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The causes and challenges of low interest rates: insights from basic principles and recent literature

Youchang Wu
Department of Finance, Lundquist College of Business, University of Oregon, Eugene, Oregon, USA

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Abstract

Purpose – What causes the downward trend of real interest rates in major developed economies since the 1980s? What are the challenges of the near-zero interest and inflation rates for monetary policy? What can the policymakers learn from the latest developments in the monetary and interest rate theory? This paper aims to answer these questions by reviewing both basic principles of interest rate determination and recent academic and policy debates.

Design/methodology/approach – The paper critically reviews the explanations for the downward trend of real interest rates in recent decades and monetary policy options in a near-zero interest rate environment.

Findings – The decline of real interest rates is likely an outcome of multiple technological, social and economic factors including diminished productivity growth, changing demographics, elevated tail-risk concerns, time-varying convenience yields of safe assets, increased global demand for safe assets, rising wealth and income inequality, falling relative price of capital, accommodative monetary policies, and changes in industry structure that alter the investment and saving behaviors of the corporate sector. The near-zero interest rate limits the space of central banks' response to economic crises. It also challenges some conventional wisdoms of monetary theory and sparks radically new ideas about monetary policy.

Originality/value – This survey differs from the existing work by taking a broader view of both economics and finance literature. It critically assesses the economic forces driving the global decline of real interest rates through the lens of basic principles and empirical evidence and discusses the merits and limitations of each proposed explanation. The study emphasizes the importance of a better understanding of economic forces driving diverging trends of corporate investment and saving behaviors. It also discusses the implications of the neo-Fisherism and the fiscal theory of price level for monetary policy in a low interest rate environment.

Keywords Interest rate, Safe asset, Tail risk, Secular stagnation, Monetary policy, Zero lower bound

Paper type Literature review

1. Introduction

There is a significant decline in real interest rates, defined as nominal rates minus expected inflation rates, in major developed economies since the 1980s. Panel (a) of Figure 1 plots the real and nominal 1-year treasury rates in the US from January 1980 to April 2020 and the real 10-year rates measured by the yield on the US Treasury Inflation-Protected Securities (TIPSs) since 2003. The downward trend is pronounced. The nominal 1-year rate declines from the peak of 16.7% per annum in August 1981 to 0.18% in April 2020, while the real 1-year rate drops from 6.9% to −2.2%. From August 2007 (the month marking the start of a series of rate cuts by the Federal Reserve System in response to the worsening subprime mortgage crisis) to the sample end, the average 1-year rate is 0.89% in nominal terms and −1.43% in real terms, while the average real 10-year rate is 0.66% per annum [1].

The secular decline of real interest rates is a global phenomenon. In fact, interest rates have been lower in many other developed countries than in the US since the 2008 financial crisis. In Japan, Switzerland and many European Union countries, even nominal interest rates have been in the negative territory in recent years. In particular, the current German

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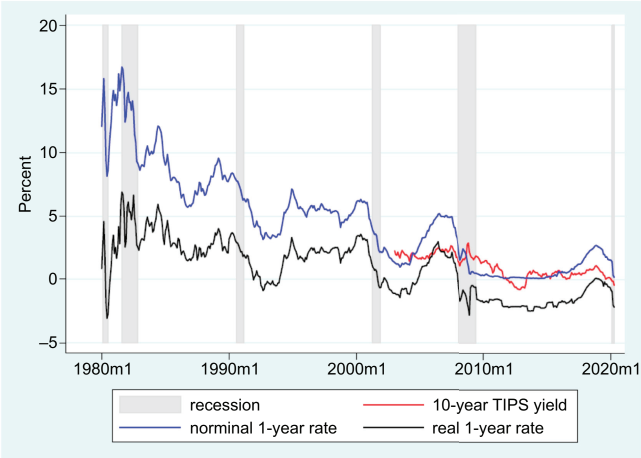
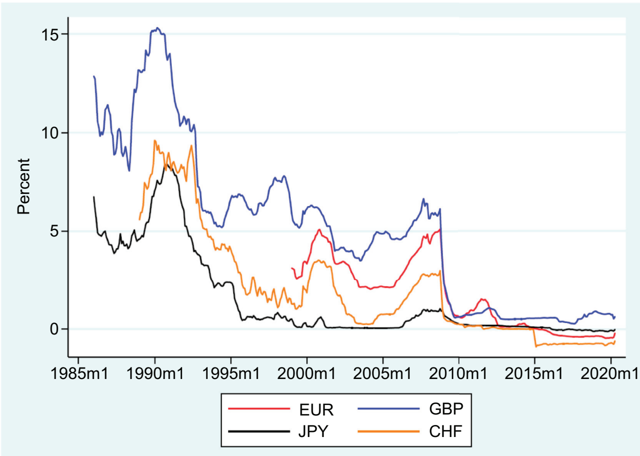


US treasure rates: Nominal and real

(a)



Nominal LIBOR rates for EUR, GBP, JPY, and CHF

(b)

Figure 1.
Interest rates trends

Note(s): Panel (a) shows the nominal and real 1-year constant maturity Treasury rates in the US from January 1980 to April 2020 and the 10-year TIPS yield from January 2003 to April 2020. The 1-year real rate is calculated as the nominal rate minus the median 12-month inflation forecast made by economists responding to the Livingston Survey. The shaded areas indicate the recession periods in the US dated by the National Bureau of Economic Research. Panel (b) shows the time series of nominal 3-month LIBOR rates for the Euro, British pound, Japanese yuan and Swiss franc up to April 2020.

Source(s): The Livingston Survey data, downloaded from the website of the Federal Reserve Bank of Philadelphia; all other data, retrieved from FRED, Federal Reserve Bank of St. Louis.

government bond yields are negative for all maturities up to 30 years. Negative nominal interest rates are not only observed in government bonds. Panel (b) of Figure 1 shows the nominal 3-month London Interbank Lending Rates (LIBOR) for the euro, British pound, Japanese yuan and Swiss franc. Among them only the rate for the British pound remains above zero at the sample end. Yi and Zhang (2017) examine real interest rates in the 20 largest economies from (up to) 1955 to 2014 and document a steady decline and convergence across countries since late 1980s.

This pronounced downward trend of real interest rates in over three decades and the persistent low interest rates in recent years have posed many theoretical and practical questions. What causes the downward trend? What are the challenges of the near-zero interest and inflation rates for monetary policy? And what can the policymakers learn from the latest developments in the monetary and interest rate theory? This paper aims to answer these questions by reviewing both basic principles of interest rate determination and recent academic and policy debates. The canonical models of the neoclassical asset pricing and growth theory point to productivity growth, risk, and population growth as the main determinants of real interest rates, in addition to the subjective discount factor. Recent studies have examined the role of these factors in depth as well as factors beyond these models, including convenience yields of safe assets, global demand for safe assets, relative price of capital, wealth and income inequality, and monetary policy. I review the explanations based on these factors and discuss their merits and limitations. While recognizing the relevance of each of these factors, I emphasize the importance of a better understanding of economic forces leading to a downward trend in corporate investment and an upward trend in corporate saving.

The near-zero nominal interest rate limits the space of central banks' response to economic crises. A series of unconventional monetary policies have been experimented following the global financial crisis in 2008, including quantitative easing, forward interest rate guidance, and negative interest rates. More aggressive actions have been taken upon the outbreak of the COVID-19 pandemic. While the monetary policies post the 2008 crisis have been successful in maintaining the stability of the financial system, they do not appear to be very effective in boosting aggregate demand and growth. In fact, most central banks consistently undershoot their inflation targets. These experiences and challenges have spurred or generated renewed interest in unconventional ideas of monetary theory, including the new Fisherism and the fiscal theory of price level. The last part of this review discusses the monetary policy conundrum in the near-zero interest rate environment and the policy implications of these new developments in monetary theory.

The literature on the low real interest rate is vast, and it is growing at a fast pace. Therefore, this is by no means a complete survey. Several papers and commentaries provide an overview of the topic. Summers (2014) discusses a list of potential contributing factors to the decline. He revives the term "secular stagnation" first introduced by Alvin Hansen and uses it as an overarching concept to describe the current prolong situation of low demand, low growth and low interest rates. Hall (2017a) discusses the causes and consequences of low interest rates. The US Council of Economic Advisors (2015) reviews the world-wide decline of long-term interest rates and discusses potential reasons. Rachel and Smith (2017) examine quantitatively the contributions of various factors to the shifting of global investment and saving schedules. This survey differs from the existing work by taking a broader view of both economics and finance literature and by critically reviewing of each proposed explanation and policy recommendation through the lens of basic principles and empirical evidence.

