PIMCO

The Natural Rate Puzzle

AUTHORS

Josh Davis
Managing Director
Global Head of Client Analytics

Joachim Fels
Managing Director
Global Economic Advisor

Alan M. Taylor
Professor of Economics
and Finance, University of
California, Davis

Executive Summary

- The history of the bond market reveals a conundrum: Yields have swung from high levels in the 1970s to low levels today. The usual explanatory factors are inflation trends, the natural rate and the bond risk premium. Conventional measures of these factors show up-and-down swings, but collectively they do not add up. They overexplain yields, so some of these explanations are incorrect or exaggerated.

- We address this puzzle with a new model that estimates the contribution of the three factors in a mutually consistent way. We obtain *market-implied* measures of the unobservable natural rate r^* and bond risk premia consistent with observable bond market yields and trend inflation π^*.

- With the incorporation of bond market data, ignored in other r^* models, our market-implied natural rate and bond risk premium differ from established estimates. Our natural rate r^* is typically much lower over the sample, especially in recent years, intensifying current concerns about secular stagnation and the effective lower bound on monetary policy in advanced economies. Our bond risk premium varies much less over time and is higher today than in other models.

- The results are important for investors. In particular, judged on a month-to-month basis, our trend factors improve the fit of linear predictions of yields and excess returns. In addition, although conventional estimates say the bond risk premium has been mostly negative in the past decade, our market-implied bond risk premium estimate has maintained an average above zero.

1. IS CONVENTIONAL MACROFINANCIAL HISTORY WRONG?

One of the most salient stylized facts of postwar macrofinancial history is the rise and fall of interest rates, starting in the Great Inflation of the 1970s and fading with the return to price stability in the following decades.

What, exactly, were the forces that drove bond markets to a state in which long-term yields stood at 4% in the early 1960s, surged to 12% in the early 1980s, returned to their starting point in the early 2010s and fell to almost zero in 2020–2021?

Consider one of the most standard financial relationships, where we define the forward yield (f) as the sum of expected trend inflation (π^*), the expected trend in the real natural rate (r^*) and the bond risk premium (BRP).

This can be written:

