiles/insight/2017/2017-corporate-pension-funding-study.pdf; Allocations to other assets are based on "2015 Asset allocation in Fortune 1000 pension plans", *Willis Towers Watson Insider,* December 2016. We allocate 5% to private equity (Cambridge Associates Leveraged Buyout (LBO)), 5% to real estate (ODCE), 5% to hedge funds (HFRI fund weighted) and 5% to cash.

54 "Public Fund Survey", http://www.nasra.org/publicfundsurvey.

Figure 20: Average 3y Funded Ratio with 10% Allocation to a Real Asset Strategy

	Corporate Plan			Public Plan	
Economic Environments	Representative Allocation	Allocation with Diversification	Allocation with Stagnation-Protection	Representative Allocation	Allocation with Inflation-Protection
Overheating	95.8%	**96.9%**	95.5%	75.3%	**75.8%**
Stagflation	86.1%	**87.5%**	**86.9%**	65.9%	**67.0%**
Ideal	90.9%	90.7%	90.0%	74.8%	73.5%
Stagnation	73.4%	**74.1%**	**74.0%**	56.7%	56.5%
Muddled	89.0%	**89.6%**	88.8%	71.1%	71.0%
Average	87.2%	**87.8%**	87.1%	69.1%	69.1%

Note: Bold suggests an improvement in the outcomes in comparison to the outcomes for the representative allocation. Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

Figure 21: 3y Surplus Risk with 10% Allocation to Real Asset Strategy

	Corporate Plan			Public Plan	
Economic Environments	Representative Allocation	Allocation with Diversification	Allocation with Stagnation-Protection	Representative Allocation	Allocation with Inflation-Protection
Overheating	12.3%	12.4%	**11.9%**	10.9%	**10.3%**
Stagflation	11.5%	11.6%	**11.2%**	11.2%	**10.6%**
Ideal	11.9%	11.9%	**11.5%**	10.1%	**9.5%**
Stagnation	10.7%	10.7%	**10.4%**	9.6%	**9.2%**
Muddled	12.3%	12.3%	**11.8%**	10.9%	**10.4%**
Average	13.5%	13.5%	**13.0%**	12.2%	**11.7%**

Note: Bold suggests an improvement in the outcomes in comparison to the outcomes for the representative allocation. Hypothetical example provided for illustrative purposes only.
Source: PGIM IAS.

percentage points (85% vs. 87.8%), while allocating to the **Stagnation-Protection** strategy improves the funded ratio by about the same (2.1 percentage points) as without real assets.

On the other hand, if we look at the standard deviation of 10,000 simulated funded ratio outcomes at a 3y horizon (*i.e.*, 3y surplus risk), allocating to the **Stagnation-Protection** strategy reduces the surplus risk in all the economic environments (on average, 13.0% vs. 13.5%). Investors wishing to improve funded ratio outcomes may benefit by allocating to the **Diversification** strategy and those seeking to reduce surplus risk may benefit by allocating to the **Stagnation-Protection** strategy.

In low growth environments, we find an allocation to real asset strategies makes a bigger difference. In stagflation, the average final funded ratio of corporate plans without real assets is 86.1%. In contrast, with an allocation to the **Diversification** strategy the funded ratio is 87.5% (outperformance of 140bp), and an allocation to the **Stagnation-Protection** strategy produces a final funded ratio of 86.9% (outperformance of 80bp). In stagnation, the funded ratio deteriorates to 73.4% for plans without real assets but is 74.1% with an allocation to the **Diversification** strategy and is 74.0% with an allocation to the **Stagnation-Protection** strategy.

For public plans without real assets, the funded ratio deteriorates, on average, at a 3y horizon (70% vs. 69.1%). An allocation to the **Inflation-Protection** strategy keeps the average final funded ratio at 69.1%, but the surplus risk drops from 12.2% to 11.7%. An allocation to the **Inflation-Protection** strategy tracks COLA liabilities better than the representative public plan allocation, as the surplus risk decreases between 40bp to 60bp across all economic environments.