The review is structured as follows. Section 2 reviews the standard neoclassical theory of real interest rate determination. Section 3 reviews the recent findings on causes of the secular decline. Section 4 discusses the challenges of low interest rates for monetary policy and the policy implications of the neo-Fisherism and the fiscal theory of price level. Section 5 concludes with a short summary.

2. The determination of real risk-free rates: basic principles

In this section, I review the determination of real risk-free rates in the standard consumption-based asset pricing theory and neoclassical growth theory. Following the tradition of the "classical dichotomy," which maintains that real variables such as the real interest rate are determined only by real factors and not by monetary factors, these standard theories abstract from potential influences of monetary policy. While the canonical models reviewed here leave out many important drivers of real interest rates, they highlight the key mechanisms and provide a foundation for models with more realistic features. The closed-form results they offer provide transparency and clarity often unavailable from the more sophisticated models in modern literature.

2.1 Risk-free rates in the consumption-based asset pricing theory

Consider a representative agent with an infinite horizon, whose preferences are described by a time-separable expected utility function over the stream of consumption $\{C_0, C_1, C_2, \ldots\}$:

$$E_0[U(C_0, C_1, C_2, \ldots)] = E_0 \sum_{t=0}^{\infty} \beta^t u(C_t),$$

where $\beta < 1$ is the subjective discount factor capturing the agent's patience (a higher β means more patience), $u(C_t)$ is the per-period utility function with $u'(C_t) > 0$, $u''(C_t) \leq 0$. The Euler equation, which characterizes the intertemporal optimization of the representative agent, dictates that the period-t price of any investment asset with the payoff x_{t+1} at $t+1$ should be

$$p_t = E_t\left[\frac{\beta u'(C_{t+1})}{u'(C_t)} x_{t+1}\right] \tag{1}$$

The marginal utility ratio $M_{t+1} \equiv \frac{\beta u'(C_{t+1})}{u'(C_t)}$ measures how much the agent values the consumption in period t+1 relative to the consumption in period t. It is called the stochastic discount factor. Eqn (1) is a fundamental consumption-based asset pricing formula – it is the first equation that appears in Cochrane's (2005) influential *Asset Pricing* textbook. The intuition for the formula is simple. The representative agent must decide how much to consume in the current period and how much to invest. If she purchases one extra unit of asset at the price p_t, she gives up p_t units of period-t consumption, so the marginal utility cost of the purchase is $p_t u'(C_t)$. In exchange, the expected marginal utility benefit from additional consumption in period-t+1 is $E_t[u'(C_{t+1})x_{t+1}]$. The first-order condition of optimality requires that marginal cost be equal to marginal benefit, hence Eqn (1).

Denoting the gross asset return x_{t+1}/p_t by R_{t+1}. Eqn (1) can be written as

$$E_t(M_{t+1}R_{t+1}) = 1 \tag{2}$$

The gross risk-free rate from period t to $t+1$, $R_{f,t}$, is known in period t, so it is given by

$$R_{f,t} = \frac{1}{E_t[M_{t+1}]}. \tag{3}$$

Assume that the preferences can be described by the power utility function with a constant relative risk aversion coefficient $\gamma > 0$: $u(C_t) = \frac{C_t^{1-\gamma} - 1}{1-\gamma}$. Eqn (3) then implies

$$R_{f,t} = \frac{1}{\beta E_t[(C_{t+1}/C_t)^{-\gamma}]} \tag{4}$$

Assume that the consumption follows a log-normal process, which implies that the continuously compounded consumption growth rate, $\Delta c_{t+1} \equiv \ln(C_{t+1}) - \ln(C_t)$, is normally distributed. The continuously compounded risk-free rate, $\ln(R_{f,t})$, is then given by

$$\ln(R_{f,t}) = -\ln(\beta) + \gamma E_t(\Delta c_{t+1}) - \frac{\gamma^2}{2}\sigma_t^2(\Delta c_{t+1}), \tag{5}$$

where $\sigma_t^2(\Delta c_{t+1})$ is the conditional variance of Δc_{t+1} [2]. Hence, the real risk-free rate is low when agents are patient (β close to 1), when the expected consumption growth rate is low, or when the risk is high; and the sensitivities of the risk-free rate to the expected consumption growth rate and the risk are governed by the relative risk aversion coefficient γ. When people are impatient or when the expected consumption growth rate is high, the marginal utility of future consumption is low, so the interest rate should increase to induce saving. By contrast, when future consumption is risky, the precautionary saving motive is strong, which lowers the equilibrium risk-free rate. Not surprisingly, the precautionary saving component of the risk-free rate is bigger in magnitude when the risk is higher and when the representative agent is more risk averse [3].

An important message of Eqn (5) is that a negative real interest rate can arise naturally when the expected consumption growth is low and when the risk is high, which is helpful for understanding the negative real interest rates recently observed in many countries.

Assume further that the gross return of a risky asset, R_{t+1}, and consumption are jointly lognormally distributed. It follows from Eqns (2) and (5) that the risk premium for this asset should be

$$E_t[\ln(R_{t+1})] + \frac{1}{2}\sigma_t^2[\ln(R_{t+1})] - \ln(R_{f,t}) = \gamma \mathrm{COV}_t(\Delta c_{t+1},\ \ln(R_{t+1})), \tag{6}$$

where $\sigma_t^2[\ln(R_{t+1})]$ is the conditional variance of $\ln(R_{t+1})$, which accounts for the difference between the expected simple return and the expected continuously compounded return; and $\mathrm{COV}_t(\Delta c_{t+1}, \ln(R_{t+1}))$ is the conditional covariance. If the return is positively correlated with the consumption growth, then the asset is less attractive because it generates high returns when the marginal utility of consumption is low. Such assets should offer a risk premium in order to attract investors.

Rubinstein (1976); Lucas (1978) and Breeden (1979) pioneer the development of the consumption-based asset pricing theory. In particular, Lucas (1978) derives asset prices in an endowment economy, in which the consumption process is pinned down by an exogenous endowment process. Mehra and Prescott (1985) test a variation of the Lucas (1978) model using the US *data*. Due to the low covariance between the aggregate consumption and the stock market returns, they show that the model needs an unrealistically high degree of risk aversion, which is inconsistent with the low and stable risk-free rate historically observed, to explain the high equity premium observed in the data. This empirical challenge, known as the equity premium puzzle, has generated a vast volume of literature (see Mehra (2003) for a brief survey) [4]. One strand of the literature, represented by Rietz (1988) and Barro (2006), argues that the high equity premium and low risk-free rate can be reconciled by accounting for rare but severe disasters such as world wars, pandemics, economic crises or natural disasters in an otherwise standard representative agent model. As we will see, this insight turns out to be quite helpful for understanding the low interest rate after the Great Recession.

2.2 Real risk-free rates in a production economy

The consumption-based asset pricing theory describes the equilibrium relation between asset returns and consumption growth. In an endowment economy such as the one in Lucas (1978), this is sufficient to pin down the risk-free rate. However, in a more general economy with production, the risk-free rate and the consumption process must be determined jointly in a general equilibrium. This brings us to the realm of the neoclassical growth theory, which has a long history and plays a fundamental role in dynamic macroeconomics. Two workhorse models of the neoclassical growth theory are the Ramsey–Cass–Koopman model developed by Ramsey (1928), Cass (1965), and Koopman (1965) and the overlapping generations model pioneered by Samuelson (1958) and Diamond (1965).

The Ramsey–Cass–Koopman model considers a representative household with an infinite horizon, which is endowed with an initial capital stock K_0 and has access to the production function:

$$Y_t = f(K_t, A_t),$$

where $\{A_t\}_{t\geq 0}$ is a process representing the evolution of technology (productivity). Assume a constant capital depreciation rate δ and the absence of capital adjustment cost. The law of motion for capital is

$$K_{t+1} = Y_t - C_t + (1-\delta)K_t.$$

The marginal return on period-t investment, R^K_{t+1}, is the marginal product of capital in period $t+1$ plus undepreciated capital:

$$R^K_{t+1} = f_K(K_{t+1}, A_{t+1}) + (1-\delta) \equiv \mathrm{MPK}_{t+1} + (1-\delta). \tag{7}$$

This is a special case of the investment return defined by Cochrane (1991). The optimality of investment requires the Euler Eqn (2) to hold for R^k_{t+1}:

$$E_t\left(M_{t+1}R^K_{t+1}\right) = 1.$$

In case the technology process $\{A_t\}_{t\geq 0}$ is deterministic, this implies

$$r_{f,t} + \delta = \mathrm{MPK}_{t+1}, \tag{8}$$

where $r_{f,t} \equiv R_{f,t} - 1$ represents the net risk-free rate. Eqn (8) shows that in the absence of uncertainty, marginal product of capital should be equal to the user cost of capital $r_{f,t} + \delta$.

