Unlikely Estimates of Ex-Ante Real Interest Rate: Another Dismal Performance fromDismal Science[1]

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ABSTRACT

The ex ante real rate of interest is one of the most important concepts in economics and finance. Because the universally-used Fisher theory of interest requires positive ex ante real interest rates, empirical estimates of the ex ante real interest rate derived from the Fisher theory of interest should also be positive. Unfortunately, virtually all estimates of the ex ante real interest rate published in economic journals and textbooks or used in macroeconomic models and policy discussions for the past 35 years contain negative values for extended time periods and, thus, are theoretically flawed. Moreover, the procedures generally used to estimate ex ante real interest rates were shown to produce biased estimates of the ex ante real rate over 30 years ago. In this article, we document this puzzling chasm between the Fisherian theory that mandates positive ex ante real interest rates and the practice of macroeconomists who generate and use ex ante real interest rate estimates that violate this theory. We explore the reasons that this problem exists and assess some alternative approaches for estimating the ex ante real interest rate to determine whether they might resolve this problem.

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Key Words: Ex Ante Real Interest Rate; Fisher Equation; Spurious Estimates of the Ex Ante Real Interest Rate

INTRODUCTION

Macroeconomics and macroeconomists are under widespread attack both from outside and within the economics profession. In his recent *Wall Street Journal* article, Kaletsky (2010) charged that

> "*The greatest embarrassment for academic economics in the 2007-2009 crisis … [is their] failure to provide any useful guidance for politicians and central bankers after the [financial] crisis struck. …What economics did claim to offer was a set of analytical tools to explain reality and suggest sensible responses to unexpected events. It was in this respect that contemporary economics revealed its inadequacy*."

Similarly, Rachman (2010), writing in the *Financial Times*, stated that *"… policies … constructed according to the 'laws' of economics have a nasty habit of collapsing.*" Wray (2011, p. 2) suggests that "*What passed for macroeconomics on the verge of the global financial collapse had nothing to do with reality. It is difficult to see that anything taught in the best-selling textbooks in 2007 will survive.*"

Kocherlakota (2010, p. 5), President of the Federal Reserve Bank of Minneapolis, provides an even stronger condemnation:

> *"… during the last financial crisis, macroeconomists (and I include myself among them) failed the country, and indeed the world. … Macroeconomics should have been able to provide […a systematic plan of attack to deal with fast-evolving circumstances …]. It could not. Of course, from a longer view, macroeconomists let policymakers down much earlier, because they did not provide [them] with rules to avoid the circumstances that led to the global financial meltdown. …*
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> *[The] overall debate inevitably leads the general public to wonder: What is the value and applicability of macroeconomics as currently practiced?*"[2]

[1]With apologies to Ferraro and Taylor (2005) for "*borrowing*" the subtitle to their paper.

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Perhaps the most extensive list of popular criticisms of macroeconomics appears in Sargent (2010, p. 28), along with his ad hominem attack on these critics, whom he labels as "*foolish and intellectually lazy … [, guilty of] woeful ignorance or intentional disregard for what much of modern macroeconomics is about and what it has accomplished.*"

In this article, we suggest that one likely cause for the alleged failures of macroeconomic models and macroeconomists' policy advice is that virtually all *estimates* of the *ex ante* real rate of interest, one of the most important variables used in macroeconomic and monetary models, are theoretically questionable and empirically flawed. It should not be surprising that faulty estimates of a key macroeconomic variable yield macroeconomic analyses and policy recommendations that fail to "*explain reality and suggest sensible responses to unexpected events.*"We begin our analysis by briefly explaining the crucial role of the *ex ante* real rate of interest in all economic decisions. Next, we review Fisher's theory of interest rates that provides the theoretical foundation for the *ex ante* real interest rates used in virtually all macroeconomic models and research. We then show that Fisher's theory requires *positiveex ante* real interest rates, while virtually all *estimates* of *ex ante* real interest rates used by macroeconomists in recent decades contain *negative* observations over extended time periods. Next, we document that negative *ex ante* real interest rate *estimates* were shown to be spurious over 30 years ago—but that these warnings have been persistently ignored by macroeconomists. We then examine one possible reason for the failure of macroeconomists to recognize this problem. Finally, we explain why this problem is likely to persist.