$$f = \pi^* + r* + BRP. \quad (1)$$

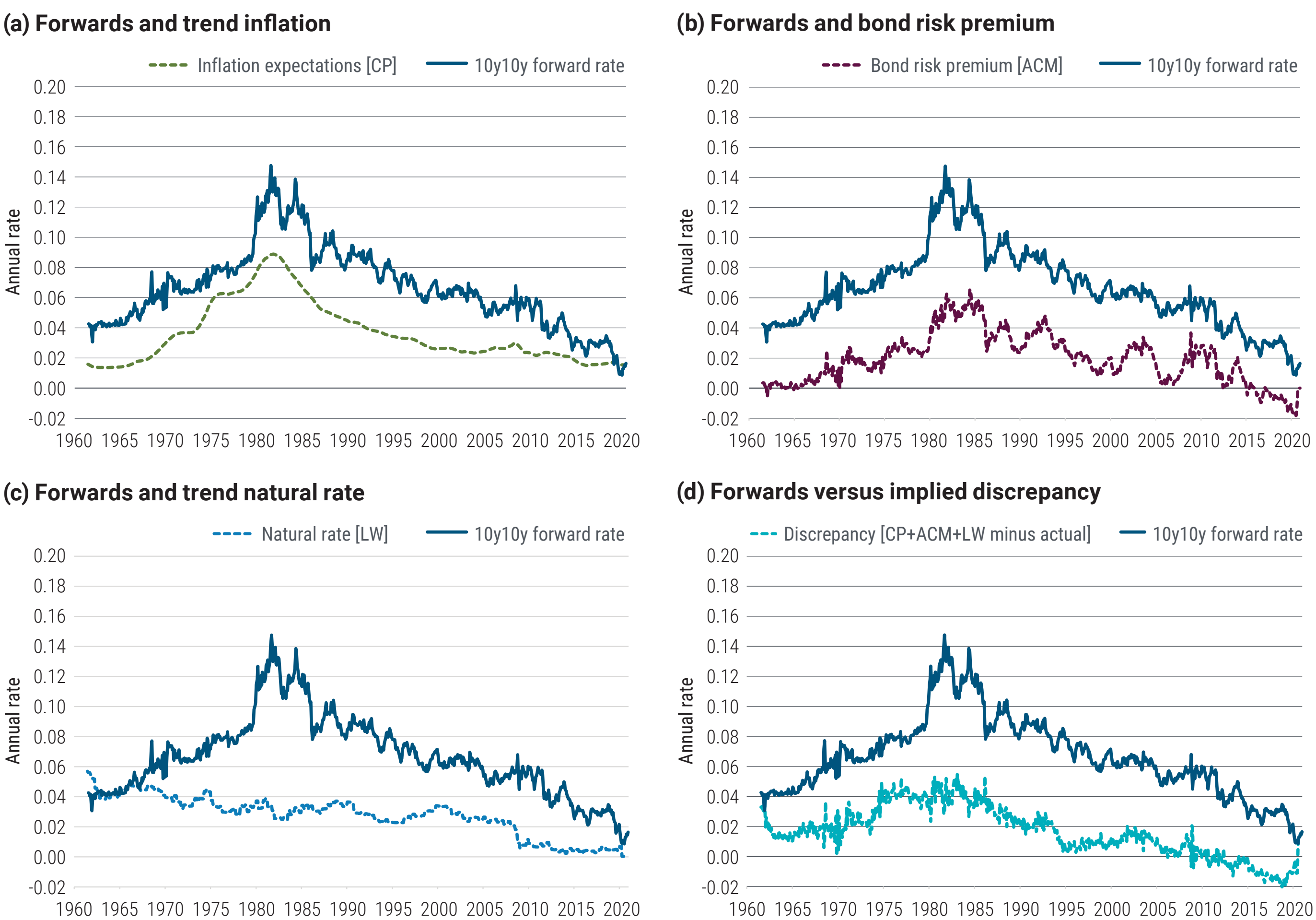
For a long time, financial research focused on the first two terms on the right-hand side of the equation, π^* and BRP, treating the natural rate as fixed. In this framework, inflation can drive yields in two ways. Directly, the Fisher effect says an extra 100 basis points (bps) of inflation require 100 bps of yield compensation. Indirectly, a risk premium can also matter if high inflation is a risk factor for which investors demand additional compensation.

The history of bond pricing in financial research can be seen as aiming to give these explanations some quantitative basis. The basic evidence is quite favorable, as shown in Exhibits 1a and 1b.

Exhibit 1a shows that the pattern of trend inflation (we use the Cieslak-Povala (CP) measure) on its own goes a long way toward explaining the rise and fall of yields via the π^* term in Equation 1. Exhibit 1b shows that shifts in a standard estimate of the bond risk premium (the Fed's preferred ACM model, by Adrian, Crump and Moench) also contribute substantial explanatory power via the BRP term in Equation 1.

In fact, adding the two would produce a satisfactory account of historical yield behavior, particularly after 1980: The two downtrends together can fully explain the 1,200 bps downswing in yields as the sum of 600 bps of reduced inflation and 600 bps of diminished bond risk premium. At this point, one might be tempted to declare victory.[1]

Exhibit 1: Forward yields and components from various standard models



Source: Bloomberg and PIMCO calculations as of December 2020, plus Cieslak and Povala (2015), and Adrian, Crump and Moench (2013). **Hypothetical example for illustrative purposes only.**

1 Cieslak, Anna and Pavol Povala, "Expected Returns in Treasury Bonds," *Review of Financial Studies*, October 2015. Adrian, Tobias, Richard K. Crump and Emanuel Moench, "Pricing the Term Structure with Linear Regressions."