When the technology process is random, investment in physical capital also commands a risk premium. Specifically, if R^K_{t+1} and M_{t+1} are jointly lognormally distributed, an assumption that is more likely to hold when $\delta = 1$, and if the representative agent has power utility, then the risk premium for investment in physical assets is simply given by Eqn (6), with R_{t+1} replaced by R^K_{t+1}.

Under the assumptions of power utility, Cobb–Douglas production function and labor-augmenting productivity growth (i.e. productivity growth has the same effect on output as labor growth does), the real interest rate in the deterministic steady state of the Ramsey–Cass–Koopman model is given by

$$\ln(R_f) = -\ln(\beta) + \gamma\ln(1+g), \tag{9}$$

where g is the simple rate of productivity growth (thus $\ln(1+g)$ is the continuously-compounded rate). Note that Eqn (9) is a special case of Eqn (5), because in the deterministic steady state (a state that the economy converges to in the absence of any shocks), per capita consumption and productivity grow at the same rate, and the variance term in Eqn (5) vanishes. The only difference is that Eqn (9) links the risk-free rate to an exogenous productivity growth rate, while Eqn (5) links it to an endogenous consumption growth rate.

When the productivity growth is random, the model converges to a stochastic steady state, in which consumption growth hovers around its long-run mean endogenously in response to random productivity shocks. As a result, the risk-free rate is driven by both the mean and the volatility of productivity shocks.

The baseline Ramsey–Cass–Koopman model can be extended to account for population growth by allowing the size of the representative household to vary over time. It turns out that this has no effect on the real interest rate in the steady state. This is because the representative household in this model internalizes the welfare of its future generations and gives more weights to future utilities if the population growth rate is higher. This effectively increases the subjective discount factor. The resulting increase in saving neutralizes the positive effect of population growth on the real interest rate. By contrast, such altruism is absent in an overlapping generations model. As a result, the real interest rate is usually positively related to the population growth rate in an economy featuring overlapping generations.

The overlapping generations models deviate from the paradigm of a representative agent economy. In the baseline model of Diamond (1965), the economy is populated by two coexisting generations in each period – the young and the old. While the economy goes on forever, each agent lives only for two periods, working when she is young and living on savings when she is old. Under the simplifying assumptions of log utility, which is a special case of the power utility (with $\gamma = 1$), Cobb–Douglas production function and labor-augmenting productivity growth, the real interest rate in the deterministic steady state of the competitive equilibrium of the Diamond (1965) model is

$$r_f = \frac{\alpha}{1-\alpha}\frac{1+\beta}{\beta}(1+g)(1+n) - \delta \tag{10}$$

where α is the capital income share of output, g and n are the productivity and population growth rates, respectively [5]. Because each generation maximizes its own utility, the effective subjective discount factor does not change with the population growth rate. As a result, if the population grows at a higher rate, the steady-state capital–labor ratio decreases, raising the marginal product of capital and the interest rate. This is also the case in the Solow (1956) growth model, in which saving rate is specified exogenously.

To summarize, the standard consumption-based asset pricing theory and neoclassical growth theory identify several major drivers of real interest rates: (1) the subjective discount factor, which can vary across countries and cultures; (2) the per capita consumption growth rate, which in steady state is driven by productivity growth; (3) risk premium, which is a function of the representative agent's risk aversion and the riskiness of the productivity (or consumption) growth. Furthermore, the overlapping generations model of the neoclassical growth theory predicts a positive effect of population growth on the real interest rate. Importantly, the theory suggests that a negative real interest rate can arise naturally when the expected economic growth is low and when the risk is high.

3. Reasons for the decline of the real interest rate

After reviewing the standard theory of interest rate determination, I now discuss the potential driving forces for the secular decline. I start with the factors highlighted by the canonical models and then discuss the factors beyond these models, including convenience yields of safe assets, demand for safe assets from emerging markets, monetary policy, relative price of capital, wealth and income inequality, and diverging trends of corporate saving and investment.

3.1 Factors highlighted by canonical models

3.1.1 Productivity. Eqn (5) suggests that a key determinant of the real interest rate is the growth rate of per capita consumption, which in turn is determined by the productivity growth Eqn (9). A natural candidate for explaining the fallen interest rates is then productivity growth, measured by either labor productivity or total factor productivity (TFP). Consistent with the standard theory, Gordon (2012) shows that the labor productivity growth in the US has slowed down significantly since the 1970s despite a temporary rise from 1996 to 2004 driven by the Third Industrial Revolution (computers and internet). He also points out six factors that are in the process of dragging down long-term growth, including demography, education, inequality, globalization, energy/environment, and the overhang of consumer and government debt. In support of Gordon's argument, Figure 2 shows the total productivity growth rate in the US from 1948 to 2019. The 10-year moving average exhibits a noticeable drop since the mid-1970s.

However, using a long sample (1890–2016) of the US data, Lunsford and West (2019) find that in contrast to the standard theory there is a negative rather than a positive long-run correlation between the risk-free rate and productivity growth. In addition, Yi and Zhang (2017) find that the median long-run marginal product of capital in their sample of 20 countries is essentially flat since 1980s; Gomme *et al.* (2011, 2015) show that unlike the real return on treasury securities, the real return on productive capital, which is an extended version of the investment return defined in Eqn (7), has not shown a downward trend in the US in recent decades. These findings suggest that slower productivity growth is probably not the reason for the decline in the real interest rate.

3.1.2 Demographics. Eqn (10) from the Diamond (1965) overlapping generations model shows that a lower population growth reduces the real interest rate due to its positive effect on the capital–labor ratio. Other demographic characteristics, such as fertility and mortality rates, life expectancy, age distribution, can also affect the interest rate through their effects on saving and labor supply. Carvalho *et al.* (2016) calibrate a life-cycle model to capture the salient features of the demographic transition in developed economies. Their model reveals three effects of the increased longevity and lower population growth on real interest rates: a negative effect through higher saving for a longer retirement period; a negative effect through reduced marginal product of capital due to higher capital-to-labor ratio; and a positive effect due to lower saving of retirees relative to workers. They show that these effects

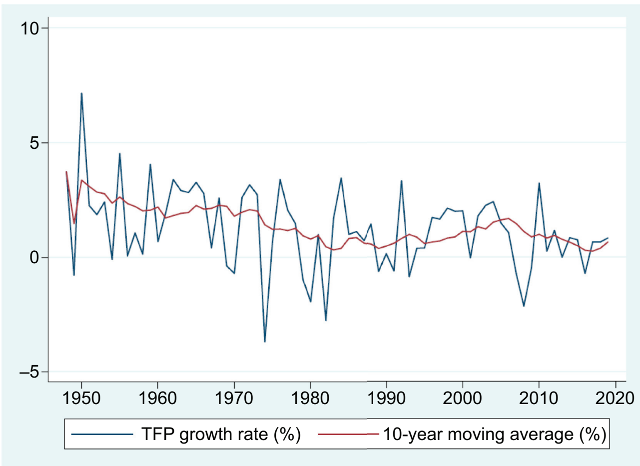


Figure 2.
Total factor productivity growth rate

Note(s): This figure plots the annual total factor productivity growth rates and its 10-year moving average in the US from 1948 to 2019.