In overheating environment (high inflation and high growth), a public plan with an allocation to the **Inflation-Protection** strategy has a final funded ratio of 75.8%, a 50bp improvement over the funded ratio without a real asset allocation. In stagflation (high inflation and low growth), an allocation to real assets improves the funded ratio by 110bp (67% vs. 65.9%). In both high inflation environments an allocation to real assets improves the outcomes for public plans, especially those with COLAs.

7. Conclusion

We illustrate the salient features and economic and financial market exposures of a variety of real assets. Our study accounts for some measurement challenges, especially for private asset returns.

We find wide diversity in real assets' sensitivities to inflation and growth, and stocks and bonds, and that these sensitivities vary between the subsample periods analyzed. In fact, the economic betas for some real assets may flip signs. Investors can try to mitigate this time-varying exposure risk by holding a portfolio of real assets or actively managing their real asset portfolios.

Based on an investor's investment objective, we construct three real asset strategy portfolios – **Diversification, Inflation-Protection** and **Stagnation-Protection**. While the portfolios' market sensitivities were still time varying their macroeconomic sensitivities of these strategies were more stable. Across the various economic environments, the three strategies had lower 3y return dispersion compared to equity, suggesting less variability in outcomes for portfolios with a real asset allocation.

We show that a real asset allocation can help sponsors improve outcomes in those economic environments of concern, like stagflation and stagnation, improving either surplus risk or the average funded ratio.

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APPENDIX

A1 Real Asset Class Indices and Sources

Asset	Index	Source
Farmland	NCREIF Farmland total returns index	NCREIF
Timberland	NCREIF Timberland total returns index	NCREIF
Infrastructure	US All vintage pooled funds time weighted rate of returns	Burgiss
Natural Resource	US All vintage pooled funds time weighted rate of returns	Burgiss
Real Estate	NCREIF ODCE total returns index, Value Add and Opportunistic - US All vintage pooled funds time weighted rate of returns	NCREIF, Burgiss
Real Estate Debt	Commercial Mortgage Performance total returns index	Giliberto-Levy
TIPS	Bloomberg-Barclays US TIPS All Maturity total returns index spliced with Pond and Mirani [2009] TIPS performance prior to April 1997	Bloomberg, Datastream
Commodities	GSCI total returns index	S&P, Datastream
Energy Equity	Datastream U.S. Oil and Gas total index	Datastream
REIT	FTSE/EPRA U.S. REITs total returns index	FTSE, Datastream
MLP	Alerian MLP total returns index	Alerian, Datastream
Currencies	US Dollar index (short)	Datastream
Gold	Gold Bullion LBM U$/Troy Ounce price returns index	Datastream
US Cash	T-Bills 3-month total returns index	Global Financial Data
US Equity (S&P 500)	S&P 500 total returns index	S&P, Datastream
US 10y Treasury	US Government 10y total returns index	Datastream
US Govt. Bond	Bloomberg Barclays US Government Bond Index	Datastream

Note: The index total returns are gross of fees and the pooled fund time-weighted rate of returns are net of fees.

A2 3y Average Inflation and Real Growth, across 10,000 Simulated 3y Scenarios

3y Average Inflation

		Growth			Average
		T1 (low)	T2	T3 (high)	
Inflation	T1 (low)	1.06%	1.54%	1.63%	1.41%
	T2	2.24%	2.22%	2.22%	2.23%
	T3 (high)	2.94%	2.89%	2.83%	2.89%
Average		2.08%	2.22%	2.23%	2.17%

3y Average Growth

		Growth			Average
		T1 (low)	T2	T3 (high)	
Inflation	T1 (low)	1.13%	2.42%	3.20%	2.25%
	T2	1.63%	2.44%	3.21%	2.43%
	T3 (high)	1.63%	2.41%	3.19%	2.41%
Average		1.46%	2.42%	3.20%	2.36%

Note: The tables summarize the average 3y annualized inflation and real growth in each tercile of 10,000 the scenarios.