Now this apparently settled debate has been upturned. The accounting exercise we just presented has fallen into conflict with evidence from macroeconomic research on the evolution of the natural rate r^* itself. Over the past 10 to 20 years, evidence has mounted of important trend changes in r^*, starting with the seminal work of Laubach and Williams (LW), who used state-space methods to uncover the unobservable natural rate, guided by restrictions from long-run macroeconomic models.[2]

Why has the natural rate fallen? In equilibrium, the natural rate adjusts in response to shifts in savings supply and investment demand. To explain its decline, macro researchers have devoted attention to forces such as lower growth rates, a slowdown in technology innovation, aging demographics, inequality, global demand for "safe assets" and falling prices of capital goods; researchers believe these are the fundamental drivers of the savings gluts and investment droughts behind the observed outcome.[3]

However, we will focus on the massive implications for the bond market. Exhibit 1c reveals the essence of the problem. Here, the LW real natural rate estimate follows a steady downtrend over the past 60 years, from about 400 bps to 0 bps. There is some stability in the 1980s and 1990s at around 200 bps, but from 2000 to 2015 the natural rate collapsed to zero, and it has stayed there ever since.

But if we plug this value for the natural rate r^* into Equation 1 along with the previously seen estimates of the π^* and BRP terms, the resulting discrepancy between the implied forward rate and the actual data becomes obvious, as shown in Exhibit 1d. The three approaches do well on their own, but together they do too well. They overexplain history, and the errors are nontrivial. Summing up the three trend estimates delivers forward rate predictions that are too high compared with observed data, by as much as 300–400 bps in the 1970s and 1980s, and too low by up to 100–200 bps in the 2010s.

2 Laubach, Thomas and John C. Williams, "Measuring the Natural Rate of Interest," *Review of Economics and Statistics*, November 2003.

3 Rachel, Łukasz and Thomas D. Smith, "Secular Drivers of the Global Real Interest Rate," Bank of England Working Paper No. 571, December 2015. Carvalho, Carlos, Andrea Ferrero and Fernanda Nechio, "Demographics and Real Interest Rates: Inspecting the Mechanism," *European Economic Review*, September 2016. Eggertsson, Gauti B., Manuel Lancastre and Lawrence H. Summers, "Aging, Output Per Capita, and Secular Stagnation," *American Economic Review*: *Insights*, December 2019. Rachel, Łukasz and Lawrence H. Summers, "On Secular Stagnation in the Industrialized World," *Brookings Papers on Economic Activity*, Spring 2019.

Standard models run into trouble here. We call this conundrum the *natural rate puzzle*.

The root cause is easily understood: None of these individual approaches to estimating the components of yields takes into account the interrelationships among the three trends – in inflation, the bond risk premium and the natural rate. That is, no consistency is enforced across three different trend estimates.

This brief survey of this problem includes some of the best-known research papers in the literature, but the problem is quite general. Our full-length working paper[4] shows that the puzzle applies to the entire range of widely used estimates of each component, and also applies outside the U.S., in five other advanced economies (Australia, Canada, Germany, Japan and the U.K.).

What is to be done? The stakes are not low. If bond risk premia are wrong, doubt falls on the bond pricing and return forecasts that are the bread and butter of fixed income research and trading strategies. If natural rate forecasts are wrong, that spells trouble for macro research, central bank analysis and policy frameworks. Until this is settled, the conventional accounts of macro-financial history hang in limbo.

This report describes a new model PIMCO has developed to address the puzzle. It is a macro-finance hybrid model in that, taking trend inflation as observable, it estimates the risk premium and natural rate unobservables *simultaneously* and with the consistency required by Equation 1.

The estimates from our new model reveal quite a different history of bond market drivers, and they deliver much better predictions of yields and excess returns, in our view.

2. THE MODEL: MARKET-IMPLIED R* AND BOND RISK PREMIA

To successfully resolve the natural rate puzzle, we need a unified model that produces estimates of the latent r^* and bond risk premium variables that obey Equation 1.

4 Davis, Josh, Cristian Fuenzalida and Alan M. Taylor, "The Natural Rate Puzzle: Global Macro Trends and the Market-Implied r*," NBER Working Paper No. 26560, December 2019.