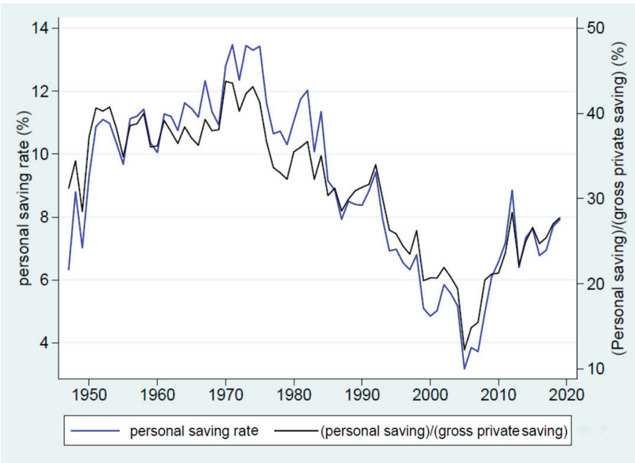
Source(s): Downloaded from the website of the Federal Reserve Bank of San Francisco.

together reduce the equilibrium real interest rate by at least one and a half percentage points from 1990 to 2014. Lisack *et al.* (2017) reach a similar conclusion. Eggertsson *et al.* (2019) show that the reductions in fertility and mortality are the most important driving forces for the real interest rate decline between 1970 and 2015. Lunsford and West (2019) examine over 30 variables that are hypothesized to have an influence. They find that real risk-free rates are correlated as expected with demographic measures: positively correlated with labor force hours growth and negatively correlated with the proportion of 40- to 64-year-old people in the population. Most other variables considered in their study have a mixed relationship with the real rate. These results further confirm the role of demographic transition as a driver of the decline in real-free rates in recent decades.

While the effect of demographic characteristics on the interest rate has been confirmed both theoretically and empirically, there are still good reasons to be cautious about putting too much weight on demographics. Figure 3 shows the personal saving rate and the ratio of personal saving to gross private saving in the US from 1947 to 2019. There is a sharp decline in the personal saving rate from 1971 (13.5%) to 2005 (3.2%). As a result, the role of personal saving in the gross saving of the private sector is greatly diminished (its weight drops from 44% to 12%). Therefore, any potential positive effect of demographic transition on personal saving rate must have been dominated by other factors.

3.1.3 Risk. Eqn (5) highlights the negative effect of risk on the risk-free rate. Barro (2006) shows that the risk of rare disasters can not only explain the long-run means of real risk-free rate in the G7 countries, but also the drops of risk-free rates during the disaster episodes such as the Second World War, because those episodes are likely associated with heightened concerns for the tail risk. The sharp declines of risk-free rates witnessed during the 2008 global financial crisis and the COVID-19 pandemic provide further examples.

One puzzle about tail events is their long-lasting effects. Why does a crisis that happened more than a decade ago continue to affect asset prices today? Kozlowski *et al.* (2018, 2020) provide an explanation. They assume that agents do not know the true distribution of shocks and learn it from data nonparametrically. By definition, tail events occur rarely, and the



Note(s): This figure plots the personal saving rate (personal saving over disposable personal income, left axis) and the ratio of personal saving to gross private saving (right axis) in the US from 1947 to 2019.
Source(s): Retrieved from FRED, Federal Reserve Bank of St. Louis.

Figure 3.
Personal saving

commonly observed nonevent periods provide little information about the distribution at the tails. Only the rarely observed extreme events are used to adjust the belief. Therefore, the effect of those events are long-lasting. These authors show that their calibrated models can account for many macroeconomic phenomena post the 2008 financial crisis. In particular, Kozlowski *et al.* (2018) show that by incorporating time-varying convenience yields of safe assets, updated beliefs about tail risk due to the 2008 crisis can reduce the risk-free rate by as much as 145 basis points. Importantly, they show that the effect is very persistent.

A market-based tail risk index, the Chicago Board Option Exchange (CBOE) SKEW Index, which is calculated from the prices of out-of-money S&P500 options, is consistent with the tail risk–based explanation. While standard measures of market risks, such as the CBOE VIX index, revert to normal soon after the peak of the financial crisis, the SKEW index remains on an upward trajectory for another ten years, as shown in Figure 4. Its subsequent decline is again reversed by a new rare disaster: COVID-19. However, in the 18 years before the 2008 financial crisis, for which the SKEW index is available, the relation between the risk-free rate and the SKEW index appears to be rather random. One possible explanation is that the crises in the 1990s are largely confined in developing countries (for example, the Mexican, Asian, and Russian crises). These crises increase the global demand for US safe assets but are not fully reflected in the SKEW index.

3.2 Factors beyond canonical models

3.2.1 Convenience yields of safe assets. While canonical models focus on the role of safe assets in smoothing intertemporal consumption, the recent literature has highlighted another aspect of these assets: the convenience yields (Krishnamurthy and Vissing-Jorgensen (2012), Greenwood *et al.* (2015)). Due to its high liquidity and high safety, safe assets such as government bonds are used as collateral in many financial transactions and used by banks and money market funds to back checkable deposits and meet withdrawals. As a result, they perform some medium of exchange role of money. Since investors value such nonpecuniary

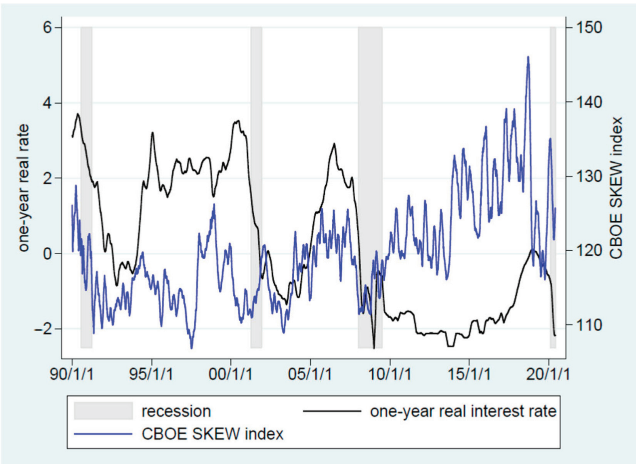


Figure 4.
Tail risk and real interest rate

Note(s): This figure shows the real one-year Treasury rate (left axis) and the COBE SKEW index (right axis) from January 1990 (when the index was first introduced) to May 2020. Both series are 60-day moving averages of daily data.
Source(s): Downloaded from the CBOE website.

benefits, the returns they demand from safe assets are reduced, relative to other assets offering only pecuniary payoff. Krishnamurthy and Vissing-Jorgensen (2012) estimate that convenience yields reduce the US Treasury yields by 73 basis points, on average, from 1926 to 2008.

Importantly, convenience yields of safe assets are time-varying, spiking up during financial crises, when the liquidity constraints tighten up and safe assets are in shortage (Nagel (2016) and Van Binsbergen *et al.* (2019)). This further explains why risk-free rates tend to decline during tail events. In fact, Kozlowski *et al.* (2018) show that the explanatory power of tail risk for the real interest rate fall post the 2008 financial crisis hinges on time-varying liquidity constraints.

The significant convenience yields of safe assets suggest that the observed nominal yields underestimate the true benefits of holding these assets . This can explain why nominal risk-free rates can be negative, as seen in Japan and Europe. While paper currency offers a nominal return of zero, it is not a perfect substitute for electronically stored safe assets such as government bonds and bank deposits due to its storage costs and its inconvenience as a means of payment, especially for large transactions. However, although convenience yields are useful for explaining the low level of the risk-free rate, they are less helpful for explaining the downward trend since the 1980s. Most empirical estimates of safe asset convenience yields do not show a clear upward trend that is consistent with the secular decline of the real interest rate. For example, the convenience yield on treasuries estimated by Van Binsbergen *et al.* (2019) based on option prices averages to 40 basis points over the sample period 2004–2018, and it is slightly higher in the precrisis period than in the postcrisis period, inconsistent with the lower risk-free rate post the crisis [6].

3.2.2 Demand from emerging markets. Bernanke (2005) argues that the large current account deficits and low interest rates in the US are caused by a "global saving glut," pointing to the increasingly strong demand for safe assets of developed countries from emerging markets since the 1990s. This somewhat surprising pattern of international capital flows is partly due to a series of financial crises in emerging markets in the 1990s, which not only raise the tail risk concerns of international investors but also push central banks in emerging markets toward accumulating more foreign reserves to better prepare for future crises.

Caballero *et al.* (2008) present a model of global imbalance in trades and capital flows. They consider the cross-country heterogeneities in the capacity to generate financial assets from real investments and in saving rate. Due to the underdevelopment of financial markets, countries like China have lower capacity to capitalize future incomes and transform them into tradable assets. The limited supply of saving assets lowers the interest rate. When such countries integrate to the world economy, global demand for financial assets of advanced economies increases, leading to a large current account deficit in these economies and a decline of the world interest rate. The integration of countries with a high saving rate into the world economy has a similar effect. Since countries with underdeveloped financial markets and high saving rates also tend to grow faster, the world interest rate declines over time as these countries gain more weight in the world economy.