A3 Asset Allocation for Pension Plans, with and without Real Assets (RAS)

Investment Allocation		Corporate Pension Plan			Public Pension Plan	
		Original Allocation	Allocation with Diversification RAS	Allocation with Stagnation-Protection RAS	Original Allocation	Allocation with Inflation-Protection RAS
Equity	ACWI	35.0%	31.5%	31.5%	50.0%	45.0%
Bond	Long Govt./Credit	45.0%	40.5%	40.5%	—	—
	US Aggregate	—	—	—	23.0%	20.7%
Alternatives[54]	Real Estate	5.0%	4.5%	4.5%	6.0%	5.4%
	Hedge Fund	5.0%	4.5%	4.5%	8.5%	7.7%
	Private Equity	5.0%	4.5%	4.5%	8.5%	7.7%
Real Assets	Diversification	—	10.0%	—	—	—
	Stagnation-Protection	—	—	10.0%	—	—
	Inflation-Protection	—	—	—	—	10.0%
Other	Cash	5.0%	4.5%	4.5%	4.0%	3.6%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%

Note: RAS abbreviation for Real Asset Strategy.
Source: PGIM IAS.

A4 Sector-level Macroeconomic and Market Exposures

Not all real asset classes are created equal – risk and economic drivers can differ – even within an asset class. For example, real[55] estate performance varies by sector. For the three years ending in 2016, the industrial sector outperformed hotel sector by 4%/y. The retail sector which had the lowest drawdown during financial crisis is now going through major disruption. Department-store anchored malls are currently not perceived as safe investments.[56]

Residential and specialty sector REITs had lowest explanatory power (R^2s of 0.27 and 0.31, respectively) from market (stocks and bonds) performance and had the lowest beta to stocks (0.56 and 0.52, respectively). The Hotel & Lodging sector had the highest and significant growth beta (8.09) and the specialty sector had the lowest and not statistically significant growth beta (2.94).

Investors who can further customize their **Stagnation-Protection** strategy may wish to include low-growth sectors of different real assets like the retail and specialty REIT sectors.

A4.1 Real Estate Exposures to Macroeconomic and Financial Market Variables; Estimated Dimson Betas
(1996-2017)

Sector	Inflation Level	Real GDP Level
Apartment	1.11	**3.11**
Industrial	0.83	**2.97**
Office	1.39	**3.33**
Retail	0.54	**2.07**
Core	1.09	**4.09**
Value Add	1.79	**5.23**
Opportunistic	–0.83	**5.38**

Sector	S&P 500	US 10y Treasury
Apartment	**0.23**	**0.31**
Industrial	**0.22**	0.21
Office	**0.30**	**0.37**
Retail	0.15	0.19
Core	**0.32**	0.35
Value Add	**0.39**	0.48
Opportunistic	**0.59**	**0.51**

Source: PGIM IAS.

55 We use ODCE as a proxy of real estate allocation, HFRI (fund weighted) as a proxy of hedge fund allocation, and Cambridge Associates LBO Index as a proxy of private equity allocation.
56 The way the risks are perceived in the retail sector are changing with more focus on location and traffic than on tenant creditworthiness. A. Jacobius. "Store closures changing way investors view retail sector" *Pensions & Investments,* January 2017.

A4.2 Farmland: Row (Annual) Crops and Permanent Crops Exposures; Estimated Dimson Betas
(1996-2017)

Both annual/row and permanent crops had negative but not significant exposure to growth (-0.37 and -1.2, respectively). For permanent crops the negative exposure to growth surprise (-4.98) was significant. Annual crops were not as countercyclical possibly due to implicit commodities exposure. Annual crops had significant and higher exposure to inflation level and surprise (1.6 and 2.45, respectively), again possibly due to commodity exposure and because short-term lease rates eventually adjust with inflation. For the **Inflation-Protection** strategy an investor may wish to include annual crops.

A4.3 Natural Resource: Upstream, Midstream and Downstream Public Equities Exposures; Estimated Dimson Betas
(1996-2017)

Sector	Inflation Level	Real GDP Level
Exploration & Production	**15.34**	4.05
Integrated Oil & Gas	**6.20**	**3.94**
Oil Equipment & Services	**16.60**	**6.26**
Pipeline	4.48	**5.51**

Sector	S&P 500	US 10y Treasury
Exploration & Production	**0.84**	–0.01
Integrated Oil & Gas	**0.71**	0.03
Oil Equipment & Services	**1.04**	–0.43
Pipeline	**1.22**	**1.14**

Source: PGIM IAS.