The new model is built from two equations for average yields $\overline{y}_t$ and bond excess returns $\overline{rx}_t$, based on a theoretically founded macro-finance model in which the natural rate and inflation serve as factors driving the short rate process, from which we can derive implications for yields. Cyclical deviations of observed yields then drive risk premia, with

$$\begin{aligned} \overline{y}_t &= a^y + b^\pi \pi_t^* + b^r r_t^* + \epsilon_t^{cyc}, \\ \overline{rx}_{t+1} &= d^0 + d^\pi \pi_t^* + d^r r_t^* + d^{cyc} \epsilon_t^{cyc} + \epsilon_t^{rx}, \end{aligned} \quad (2)$$

to which we add an equation linking the natural rate to a macroeconomic growth factor g_t and a "headwinds" term z_t,

$$r_t^* = g_t + z_t. \quad (3)$$

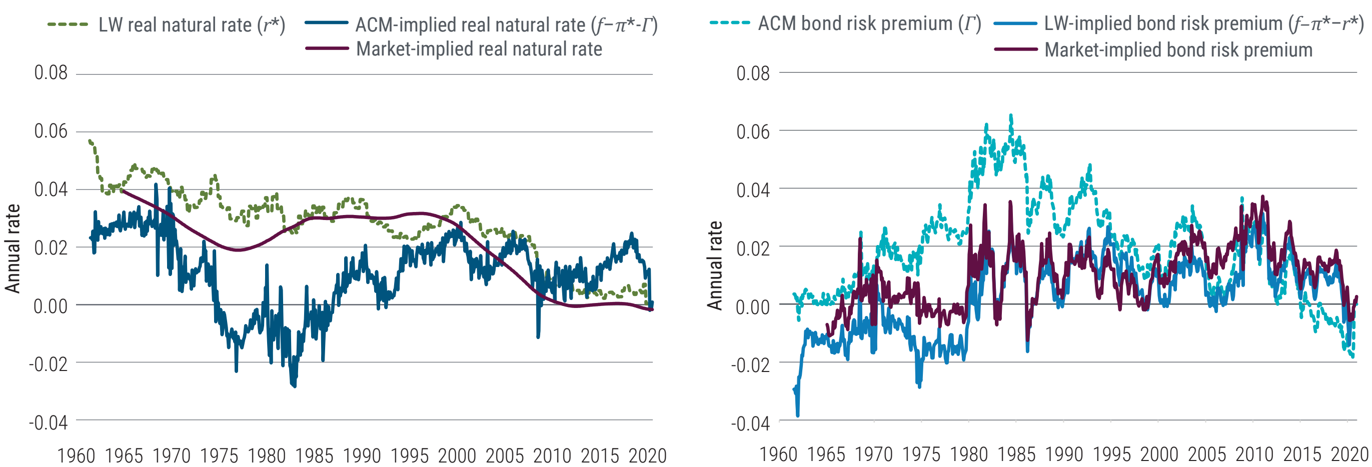
Note that the bond pricing error ϵ_t^{cyc} is in essence a "detrended yield," or residual once the raw yield has been projected onto the factors r^* and π^*; if this cyclical yield is an average bond equilibrium error, it must enter as a factor in expected bond returns $\overline{rx}_t$. The critical difference between our modeling approach and LW and ACM is that we estimate the natural rate and the bond risk premium jointly, in a single step, without assuming either step can in isolation provide the right answer. This is necessary, as we saw, because single-equation estimates lead to contradictory answers about the drivers of bond market trends.

We assume the bond pricing error ϵ_t^{cyc}, the bond return error ϵ_t^{rx} and the headwinds term z_t follow autoregressive processes, calibrated in line with the literature. The inflation trend π^* is less controversial and is treated as an observable using a constant-gain learning estimate (an exponentially weighted average of past inflation – a reasonable benchmark to measure market inflation expectations, as in CP).