Hall (2017b) proposes a similar explanation for the secular decline of the risk-free rate but with a focus on heterogeneities in risk aversion and beliefs. He assumes that some countries, such as China and Japan, have higher risk aversion and more cautious beliefs about the probability of rare disasters. As the wealth of these countries grows relative to the more risk-tolerant countries, such as the US, the demand for safe assets grows, and the world-wide risk-free rate declines.

It is certainly true that interest rates are increasingly driven by global factors due to the integration of the world economy. However, the impact of demand from emerging markets is hard to quantify. While industrial countries as a whole have net financial capital inflows in recent decades, they also have large net FDI (foreign direct investment) outflows. Wang *et al.* (2017) shows that when the two-way capital flows are considered simultaneously, the impact of capital flows on the world interest rate can be quantitatively negligible. Furthermore, among the countries with the world's lowest interest rates, some enjoy persistent current account surpluses (e.g. Germany and Japan). Clearly, low interest rates in those countries cannot be attributed to the global imbalance.

3.2.3 Monetary policy. One common feature of the canonical models reviewed in Section 2 is that they all focus on the real determinants of real interest rates and ignore the role of monetary policy. This is consistent with the notion of classical dichotomy – real variables are determined by real factors and nominal variables are determined by monetary policy. According to this view, the effect of monetary policy on real interest rates is short-lived at most. Such a dichotomy may be too simplistic. Empirical evidence surveyed by Williams (2014) and Kuttner (2018) suggests that large-scale purchases of long-term securities by central banks have sizable effects on long-term interest rates. In particular, Krishnamurthy and Vissing-Jorgensen (2011) find that the quantitative easing operations conducted by the Federal Reserve not only lowered the nominal long-term risk-free rates but also increased expected inflation, implying a larger reduction in real rates than in nominal rates. In addition to quantitative easing, the tightened postcrisis financial regulations have also increased demand for safe and liquid assets, adding further pressure on the risk-free rates. However, since the decline in real interest rate occurred long before the Great Recession, any explanation based on the postcrisis monetary policy is unlikely to be a full story. Furthermore, while monetary authorities can determine the nominal rate, they have no ability to keep the real rate substantially above or below the natural rate persistently. Therefore, the role of monetary policy in the secular real interest rate decline should not be exaggerated.

3.2.4 Relative price of capital. Together with the decline of the real interest rate is a steady decline in the price of investment goods relative to consumption goods as well as the decline of the investment–output ratio. Using a large global sample, Karabarbounis and Neiman (2014) show that the relative price of investment goods fell by almost 30% between the late 1970 and 2000s. Sajedi and Thwaites (2016) show that the nominal investment-to-output ratio declined by about one-quarter between 1980 and 2012. Summers (2014) argues that a lower relative price of capital should have a negative effect on the interest rate because it means that the same investment projects can be funded by less savings. Even though the lower price would encourage firms to expand investment to less profitable projects, when the elasticity of substitution between capital and labor is less than one, the total spending on capital still falls, resulting in a lower investment-out ratio and a lower interest rate. Sajedi and Thwaites (2016) explore this possibility in an overlapping generations model. In response to a 25% drop in the relative price of capital, their calibrated model can reproduce about one-third of the empirically observed fall in the investment–output ratio. However, it generates a fall in the real interest rate only by 12 basis points, suggesting that the relative price of capital is unlikely to be an important driver of the real interest rate decrease. Furthermore, Eichengreen (2015) shows that the quality-adjusted relative price of investment has been falling steadily since the early 1950s, long before the start of the real interest rate decline. This casts further doubt about the explaining power of the falling relative price of capital.

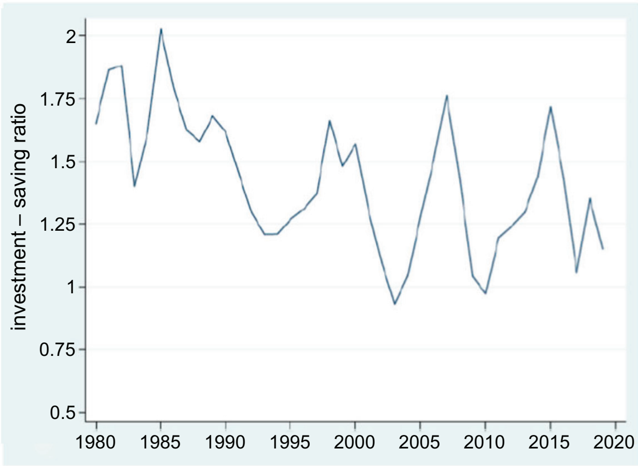
3.2.5 Wealth and income distribution. Another potential contributing factor that has drawn a lot of attention is the rise of inequality in income and wealth distributions. There is a substantial body of evidence showing the decline of the labor share in corporate gross value added since the 1970s. For example, Karabarbounis and Neiman (2014) find that the global labor share drops from 61% in 1975 to 59% in 2012 [7]. In addition, income has become increasing skewed toward the top 1% or 0.1% (see, for example, Atkinson *et al.* (2011)). While the diminished labor share and increased income/wealth inequality can in principle have both positive and negative effects on real risk-free rate, several recent studies have shown that the negative effect turns to dominate under reasonable model calibrations (Favilukis (2013), Kaymak, and Poschke (2016); Eggertsson *et al.* (2019)), due to the higher saving rate of the richer and the higher precautionary saving associated with more dispersed income shocks [8]. However, the estimated magnitudes of these effects are typically relatively small (for example, Eggertsson *et al.* (2019) estimate the effect of the labor share decline from 1970 to 2015 on the real interest rate to be −52 basis points).

3.2.6 Corporate investment and saving. One potentially important contributing factor to the real interest rate decline, which has not been fully explored in the literature, is the diverging trends of corporate saving and investment. Using a large international sample, Chen *et al.* (2017) document a global rise in corporate saving, measured as undistributed corporate profit. Consistent with what Figure 3 shows for the US, they also document a pervasive shift in the composition of saving away from the household sector and toward the corporate sector. While most of global investment was funded by household saving in the early 1980s, nearly two-thirds of it is funded by corporate saving in 2013.

Following the definition of corporate saving and investment in Chen *et al.* (2017), I plot in panel (a) of Figure 5 the ratio of corporate sector aggregate investment to aggregate saving in the US from 1980 to 2019, constructed using the Compustat North America database [9]. Although the ratio is quite volatile, the overall downward trend is obvious, suggesting that firms rely less on outside finance for capital formation in more recent years. Chen *et al.* (2017) identify the low interest rate as one of the reasons for the dramatic increase in corporate saving. However, the causality can also go in the opposite direction: given the size of the corporate sector, rising corporate saving relative to investment can be an important reason for the decline of the interest rate.

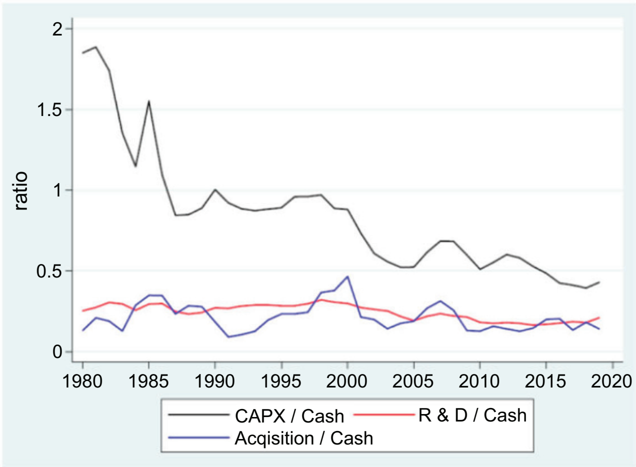
Consistent with the declining investment-saving ratio of the corporate sector, there is a dramatic increase in corporate cash holdings since the 1980s. Bates *et al.* (2009) document that the average cash-to-asset ratio increased from 10.5% in 1980 to 23.2% in 2006. The cash hoarding is especially prevalent among the superstar firms such as Google, Microsoft and Apple, leading to a large increase in aggregate. Panel (b) of Figure 5 shows the times series of the ratios of three different components of aggregate corporate investment, i.e. capital expenditures, R&D, and acquisition expenditures, to aggregate cash holdings at the prior year end. The ratios of R&D and acquisition expenditures to cash are relatively stable, but the ratio of capital expenditures to cash drops by more than three-quarters, from 1.85 in 1980 to 0.43 in 2019. This dramatic drop is due to both the decline of capital expenditures and the increase of cash holdings: from 1980 to 2019, aggregate capital expenditures scaled by lagged capital stock (measured by net value of property, plant and equipment) drop from 24% to 15%, while aggregate cash holdings scaled by lagged capital stock increase from 14% to 37%. At the end of the fiscal year 2019, the total amount of cash held by the firms in the sample amounts to $3.4 trillion [10].