In the common period analysis, all energy equity industries had significant exposure to stocks and their equity betas varied from 0.71 to 1.22. The Integrated O&G industry, which has both upstream and downstream operations had a lower beta than the E&P industry, which has upstream operations (0.71 vs 0.84). The pipeline industry, which has midstream operations, had the highest equity beta (1.22) and was the only industry to have significant and positive bond beta (1.14). All other industries had insignificant and mostly negative bond betas.

Within the energy sector E&P had the highest and significant inflation surprise beta (27.72) while E&S had the highest inflation beta (16.6). The pipeline industry had the lowest and not significant inflation level and surprise betas (4.48 and 5.08, respectively). E&S had high growth level and surprise betas (6.26 and 14.56, respectively) and pipeline followed E&S with second high growth level and surprise betas (5.51 and 10.9, respectively).

A5 Real Asset Strategy Portfolios: In-Sample vs. Out-of-Sample Test

To test our approach to real asset investing, we split the full sample (FS) period (*i.e.*, 1996 – 2017) into two periods: An "in-sample" (IS) period (January 1996 – June 2010) and an "out-of-sample" (OOS) period (July 2010 – June 2017). We then apply our methodology using data only from the IS period, and then examine if our approach holds up in the OOS period.

For each of the real assets we estimate their sensitivity to inflation, real growth, stocks and bonds using IS data. Results are shown below.

Using these estimated macroeconomic and market sensitivities from the IS period and applying the same real asset selection criteria as discussed in Section 5, we construct the three real asset strategy portfolios. We label these portfolios (Figure A5.2) as "OOS strategy portfolios" to distinguish them from the full sample (FS) strategy portfolios presented in the main text.

The OOS Diversification strategy portfolio has 10 assets, including all 6 that were identified in the FS Diversification strategy portfolio.[57] While the FS Inflation-Protection strategy included gold, the OOS Inflation-Protection strategy excludes gold. For the IS data period, gold had positive, but statistically insignificant, sensitivity to both the inflation level and surprise (p-values were just above the threshold, 0.21 and 0.15, respectively). To consistently apply our methodology, we therefore exclude gold in the OOS Inflation-Protection strategy portfolio. The real assets in both the OOS and FS Stagnation-Protection strategy portfolios are the same.

Next, we compare the performance of the OOS strategy portfolios between the IS and OOS periods. The OOS period experienced strong US equity market performance (14.8%). In both periods, equities had the highest volatility and government bonds had the lowest. Among the three strategies, the Stagnation-Protection strategy had bond-like low volatility in both sample periods (4.5% in IS and 5.3% in OOS). The Inflation-Protection strategy had equity-like high volatility in both sample periods (10.1% in IS and 9.6% in OOS).

57 When constructing the Diversification strategy using the full sample we were able to split the sample and conduct subsample analysis to further filter for truly diversifying assets that did not have high subsample R^2s.

A5.1 Inflation and Real GDP Level and Surprise Exposures; Estimated Dimson Betas

(In-Sample period; 1996–2017)

Asset	Inflation Level	Inflation Surprise	Real GDP Level	Real GDP Surprise	Stocks and Bonds Explanatory Power (R^2)
Real Estate	2.34	0.52	5.39	2.20	0.26
Real Estate Debt	–1.17	–1.65	–0.09	0.42	0.30
REIT	6.28	10.88	6.29	15.09	0.45
Natural Resource	9.91	14.26	2.65	–2.20	0.12
Energy Equity	10.04	18.17	5.97	10.48	0.51
Infrastructure	7.95	11.04	1.89	–2.85	0.17
MLP	–0.81	–4.10	1.15	–0.25	0.09
Timberland	2.82	2.18	0.92	–0.14	0.10
Farmland	1.66	1.49	–0.39	–3.66	0.05
TIPS	1.90	2.64	–0.03	0.46	0.24
Commodity	22.90	41.86	5.21	9.54	0.13
Gold	1.83	7.25	–1.38	–4.35	0.10
Currency	3.77	6.47	0.24	1.54	0.08
Cash	0.37	–0.12	0.39	0.43	0.13
US Equity (S&P 500)	1.03	4.00	6.84	20.75	1.00
US 10y Treasury	–1.05	–1.47	–0.40	–1.26	1.00