Exhibit 2 shows the model's estimates of the U.S. natural rate and bond risk premium compared with established estimates. In the left panel, our r^* estimate (solid purple line) often lies below the benchmark LW estimate (dotted green line) of the natural rate, by between 0 bps and about 150 bps, although our estimate was above it in the 1990s. Our estimate disagrees strongly with the ACM implied estimate (solid blue line), which diverges well below zero in the 1970s and 1980s, then crosses to finish some way above our estimate in the 2010s.

The right panel shows the model's estimates of the U.S. bond risk premium, as implied by Equation 1, given inflation and forward data. Our bond risk premium estimate (solid purple line) again lies close to, but now often slightly above, the LW

Exhibit 2: The market-implied r* and bond risk premia in U.S. data



Source: Bloomberg and PIMCO calculations as of December 2020, plus Laubach and Williams (2003), and Adrian, Crump and Moench (2013). **Hypothetical example for illustrative purposes only.**

implied estimate (solid blue line), but it diverges in a much more pronounced way from the ACM estimate (dotted blue line). The bond risk premium has been nearly stable over time in our model, but according to ACM it has played a very large role as a driver of yields.

Two core disagreements with previous estimates arise.

First, our natural rate in the U.S. is near zero and sometimes negative for the last part of the sample. This suggests that structural factors, or headwinds, driving the natural rate (e.g., demographics, changes in savings behavior, global inequality dynamics, foreign capital flows chasing "safe assets," and unconventional monetary policies) have been pushing equilibrium rates toward a "negative New Normal."[5]

Second, our bond risk premium moves very differently from conventional wisdom. Our estimate is flat since the 1980s, with a small rise in the 2000s. The ACM bond risk premium shows a large risk premium in the 1980s, followed by a steady decline. We argue that correct model attribution must account for the two macro trends, inflation and the natural rate, without assuming they are constants. A model like ACM, which omits both macro trends, will tend to attribute shifts to the bond risk premium instead.

Probably the most striking discrepancy in the story of the bond risk premium can be seen over the past 25 years. While a narrative of low and even negative bond risk premia in recent years is embedded in most people's minds, our estimates substantially elevate the BRP above zero over the past decade.

Exhibit 3 presents the model estimates of the unobservable natural rate r^* for six countries. Although data availability confines these results to a short time period, the findings echo what we saw in the U.S. case. Our model estimates of the natural rate are close to but typically below the LW estimates, and far from the ACM implied estimates.

Outside the U.S., our model indicates that the advanced economies in general are currently in a very low r^* configuration, with natural rates well below what standard LW-type estimates have suggested in recent years.

The divergence with ACM is most pronounced in the 1980s in the high inflation economies of Australia, Canada, the U.K. and the U.S. Here again, the ACM model attributes high yields to unusually high bond risk premia and not to changing macro fundamentals. For that to add up, given the constraint of Equation 1, the ACM model has to imply a very low natural rate (indeed, it often goes extremely negative). Our model disagrees.

In short, around the world, the rise and fall of interest rates in the 1970–2000 era were mainly driven by shifts in the bond risk premium, according to ACM estimates. But our new, model-consistent estimates suggest that the bond risk premium has been largely stable, with yields moving mainly as a result of large swings in the macro trends r^* and π^*.

In that sense, our new estimates provide compelling evidence that the conventional view of the course of modern macro-financial history may need to be reconsidered.

3. DISCUSSION

Although our reduced-form model does not provide attribution to economic factors, we conjecture that key drivers behind the global decline in natural rates likely include aging demographics, slowing productivity growth and increasing demand for "safe assets." We believe a reversal of these slow-moving yet persistent macro trends is unlikely and therefore that r^* will remain anchored near current estimates over the secular horizon, much like r^* has been anchored over most three- to five-year subperiods in our historical sample.

5 These findings echo what Kiley has observed about the U.S. natural rate being lower than previously estimated, with its decline driven by global factors. He finds a lower and even negative rate to be a robust finding to different estimation methods based on simple trends, term structure or small macroeconomic model approaches. Michael T. Kiley, "The Global Equilibrium Real Interest Rate: Concepts, Estimates, and Challenges," *Annual Review of Financial Economics,* November 2020.