There are several reasons for the fallen investment-saving ratio. First, the increase of firms' market power, which is most evidently shown by the rise of superstar firms in many industries (Autor *et al.* (2020)). Market power not only increases firms' profitability and valuation but also creates a gap between the average Tobin's Q and the marginal Q, weakening firms' incentive to invest, as shown by Gutierrez and Philippon (2017); Farhi and Gourio (2019) and Corhay *et al.* (2020). Second, changes in economic environments, including more global tax arbitrage opportunities, more disruptive innovations, larger first mover advantages and higher asset intangibility, induce firms to hold more cash instead of paying it out to shareholders; at the same time, a lower interest rate also lowers the cost of carrying cash [11]. Third, a misallocation of financial resources and investment opportunities. The established firms flooded with cash may not have the best investment opportunities or the incentives to engage in radical innovations, while those with opportunities and right incentives have difficulty in raising capital [12].



Corporate investment-saving ratio

(a)



Ratios of CAPX, R&D, and acquisition to cash

(b)

Figure 5. Corporate investment, saving and cash holdings

Note(s): Panel (a) shows ratio of aggregate corporate investment to saving. Panel (b) shows the ratios of aggregate capital expenditures (CAPX), R&D, and acquisition expenditures to lagged aggregate cash holdings. Investment is defined as sum of capital expenditures (net of sales of property, plant & equipment), R&D expenses, and acquisition expenditures; saving is defined as operating income before depreciation (OIBDP in Compustat) plus R&D, minus taxes, interests, dividends, and share repurchases. The sample includes all nonfinancial, non utility firms covered in the Compustat North America database from 1980 to 2019. Firms are required to file financial reports in the US dollar. In panel (b), they are also required to have positive cash holdings at the prior fiscal year end.

Source(s): Compusta North America.

Given the central role of the corporate sector in capital formation and technological developments and its increasingly important role in funding these activities, a better micro-level understanding of what drives the diverging trends of corporate saving and investment and their macro implications is crucial for understanding the current low interest rates and potential inefficiencies in the economy.

To summarize, there has been very active research on the causes of the secular decline of real interest rates, and significant progresses have been made. Each explanation offered in the literature is helpful for understanding this trend. However, none of them fully accounts for the observed interest rate dynamics. It is plausible that the decline is a joint outcome of most if not all the factors discussed above. A fruitful area for future research is the changes in industry structure that alter the investment and saving behaviors of the corporate sector. To the extent that most of economic forces driving the downward trend represent relatively slow evolution of the real economy without a clear sign of reversal in the near future, low real risk-free interest rates are likely to persist for some considerable time.

4. Challenges for monetary policy

The extended period of low real interest rates and low inflation have posed serious challenges for conventional monetary policy. It also challenges some conventional wisdoms of monetary theory and sparks radically new ideas. As Rogoff (2017) writes, "despite an outward appearance of stability, the core of the global monetary system today is immersed in a level of intellectual turmoil not seen since the breakup of the Bretton Woods system in the early 1970s". In this section, I briefly discuss the monetary policy conundrum in the low interest rate environment and the policy implications of two recent developments in monetary theory, the neo-Fisherism and the fiscal theory of price level.

4.1 The monetary policy conundrum at the zero bound

Because of the unstable relation between money supply and price level, starting from the 1980s, most central banks abandoned money growth as the main instrument for monetary control. Instead, they have relied heavily on a "leaning-against-the-wind" interest rate policy. The famous Taylor rule specifies how nominal interest rate i_t should respond to divergences of actual inflations π_t from target inflation rate π_t^* and of actual GDP y_t from potential GDP $\bar{y}_t$:

$$i_t = \pi_t + r_t^* + a_\pi(\pi_t - \pi_t^*) + a_y(y_t - \bar{y}_t),$$

where r^* is the equilibrium real interest rate (the natural rate), and $a_\pi > 0$ and $a_y > 0$ describe the responses to inflation and output deviations. The rule thus says that central banks should reduce the nominal interest rate, usually through open market purchases of short-term government bonds, when inflation and GDP are above their target levels, and vice versa. In his original paper, Taylor (1993) set the target inflation π_t^* at 2%, although he provided little discussion for this choice. This number has been embraced by many central banks in advanced economies (including the USA and Japan), potentially because it strikes a balance between the cost of inflation and the risk of deflation. Central banks in developing countries tend to have a slightly higher target inflation, but mostly in single digits.

When the natural rate is 3%, a target inflation rate of 2% means a nominal interest rate of 5% in normal times. Assuming that the nominal interest rate has a lower bound at zero (which is referred to as the zero bound), a nominal rate of 5% allows the central bank to cut the interest rate by a maximum 5 percentage points. However, when the natural rate is 1%, the nominal interest is only 3% in normal times. According to Summers (2018), the average rate cut implemented by the Federal Reserve since 1960s to combat recessions is 5%. Therefore, there is a concern about not having enough room for rate cuts when the next recession arrives. Even worse, since the 2008 financial crisis, the Fed has constantly fallen short of the 2% target inflation rate, and the short-term nominal interest rate stays close to zero for most of the time.

Of course, the Taylor rule is not the only tool at central banks' disposal. During the Great Recession and the subsequent low interest rate years, the Federal Reserve System intervenes through so-called quantitative easing, which involves large-scale purchases of public or private debt of longer maturities. Such operations allow the Fed to lower interest rates at longer maturities and target at specific market sectors (such as the mortgage markets). It also actively uses "forward guidance" to influence expectation about the future path of interest rates. Central banks in Europe and Japan go beyond the zero bound to experiment with negative nominal rates. Upon the outbreak of the COVID-19 crisis, the central banks react swiftly, displaying a whole spectrum of weapons they command. For example, in addition to decisive rate cuts and massive purchases of long-term securities, the Fed lends directly to banks, primary dealers, corporate employers and state and local governments. It also provides liquidity support to money market funds, repo markets, commercial paper markets and temporarily relaxes bank regulatory requirements.

Nevertheless, these unconventional operations have their own limitations, and people are rightly concerned about their potential side effects. Therefore, many economists have argued for raising the target inflation rate to get more headroom for the interest rate policy. For example, Summers (2018) argues for a monetary framework that would "foresee nominal interest rates in the range of 5 percent in normal times." Williams (2016) expresses similar views [13]. However, even if a switch to a higher inflation target is desirable, central banks still face the challenge of how to achieve the target, as many of them, especially Bank of Japan, have realized, generating inflation is not always an easy task.

Rogoff (2017), on the other hand, is less concerned about the zero bound and advocates for clearing the way to allow normal interest rates to go deeper in the negative territory. Pointing to the current practice in Japan and Europe, he argues that, fundamentally, there is no practical obstacle to paying negative interest rates on electronic currency. The main concern is that if a central bank pushes the interest rate on electronic currency too deeply negative, there will a massive flight into paper currency. However, in today's world, the use of paper currency as a means of payment has been largely limited to small transactions. Even for those transactions, electronic payments by credit cards or smartphones have become increasingly ubiquitous. The recent launch of a digital currency by the central bank of China is the latest example of this trend. As a result, the issue of a potential flight to paper currency may not be as hard to address as it used to be. Rogoff (2017) proposes two approaches. One involves getting rid of large-denomination notes, and the other involves creating a crawling pegged exchange rate between paper currency and bank reserves.

However, even if a significantly negative nominal interest rate is operationally feasible, its stimulating effect is not guaranteed. Brunnermeier and Koby (2019) show theoretically that there is a threshold beyond which further interest rate cuts will become contractionary. They call this threshold rate the reversal rate. The reversal occurs because of two opposing effects of a rate cut on banks' net worth. On the one hand, a rate cut generates capital gains on banks' long-term fixed-rate assets. On the other hand, it shrinks banks' net interest income going forward. When the second effect dominates, a rate cut reduces banks' lending capacity and becomes contractionary. The exact level of this reversal rate depends on banks' initial asset holdings and capitalization, the strictness of capital requirement, and the degree of the policy rate pass-through to deposit rates. Importantly, the reversal rate is not necessarily zero. In fact, the structural estimation conducted by Wang *et al.* (2019) shows that when the federal fund rate falls below 0.9%, the money policy effect will be reversed due to the interaction between banks' market power and capital requirement. According to this estimate, the current interest rate at the zero bound is too low to be stimulating. Furthermore, Acharya *et al.* (2019) find that the glut of cheap credit has a disinflationary effect by allowing many struggling “zombie firms” to stay afloat, which creates excess production capacity and downward pressure on product prices.