Note: Each of the assets are regressed on inflation and real GDP levels (QoQ). We also regress each of the assets on inflation and real GDP surprises. The beta is a sum of lead, current, and lag betas (Dimson beta). Betas in bold suggests significance at a 90% confidence level. Assets in bold are private assets and assets in italics are for reference purposes only.
Source: PGIM IAS

A5.2 Out-of-Sample Real Asset Strategy Portfolio Weights

Asset	Diversification	Inflation-Protection	Stagnation-Protection
Real Estate	10.0%	—	—
Real Estate Debt	10.0%	—	25.0%
REIT	—	—	—
Natural Resource	10.0%	20.0%	—
Energy Equity	—	20.0%	—
Infrastructure	10.0%	20.0%	—
MLP	10.0%	—	—
Timberland	10.0%	—	—
Farmland	10.0%	—	25.0%
TIPS	10.0%	20.0%	25.0%
Commodity	10.0%	20.0%	—
Gold	10.0%	—	25.0%
Total	**100%**	**100%**	**100%**

Note: Assets in bold are private assets.
Source: PGIM IAS

A5.3 In-Sample vs. Out-of-Sample Performance Comparison Real Asset Strategies, Stocks and Bonds

		Diversification	Inflation-Protection	Stagnation-Protection	US Equity (S&P 500)	US Govt. 10-year	60/40
Return	**IS**	10.1%	9.5%	8.7%	5.5%	6.0%	6.4%
	OOS	5.4%	2.8%	5.3%	14.8%	2.4%	9.9%
Annual Risk	**IS**	6.3%	10.1%	4.5%	18.0%	4.7%	9.7%
	OOS	5.5%	9.6%	5.3%	12.5%	3.9%	6.7%
Return/Risk	**IS**	1.60	0.94	1.93	0.31	1.28	0.66
	OOS	0.98	0.29	1.00	1.18	0.62	1.48

Source: PGIM IAS

We also compare the macroeconomic sensitivity and market explanatory power of the three real asset strategy portfolios. We find that the OOS Inflation-Protection strategy had both the highest inflation level and surprise beta in the out-of-sample period (as desired). Similarly, the OOS Stagnation-Protection strategy had both the lowest growth level and surprise beta on an out-of-sample basis (as desired). Finally, the OOS Diversification strategy (and the OOS Inflation-Protection strategy) had low market explanatory power (as desired).

A5.4 In-Sample vs. Out-of-Sample Macroeconomic Sensitivities Real Asset Strategies

		Diversification Strategy	Inflation-Protection Strategy	Stagnation-Protection Strategy
Explanatory Power (R^2) of Bond & Equity Market	**IS**	0.10	0.18	0.13
	OOS	0.44	0.42	0.56
Sensitivity to Inflation Level	**IS**	4.70	8.71	1.42
	OOS	5.95	11.24	2.47
Sensitivity to Inflation Surprise	**IS**	7.85	15.64	3.13
	OOS	7.27	13.20	2.22
Sensitivity to Real Growth Level	**IS**	1.41	2.72	–0.05
	OOS	0.83	0.87	–0.75
Sensitivity to Real Growth Surprise	**IS**	–0.99	–0.19	–2.15
	OOS	2.14	2.37	–2.86

Note: The performance of each strategy is regressed on inflation and GDP levels (QoQ). We also regress each of the assets on inflation and real GDP surprises. The beta is a sum of lead, current, and lag betas (Dimson beta). Betas in bold suggests significance at a 90% confidence level.
Source: PGIM IAS

As in Section 5, if we were to conduct scenario analysis using only the IS data period, 59% of the scenarios would be muddled environments and 30% would be stagnation. Only 3% of the scenarios were stagflation environments and no scenarios were overheating environments. Therefore, for the IS data period it is difficult to validate the performance of real assets in inflationary environments.

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