Exhibit 3: The market-implied r* in data from six economies

Source: Bloomberg and PIMCO calculations as of December 2020, plus Laubach and Williams (2003), and Adrian, Crump and Moench (2013). **Hypothetical example for illustrative purposes only.**

We even see some potential for r^* to decline further in the future. The pandemic may result in economic scarring and a greater preference for saving, similar to the household response observed in the Great Depression.[6] Furthermore, as rates remain low there's a potential for the emergence of "zombie" firms that remain solvent because of their ability to roll debt at low rates, leading to lower overall productivity growth. One thing is for certain: Further declines in r^* will only intensify concerns about economic stagnation and the effectiveness of monetary policy in a world of fiat currency where nominal interest rates cannot be too negative.

Debt is the fly in the ointment. Our estimates for r^* suggest that over the past 30 years the factors driving the demand for "safe debt" in advanced economies have outstripped the increased supply. However, advanced economies may not be able to endlessly borrow their way out of problems, and fiscal adjustments may one day be needed to keep today's perceived "safe debt" safe. Though we believe these concerns live in the tails today, increasing debt and leverage around the world could become a source of uncertainty and economic fragility.

4. A BETTER GUIDE TO BOND YIELDS AND RETURNS?

An investment strategy that ignores shifts in macro fundamentals is likely to misplace equilibrium levels of yields and misjudge excess returns. A failure to update could be a costly mistake; for example, it was a common view in 2010–2011 that yields would revert to pre-2007 levels after a recovery from the global financial crisis, but the natural rate had shifted profoundly. Instead of updating their strategies to track a moving target, as they should, investors may mistakenly chase stale r^* and π^* estimates taken from historical data that no longer apply in reality.

Our analysis, using our preferred regression estimates of yields and excess returns, indicates that, indeed, the failure to detrend yields with the two macro fundamentals omits important information and can lead to less precise estimates. Exhibit 4 shows estimates of 10-year zero-coupon yields as a function of the natural rate factor r^*, inflation factor π and the cyclical or *detrended* component yields $\bar{c}$, estimated by projecting on the two factors. The regressions fit well, as is typical when pricing yields, with R^2 statistics above 0.98.

Exhibit 4: Yield regressions

	(1) U.S.	(2) Japan	(3) Germany	(4) U.K.	(5) Canada	(6) Australia
r^*	0.875***	**1.165*** **	1.356***	1.025***	0.944***	**1.073*** **
	(0.023)	(0.024)	(0.023)	(0.021)	(0.024)	(0.014)
π^*	1.080***	0.456***	0.800***	0.532***	1.182***	1.009***
	(0.013)	**(0.025)**	(0.024)	(0.009)	(0.039)	**(0.013)**
$\bar{c}$	0.847***	**0.569*** **	0.724***	0.844***	0.849***	**0.930*** **
	(0.024)	(0.130)	(0.048)	(0.041)	(0.045)	(0.025)
Constant	0.003***	0.002***	0.003***	0.002***	0.001	0.003***
	(0.001)	**(0.000)**	(0.001)	(0.001)	(0.001)	**(0.000)**
Observations	671	455	551	455	384	353
R^2	0.991	**0.989**	0.992	0.992	0.992	**0.996**

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: PIMCO calculations. Data through December 2020. **Hypothetical example for illustrative purposes only.**

6 Òscar Jordà, Sanjay R. Singh and Alan M. Taylor, "Longer-Run Economic Consequences of Pandemics," *Review of Economics and Statistics* (forthcoming).

Two related findings deserve comment. First, if we estimated these equations with just average *non-detrended* yields (i.e., the widely used level factor), the results would be identical but the coefficients would change, as the projection would be undone. Cyclical detrending is an attribution exercise; it is important when accounting for deeper macro fundamentals driving yields, and it steers us away from "ketchup economics"[7] – the circularity of explaining yields with yields. Second, without including macro fundamentals and using only yields, the fit worsens; this matters when cyclical yield residuals play an informative role in return prediction, as we find they do.