4.2 Neo-Fisherism

The low interest rate policy as well as the whole philosophy of the Taylor rule are also criticized by a new school of the monetary theory: the neo-Fisherism. The famous Fisher Effect, hypothesized by Irvine Fisher in his classic book *Theory of Interest* published in 1930, describes the following relationship between nominal interest rate R_t and real interest rate r_t:

$$R_t \approx r_t + E_t(\pi_{t+1}),$$

where $E_t(\pi_{t+1})$ is the expected inflation rate. This hypothesis states that nominal interest rates tend to move in parallel with inflation rates so that monetary policy has little effect on the real interest rate, a version of the classical dichotomy (or money neutrality).

Empirically, there is a robust relation between nominal interest rates and inflation: high inflation is accompanied by high nominal interest rates, both over time and across countries (see, for example, Williamson (2019)). The conventional interpretation of this relation is that high inflation causes high nominal interest rates: because both borrowers and lenders care about the real rate, when they expect high inflation, they would mutually agree to set a high nominal interest rate. The neo-Fisherism departs from this conventional wisdom with two radical claims: (1) it turns the causality around and argues that it runs from the nominal interest rate targeted by the central bank to inflation; (2) it argues that a permanent increase in the nominal interest rate leads to an increase in inflation not only in the long run but also in the short run. These claims are supported by a number of theoretical analysis including Schmitt-Grohe and Uribe (2014); Cochrane (2016), and Williamson (2018, 2019), as well as some empirical evidence Williamson (2019), and Uribe (2019).

The Neo-Fisherian view of monetary policy questions the validity of the Taylor rule as a principle for inflation control. According to the Fisher equation, for an increase in the nominal interest rate to induce a decrease in anticipated inflation the real interest rate must increase more than one-for-one with the nominal interest rate. This requires a large money nonneutrality and thus may be unrealistic. Neo-Fisherians further argue that the conventional practice may be the reason why many central banks find themselves trapped at the zero bound: When inflation is falling, a central bank following the Taylor rule reacts by cutting the nominal interest rate. However, because of the Fisher effect, this actually leads to lower inflation, which causes further nominal interest rate cuts. Ultimately, the nominal interest rate hits the zero lower bound. This tendency of converging to the liquidity trap is referred to as “the Perils of Taylor Rules” (Benhabib *et al.* (2001)).

The Neo-Fisherian policy recommendation for the exit from the liquidity trap at the zero bound is both simple and radical: instead of a negative interest rate or quantitative easing, central banks should increase the nominal interest rate, and a higher inflation will follow (Grohe and Uribe (2014), Williamson (2016, 2019)). Whether this radical view can gain traction among central banks remains an open question. The seemingly simple solution is unlikely to be a free lunch, unless the interest rate is already below the reversal rate. Theoretical analysis by Cochrane (2020) shows that there is a temporary output fall in response to a permanent nominal interest rate increase, even if inflation starts to rise immediately. If inflation drops initially before it rises, the negative output response is even more severe [14].

4.3 The fiscal theory of price level

To Cochrane (2018), the post-crisis low interest/low inflation period is “a decisive experiment” that overturns many conventional wisdoms. The prolonged situation of massive increases in bank reserves on one hand and stable and below-target inflation rates on the other is inconsistent with the traditional monetarist quantity theory of price level, which postulates that price level P is determined by money supply M: $MV = PY$, where V is more or less constant and Y is the output. It also challenges the Keynesian view of a need for a responsive interest rate policy such as the Taylor rule to keep the inflation stable. Cochrane (2018) argues that the recent macroeconomic experience can be best explained by the fiscal theory of price level. First developed in 1990s, this alternative monetary theory has gained more momentum recently. It incorporates some elements of the neo-Fisherism but aims to provide a more general framework for macroeconomic analysis. The main contributors include John Cochrane, Eric Leeper, Christopher Sims and Michael Woodford. Cochrane (2020) provides a systematic exposition of the theory.

According to the fiscal theory of price level, inflation is fundamentally anchored by fiscal policy instead of money supply. The value of money comes from the government's commitment to accept it for tax payments. Nominal government debt represents the claim to future primary fiscal surpluses (tax incomes minus government spending excluding interest payments), just as a stock represents a claim to a company's stream of dividends. The real value of government debt, which is the nominal value divided by the price level, must equal the present value of primary surpluses. When the amount of nominal debt is fixed, the price level moves inversely with the real debt value, which in turn is determined by the expected stream of primary surpluses and the real discount rate. If the expected stream of surpluses falls or the real discount rate increases, the discounted value of surpluses falls, and the price level must increase until the real value of the debt is equal to the lower discounted value. Economically, this mechanism materializes as follows: if people feel that fiscal surpluses are insufficient to pay off the government debt or that the return from the government debt is too low relative to the required return (i.e. the discount rate), they will sell government debt in exchange for goods and services, which pushes up the price level. Thus, by making the price level adjust endogenously to satisfy the valuation equation for government debt, the fiscal theory offers an alternative explanation for the determination of price level, rooted in the supply and demand of government debt.

This theory offers a radically new explanation for the low inflation since the 2008 financial crisis. Both nominal and real interest rate dropped sharply in 2008, driven by poor growth perspectives and a flight to quality. For reasons reviewed in Section 3, the downward trend continues even after the crisis. Therefore, despite the large increase in government deficit, the discounted real value of government debt still increases. To match this increase in real value of government debt, the price level fell during the crisis and increased little since then.

The theory also offers a new perspective on the current macroeconomic situation and monetary policy choice. First, there is no need to worry unduly about the zero bound. It is possible to have a stable economy with a low nominal interest rate insensitive to economic conditions. An active interest rate policy is not necessary for inflation stability or determinacy. Second, there is no need to worry unduly about the inflationary effect of large bank reserves. From the banks' perspective, bank reserves issued by central banks in exchange for government debt are almost perfect substitutes for the government debt itself. Therefore, banks holding reserves are not more inflationary than banks holding government debt, which explains why quantitative easing has no effect on inflation. Third, while central banks *can* maintain a fixed nominal interest rate and let inflation adjust to variation in real interest rate, they can also respond more actively to variation in real interest rates to reduce the necessary adjustment in inflation, which may otherwise take a long time. The theory also suggests a good target for such an active policy: the interest spread between nonindexed debt and indexed debt (such as the TIPS), which reflects expected inflation. By focusing on the spread instead of the interest rate level, this strategy nails down expected inflation but allows the interest rate level to adjust automatically to market forces. Unlike the Taylor rule, aiming at this target does not require an estimation of the natural interest rate. Finally, price stability can only be achieved on the foundation of fiscal stability. Once the market loses confidence in the government's ability to repay its debt, the real value of government debt drops and inflation may be out of control.

Given that the majority of money in today's economy is not "chasing goods," but chasing stocks, bonds, real estate and other assets, it is not surprising that the quantity of money is no longer linked so directly to the CPI or other price indexes of goods and services. An alternative theory of price level based on the supply and demand of government debt offers a valuable new perspective. However, the valuation of government debt proves to be challenging. Jiang *et al.* (2020) estimate a quantitative model of the US government debt and find a large gap of the size of 287% GDP between the value of the aggregate surplus claim and the market value of the outstanding debt. Because primary fiscal surpluses are strongly procyclical, the standard asset pricing theory implies that the aggregate claim to fiscal surpluses should earn a risk premium, but investors seem to be willing to purchase government debt at low yields. Since the valuation of government debt plays a central role in the fiscal theory of price level, the lack of a clear understanding of how it works is unsettling. Furthermore, while the fiscal theory of price level seems to provide a more optimistic view of the economic situation near the zero bound, it is important to recognize that the stability we observe is still just an experience of limited time, and it is conditioned on massive holdings of government debt by central banks. The subjectivity of government debt discount rate implies that it could increase abruptly, in which case price stability will be jeopardized.