THE CRUCIAL ROLE OF THE *EX ANTE* REAL INTEREST RATE

The *ex ante* real interest rate [hereafter, for simplicity, called the real rate of interest] is widely recognized as one of the most important variables in economics and finance. Because it represents the expected tradeoff between present and future consumption of goods and services, it plays a prominent role in virtually every decision that people make. Mishkin (1988; p. 1064), for example, summarizes its role as follows:

> "*Real interest rates are among the most important economic variables and have been studied extensively. They figure prominently in discussions of the transmission mechanisms of monetary policy and also play a prominent role in explanations of business cycles and particular business cycle episodes [our emphasis]. Real interest rates are a central element in savings-consumption decisions and in debates about how to encourage savings …. Real interest rates are also a critical explanatory variable for investment decisions since they represent the real cost of borrowing.*"

Taylor (2000; p. 91) stresses its great importance in macroeconomic modeling and policy as follows: *"… [The] nearly universal model … used to explain fluctuations [of real GDP] around the growth trend … can be boiled down to three relationships and three variables …*" These key macroeconomic variables are real GDP, inflation and the real interest rate.

FISHER'S THEORY OF INTEREST: THE REASONS FOR POSITIVE REAL INTEREST RATES

Over a century ago, Fisher (1896, 1906a, 1906b) began to develop his theory of the determinants of nominal interest rates, culminating in the publication of *The Theory of Interest* (1930). Fisher theorized that the nominal (or market) rate of interest (i) on a specified financial asset is determined by the real

[2] Amusingly, after his eloquent "*mea culpa*" for the failures of macroeconomics and macroeconomists, he then reassures the public that, actually *"… macroeconomics has madeimportant advances in recent years… [that] – coupled with a rededicated effort following this recent economic episode—position macroeconomics to make useful contributions to policymaking in the future." Who said that "irony is dead*"?

interest rate (r^e) and the expected inflation rate (Π^e). Equation (1) presents the well-known simplified statement of his theory[3]:

$$i_t = r_t^e + \Pi_t^e \quad (1)$$

The expected inflation rate (Π^e) in Equation (1) represents the anticipated change in a broad price index that incorporates the prices of all assets (new and used), commodities and services.[4] It measures the change in the general purchasing power of money over some specified time period. Since this price index can move up, down or remain unchanged, the associated expected rate of inflation can be positive, negative or zero.

The real rate of interest (r^e) in Equation (1) represents the expected relative price paid for earlier availability of goods and services in real terms—that is, in terms of the goods and services themselves. Stockman (1996, p. 705) notes: "*Economists define the real interest rate as the relative price of a single good at two points in time.*" Fisher (1930, pp. 61-2) stated that real interest rates, in the world we inhabit, must be *positive* for two reasons: time preference and investment opportunities.

> "*… [The real] rate of interest expresses a price in the exchange between present and future goods…. [In] the theory of interest, the [real] rate of interest, or the premium on the exchange between present and future goods, is based, in part, on … the marginal preference for present over future goods …called time preference or human impatience. The other chief part is the objective element, investment opportunity.*"

The marginal preference for present over future goods is called *positive* time preference. If individuals prefer consuming goods and services sooner rather than later, they require and, therefore, *expect* a *positive* real return for foregoing current consumption of goods and services. Of course, positive time preference exists for reasons beyond simple "*human impatience*". As Alchian and Allen (1972, p. 176) note, "*Some other considerations imply a lower present value of deferred goods. The certainty of death—the certainty that we shall some daynot be able to enjoy some postponed goods may make us unwilling to give up 1 gallon of gasoline (or anything else) today for just 1 gallon in the future.*" Thirty years ago, Olson and Bailey (1981, p. 24) concluded that *"… the case for positive time preference is absolutely compelling.*" Laury et al. (2011) and Perez-Arce (2011) provide the latest evidence for positive time preference.

Fisher (1930, pp. 191-193) explained why the existence of investment opportunities also required *positive* real interest rates:

> "*In the real world our options are such that if present income is sacrificed for the sake of future income, the amount of income secured is thereby greater than the present income sacrificed … Nature's productivity has a strong tendency to keep up the rate of interest. Nature offers man many opportunities for future abundance at trifling present costs. So also, human technique and innovation tend to produce big returns over costs.*"

What would it actually take to observe negative (or zero) real interest rates? Fisher considers this question and, whimsically, imagines the economic conditions necessary for negative or zero real interest rates. In "*The Imaginary 'Hard-Tack' Illustration", he discusses the plight of sailors shipwrecked on a desert island with only a few pounds of hard-tack for sustenance and no way to increase their stores of food. He demonstrates (p. 186) that, "in such a community, the rate of interest in terms of hard-tack [which does not deteriorate over time] would necessarily be zero!*" He then considers "*The Imaginary 'Figs' Example*" in which shipwrecked sailors were left with a stock of figs rather than hard-tack (p. 191). Because, figs deteriorate naturally over time, the rate of interest in terms of figs would necessarily be negative. He concludes his discussion of these imaginary worlds as follows (p. 191-2): "*The fact that we*

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[3] Equation (1) ignores risk factors, taxes and the "*cross product*" term (if the yields are not continuously compounded) that, if included, would alter somewhat the right-hand side of the equation but have no effect on our discussion.