On that point, Exhibit 5 shows affine bond excess return regressions and finds the cyclical return significant in five out of six cases. Here, a worse fit would result from poor detrending choices. If we leave macro fundamentals out and rely on raw yields alone, the R^2 in these regressions collapses to near zero and the forecasts get noisy. Instead, our detrending with macro factors gives an R^2 of 0.012–0.043, respectable for a return prediction regression. The macro factors are indeed an important moving target for investors.

Exhibit 5: Excess return regressions

	(1) U.S.	(2) Japan	(3) Germany	(4) U.K.	(5) Canada	(6) Australia
r^*	-0.004	**0.007**	-0.008	-0.004	0.004	**-0.015**
	(0.010)	(0.016)	(0.008)	(0.008)	(0.010)	(0.009)
π^*	0.000	-0.005	0.012	0.002	0.001	0.032*
	(0.012)	**(0.018)**	(0.015)	(0.006)	(0.021)	**(0.015)**
$\bar{c}$	0.061**	**0.090***	0.041	0.065*	0.069**	**0.054***
	(0.020)	(0.037)	(0.030)	(0.026)	(0.023)	(0.023)
Observations	670	454	550	454	383	352
R^2	0.022	**0.033**	0.012	0.025	0.025	**0.043**

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: PIMCO calculations. Data through December 2020. **Hypothetical example for illustrative purposes only.**

A clearer picture of the improved fit from using the new model to estimate yields and excess returns emerges from a bivariate regression and scatter plot of excess returns against the model's estimated bond risk premium. Exhibit 6 does this exercise using full in-sample U.S. estimates from this new PIMCO model and the established ACM model.

Here, the horizontal axis is the model-estimated average bond risk premium in a given month, treated as a signal, and the vertical axis is the average bond excess return over the subsequent month. A scatter is used with 20 bins and a line of best fit. The PIMCO model has an R^2 of 0.0195. The ACM model has a much smaller R^2 of 0.0068. In our analytical working paper on NBER, we present an out-of-sample test of predictive power using recursive estimates that update each period. These also show that the PIMCO model delivers a meaningful forecast improvement over its predecessors.

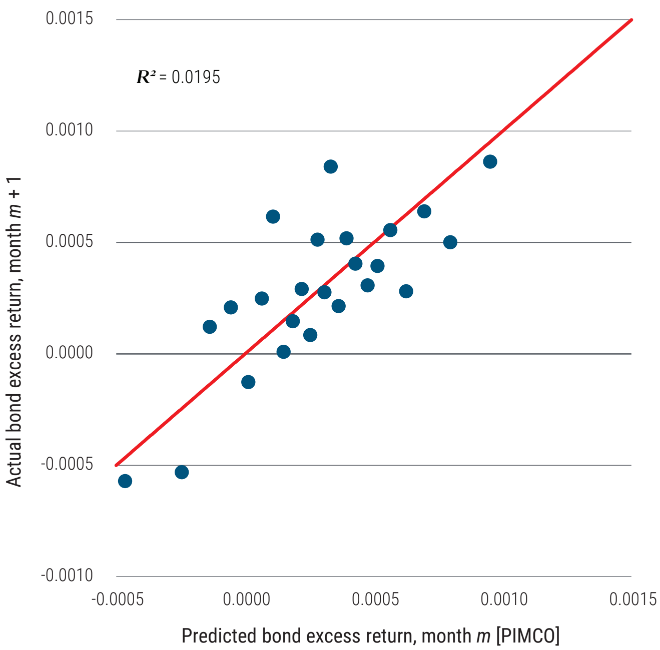
5. CONCLUSION

Benchmark models of the bond risk premium are at odds with benchmark models of the neutral rate of interest. To resolve this natural rate puzzle, we estimate a unified macro-finance model and identify a *market-implied* natural rate r^* that is jointly consistent with long-run trends in real growth, inflation expectations and bond yields.