Even if the macroeconomic stability is not at immediate risk, low interest rates still bring many pains, especially for financial institutions and populations that rely heavily on stable cash flows from fixed-income assets, such as banks, insurance companies, endowments and retirees. Take the two largest German banks, Deutsch Bank and Commerzbank, as examples. By the end of May 2020, Deutsch Bank stock price has dropped by 88% since 2010, following a more than 50% drop during the 2008 financial crisis; Commerzbank stock price has dropped by 94%, following a more than 80% drop during the financial crisis. A fragile banking sector is hardly conducive to a dynamic economy. It can itself be a source of instability. In addition, there are also concerns about the implications of low interest rates on long-term growth. For example, Liu *et al.* (2019) show that a low interest rate gives industry leaders a strategic advantage over followers, which in turn reduces competition, investment and overall productivity growth.

5. Conclusion

It is now time to conclude this somewhat long intellectual journey in the theory and reality of the real interest rate. What are the main takeaways from this journey?

The neoclassical asset pricing theory and growth theory provide a useful framework for understanding the downward trend of real interest rates. The canonical models suggest that the risk-free interest rate is determined by the subjective discount factor, the expected consumption/productivity growth, the riskiness of the consumption/productivity growth, and the population growth. It also suggests that a negative real interest rate can arise naturally when the expected growth rate is low and when the risk is large. These predictions are helpful for understanding the downward trend.

The decline coincides with a slowdown of productivity growth since the 1970s. However, recent studies only find a tenuous long-run correlation between the real risk-free rate and productivity growth. In addition, the real return on productive assets has been stable in recent decades. These findings suggest that slow productivity growth may not be the reason for the secular decline of the real interest rate. The negative effects of some demographic trends, including lower population growth, lower fertility rate, increased longevity, have received stronger empirical support. Nevertheless, the quantitative importance of these demographic trends needs to be assessed with caution, given that these trends coincide with a sharp decline in the personal saving rate and a diminished share of households' contribution to the aggregate saving of the economy. Elevated tail-risk concerns, together with large convenience yields of government bonds during extreme events, provide a credible explanation for the decline of real interest rate after the 2008 financial crisis. Since agents do not know the true shock distribution, extreme events such as the 2008 crisis and the 2020 pandemic can have a long-lasting effect on the perceived tail-event probability. Tail-risk concerns may also have contributed to the increased demand for safe assets of developed countries after the financial crises in emerging markets in the 1990s.

Factors beyond the standard theory also help to explain the interest rate decline. These include the increased global demand for safe assets of developed countries, the accommodative monetary policy, the falling relative price of capital, and the rising wealth/income inequality. The convenience yields of safe assets provide an explanation for negative nominal risk-free rates in Japan and Europe. Given the large increase in corporate saving relative to corporate investment in recent decades, a better understanding of economic forces driving the diverging trends of corporate investment and saving behaviors should be very helpful for understanding the trend of the real interest rate.

A critical review of each explanation put forward in the literature suggests that each explanation has its merits, but none of them provides a full qualitative and quantitative account of the real interest rate dynamics in recent decades. It is plausible that the secular decline of the interest rate is a joint outcome of most if not all the factors mentioned above. Furthermore, since most of these factors represent relatively slow evolution of the real economy without a clear sign of reversal in the near future, the low real risk-free rate is likely to persist for some considerable time.

The low interest rate poses a conundrum for monetary policy as it limits the space for rate cuts in response to potential crises. Even if a negative nominal rate is theoretically justifiable and technically feasible, it is not necessarily stimulating. Due to its negative impact on banks' net worth, a low interest rate can reverse to become contractionary. Importantly, this reversal rate is not necessarily negative.

The low interest rate and low inflation economy also push economists to rethink the fundamental principles of monetary theory. The neo-Fisherist view of the monetary policy argues that the conventional Taylor rule–based policy has a tendency of falling into the liquidity trap. A radical policy recommendation coming out of this theory is that in order to break the liquidity trap central banks should increase instead of decreasing the nominal interest rate. If the prevailing interest rate is below the reversal rate, then a rate increase can indeed be stimulating. Unconventional monetary policies like this should be evaluated with caution as there may be unintended consequences. Quantitative estimation of the reversal rate such as done by Wang *et al.* (2019) is very useful for this purpose.

According to the fiscal theory of price level, the general price level is determined by the demand and supply of government debt instead of money supply. Quantitative easing itself has little inflationary effect because government debt and bank reserves are almost perfect substitutes for banks. Furthermore, it is possible to have a stable economy with a low interest rate without a Taylor rule-type intervention policy. Given that the majority of money in today's economy is used for financial transactions instead of buying goods and services, an alternative theory of price level based on the supply and demand of government debt offers a valuable new perspective. However, it is important to recognize the negative effects of low interest rates on institutions and populations relying on stable cash flows of fixed-income assets. Also, the valuation of the aggregate government debt portfolio is still a challenge for the asset pricing theory. The subjectivity of government debt discount rate implies that it could increase abruptly when investors become concerned about the government's ability to pay off its debt, in which case the resulting runaway from government debt in exchange for goods and services will jeopardize price stability. The fiscal theory of price level builds on the idea that price level is anchored by fiscal policy; a natural conclusion that should follow is that price stability must be built on fiscal discipline.

Notes

1. Instead of measuring the real interest rate as the nominal rate minus the *expected* inflation rate, one can also measure it as the difference between the nominal rate and the *realized* inflation rate. Using this ex post measure, the peak real interest rate in the early 1980s is over 12%. Therefore the subsequent decline is even more dramatic. Since a forward-looking measure is more meaningful for economic decisions, the real interest rate in this survey always refers to the ex ante real rate.

2. A lognormally distributed random variable X has the following convenient property:

$$\ln E(X) = E[\ln(X)] + \frac{1}{2}\sigma^2[\ln(X)],$$

   where $\sigma^2[\ln(X)]$ denotes the variance of $\ln(X)$.

3. The intuition for a higher sensitivity of the risk-free rate to the expected consumption growth rate is as follows. Under the power utility, γ not only measures the aversion against variation of consumption across states (i.e. risk) but also measures the aversion against variation of consumption over time ($1/\gamma$ is equal to the elasticity of intertemporal substitution). A higher γ implies a stronger desire to smooth consumption over time, which means that a larger move in the interest rate is needed for the agent to accept a certain expected change in consumption.

4. Under the power utility, the equity premium puzzle and the risk-free rate puzzle are the two sides of the same coin because of the mechanical inverse relation between risk aversion and elasticity of intertemporal substitution. However, Weil (1989) shows, using the now famous Epstein–Zin–Weil preferences, that both puzzles remain intact when these two preference parameters can be calibrated independently.

5. This result is easily obtained by extending the canonical overlapping generation model in Chapter 9 of Acemoglu (2009) to allow for depreciation and labor-augmenting productivity growth.

6. Del Negro *et al.* (2017) estimate an increase of convenience yield on treasuries by 93 basis points from 1998 to 2016.

7. See also Caballero *et al.* (2017) and Greenwald *et al.* (2020).

8. Eqn (10) shows that the interest rate is positively related to the capital income share α in the canonical growth model with overlapping generations. This is because saving in the model comes exclusively from the labor income of the young generation. The old generation owns all capital and consumes all capital income. There is no heterogeneity within a generation.

9. My definition of corporate saving differs from theirs in one aspect: I view share repurchase as an alternative way of paying dividends and exclude it from what they define as corporate saving. Without this modification the investment-saving ratio declines even more.

10. Following the standard practice in corporate finance research, cash is measured as the sum of the balance sheet items "cash and cash equivalents" and "short-term investments." Duchin *et al.* (2017) find that on average this measure underestimates firms' financial asset holdings by 25% because some financial assets are reported as "long-term investments" and "other assets." They also show that 61.7% of the aggregate financial asset portfolio is invested in money-like safe assets.

11. Fritz *et al.* (2007); Azar *et al.* (2016); Mello *et al.* (2020) and Falato *et al.* (2020) analyze how these factors increase corporate cash holdings.

12. Dangl and Wu (2016) provide an explanation for slow recoveries of corporate investment after recessions.

13. On August 27, 2020, Fed Chairman Powell (2020) announced a major shift in the Fed's approach in managing inflation. Rather than making 2% a fixed goal, the Fed now seeks to achieve inflation that

averages 2% over time. This more flexible inflation target means that the Fed may aim to achieve inflation moderately above 2% for some time following periods of inflation below 2%.

14. However, empirical estimation by Uribe (2019) shows that while a temporary increase in nominal interest rate decreases inflation and output and increases real rates, a permanent nominal interest rate increase leads to an immediate increase in inflation and output and a decline in real rates.

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Corresponding author
Youchang Wu can be contacted at: ywu2@uoregon.edu