[4] See Alchian and Klein (1973) for a detailed discussion of the major differences between the broad price index envisioned by Fisher and the narrower price indices typically used in macroeconomic analysis and models.

seldom see an example of zero or negative interest rates is because … we happen to live in an environment so entirely different from that of the shipwrecked sailors."

Thus, according to Fisher's theory of interest, positive time preference and productive investment opportunities mandate *positive* real interest rates in the *real* world. Unfortunately, recent discussions of the negative estimates of real interest rates have either misunderstood or ignored Fisher's rationale for positive real interest rates. Hamilton (2010), for example, offers the following puzzling analysis that, at the same time, supports and denies Fisher's contention that the real interest rate must be positive:

> "*What does a negative real rate signify? If you consider a simple one-good economy in which the output is costlessly storable, a negative real rate could never happen—people would simply hoard the good rather than buy such miserable assets. You're better off storing a can of tuna for a year than messing with T-bills at the moment. But there's only so much tuna you can use, and many expenditures you might want to save for can't really be stored in your closet for the next year. It's perfectly plausible from the point of view of more realistic economic models that we could see negative real interest rates, at least for a while.*"

While it may be "*plausible from the point of view of more realistic economic models*", it is exceedingly implausible—actually impossible—from the point of view of Fisher's analysis of the real rate in the world as we know it. Hamilton's tuna fish example, a modern equivalent, perhaps, to Fisher's hard-tack, correctly shows why the real interest rate cannot be negative in the cheaply storable one-good case. However, in a world with assets galore that provide *positive* real returns and numerous goods, like tuna, that can also be cheaply stored, it is highly implausible that the real interest rate can be negative. Hamilton's casual comment about the likelihood of negative real interest rates is simply wrong.[5]

FROM THEORY TO PRACTICE: *ESTIMATING* THE REAL RATE OF INTEREST

As Equation (1) indicates, Fisher's theory is designed to explain the level of observed nominal interest rates on selected credit instruments. In contrast, r^e and Π^e are theoretical concepts that are neither directly observable nor measurable. Thus, some procedure must be used to generate *estimates* of, or proxies for, them in order to test the validity of the theory.

Equations (2) and (3) show how real interest rate *estimates* are typically produced.

$$r_t^e = i_t - \Pi_t^e \quad (2)$$

$$r_t\hat{} = i_t - p_t\hat{} \quad (3)$$

In Equation (2), the Fisher interest rate equation [Equation (1)] is "*shuffled*" to demonstrate how analyses of the real interest rate typically begin. As Haug et al. (2011, p. 1) note: "*Fisher's model determines the real interest rate as the difference between the nominal interest rate and the expected inflation rate.*"[6] However, because $\Pi^e$is a theoretical concept, specific econometric techniques or survey procedures are used to produce *estimates* of the expected inflation rate, (pˆ), as measured by changes in some selected price index (e.g., the CPI, the Core CPI, the GDP Implicit Price Deflator, etc.). Abel and Bernanke (2005, pp. 53-4) provide a brief discussion of this process:

> "*… [Because] economists generally don't know exactly what the public's expected rate of inflation is … [, they] use various means to measure expected inflation. One approach is to survey the public and simple ask what rate of inflation people expect. A second method is to assume that the public's expectations of inflation are the same as publicly announced government or private forecasts. A third possibility is to assume that people's inflation expectations are an extrapolation of recently observed rates of inflation.*"

[5]Another problem with his discussion is that he applies the term "*real rate*" to both the *ex ante* real rate of interest and the *ex post* real interest rate.

[6]Of course, it is equally true that the expected inflation rate is equal to the nominal interest rate minus the real rate. However, Equation (2) is used because macroeconomists and econometricians believe that it is easier to estimate the expected inflation rate and, then, solve for the real interest rate than vice versa. However, for examples of the reverse of the usual procedure, see Barro (2010, p. 200-1) and Gavin (2010).

Barro's (2010, p. 199) list of alternative procedures is similar, but not identical, to Abel-Bernanke's list:

> "*1. Ask a sample of people about their expectations.*
> *2. Use the hypothesis of rational expectations, which says the expectations correspond to optimal forecasts, given the available information. Then use statistical techniques to gauge these optimal forecasts.*
> *3. Use market data [from indexed bonds] to infer expectations of inflation.*"

Regardless of the exact process used to derive *estimates* of the expected inflation rate, Equation (3) indicates that they are then subtracted from the nominal interest rate to obtain *estimates* of the real interest rate, $\hat{r}$. The plethora of alternative procedures used to generate expected inflation rates indicate that there is considerable disagreement among macroeconomists about the best way to generate these estimates and, hence, to calculate *estimates* of the real interest rate. Darin and Hetzel (1995, p. 17) note that "*Despite [its] importance …, there is no generally available measure of the real interest rate … Economists who have studied the real interest rate have had to create their own series.*" Moreover, as Abel and Bernanke (2005, p. 54) comment: "*Unfortunately, none of these methods is perfect, so the measurement of the expected real interest rate always contains some error.*" Consequently, the real interest rate *estimates* widely used in macroeconomic models and policy discussions are obviously idiosyncratic and subject to errors of various kinds. In the following sections, we emphasize one crucial error associated with these *estimates* of the real interest rate.