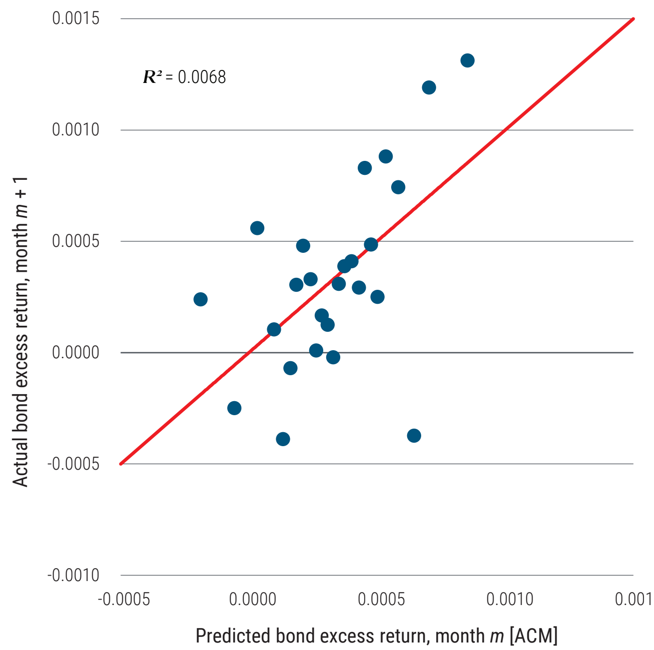
7 Summers, Lawrence H., "On Economics and Finance," *Journal of Finance*, July 1985.

Exhibit 6: Excess returns and bond risk premia, PIMCO and ACM models compared

(a) PIMCO model



(b) ACM model



Source: PIMCO calculations. Data through December 2020. **Hypothetical example for illustrative purposes only.**

The model attributes lower-frequency movements in bond yields to movements in inflation expectations and r^*, and higher-frequency movements to changes in the bond risk premium. The estimates provided for several advanced economies reveal a common pattern: r^* exhibits a persistent decline over the past 30 years, and current estimates are all less than zero.

With the incorporation of bond market data, ignored in other r^* models, our market-implied natural rate and bond risk premium differ from established estimates. Our bond risk premium varies much less over time and is higher today than in other models. Our natural rate r^* is typically much lower over the sample, especially in recent years, intensifying current concerns about secular stagnation and the effective lower bound on monetary policy in advanced economies.

The results are important for investors. In particular, our trend factors improve the fit of standard affine yield and excess return predictions. In addition, although conventional estimates say the bond risk premium has been mostly negative in the past decade, our consistent bond risk premium estimate has maintained an average above zero.

The analysis contained in this paper is based on hypothetical modeling. Hypothetical performance results have many inherent limitations, some of which are described below. No representation is being made that any account will or is likely to achieve profits or losses similar to those shown. In fact, there are frequently sharp differences between hypothetical performance results and the actual results subsequently achieved by any particular trading program or strategy.

One of the limitations of hypothetical performance results is that they are generally prepared with the benefit of hindsight. In addition, hypothetical trading or modeling does not involve financial risk, and no hypothetical example can completely account for the impact of financial risk in actual trading. For example, the ability to withstand losses or to adhere to a particular trading program in spite of trading losses, are material points which can also adversely affect actual trading results. There are numerous other factors related to the markets in general or to the implementation of any specific trading program which cannot be fully accounted for in the preparation of hypothetical performance results, all of which can adversely affect actual results. No guarantee is being made that the stated results will be achieved.

Figures are provided for illustrative purposes and are not indicative of the past or future performance of any PIMCO product.

There is no such thing as a "**safe asset**" or "**safe debt**". These assets are typically referred to as a "risk-free" asset, which refers to an asset which in theory has a certain future return. U.S. Treasuries are typically perceived to be the "risk-free" asset because they are backed by the U.S. government. **All investments** contain risk and may lose value.

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