THEORY AND PRACTICE: REAL INTEREST RATE *ESTIMATES* PRIOR TO THE MID-1970s

Macroeconomic research in the decades following publication of Fisher's *The Theory of Interest* provided real interest rate estimates consistent with Fisher's theoretical view that the real rate of interest is positive. For example, Figure 1 shows Yohe and Karnosky's (1969, p. 34; their Chart VII) estimates of the long-term real interest rate from 1961-9. Their alternative real interest rate estimates (which differ due to different estimation procedures) are all positive and range between 2 to 4 percent.

The theoretical rationale and extant empirical evidence that real interest rates are positive was so well accepted that this conclusion appeared prominently in the leading principles of economics textbooks. For example, Alchian and Allen (1972, pp. 176-7) told their readers that:

> "*The [real] rate of interest, then, reflects: (1) convenience of earlier availability, (2) preference for assured consumption over contingent consumption, and (3) ability to use income to increase total output. Any society—capitalist, communist, advanced, primitive, industrial, agrarian, democratic, totalitarian—in which these elements are present will have a positive rate of interest—that is, a rate greater than zero.*"

Similarly, Samuelson (1964, pp. 584-5) explained that:

> " *.. as long as any increase in time-consuming processes could be counted on to produce any extra product and dollars of revenue, the yield on capital could not be zero. Also, as long as any land or other asset exists with a sure perpetual net income—and as long as people were willing to give up only a finite amount of money today in exchange for an infinitely large amount of income spread over the whole future—then we can hardly conceive of the [real] rate of interest as falling to zero.*"

Thus, up to the mid-1970s, virtually all economists agreed with Fisher's theoretical arguments, supported by empirical estimates, that, in the "*real*" world, the real rate of interest must be positive. Then, abruptly, this consensus changed.

THEORY VS PRACTICE: NEGATIVE REAL INTEREST RATE *ESTIMATES* SINCE THE MID-1970s

Since the mid-1970s, virtually all macroeconomic studies have generated positive *and negative* real interest rate estimates, depending on the specified time period. Figure 2, which shows the *nominal* 3-month Treasury bill interest rate and the *actual* rate of inflation (measured by the movement in the consumer price index for urban workers) from 1954, offers a potential reason for the change in the consensus that the real interest rate is always positive. In Figure 2, the nominal interest rate typically exceeded the actual inflation rate prior to 1973. Of course, the *actual* inflation rate should never be confused either with the *expected* inflation rate in Equations (1) and (2), or various *estimates* of the *expected* rate of inflation shown in Equation (3). Yet, the common movement in the interest rate and the inflation rate and the positive difference between them might be taken, somewhat loosely, as confirmation of the Fisher theory of interest and positive real interest rates.

Then, unexpectedly, from 1973 to 1980 (see the shaded area in Figure 2), the interest rate-inflation rate relationship inverted: the actual inflation rate exceeded the interest rate. This same inversion has occurred during the current decade (see shaded areas). Thus, during much of the 1970s and the 2000s, the actual inflation rate exceeded the nominal interest rate, which made the *ex post* real interest rate *negative*. More importantly, macroeconomists' *estimates* of the real interest rate were negative as well for these periods.

We will not even attempt to list the hundreds (if not thousands) of articles, books and working papers that have produced and/or used *negative estimates* of the real rate of interest over the past 35 years. Instead, we will simply cite four examples to illustrate our general theme: *negative estimates for the real interest rate now appear everywhere in the economic literature*.

- To *"…construct and make available a number of alternative empirical measures of the real rate of interest*", Darin and Hetzel (1995, p. 17) compare inflation forecasts from four different sources and generate five alternative monthly estimates of the real rate of interest from November 1965 through December 1994. All five of their series (pp. 37-45) contain negative real interest rate estimates for various months, especially during 1975 through 1977.
- Gavin et al. (2005, p. 633) use "*… four monetary general equilibrium models … [that] differ along two dimensions: the monetary authority's policy rule and the nature of price adjustments.*" They generate 12 alternative response patterns for their selected macroeconomic variables, including the real interest rate, r, when they solve their models for the impact of different "*shocks*". Seven of their 12 alternative model solutions yield negative real interest rates.
- Figure 3 [labeled, coincidentally, Figure 3 in their study] shows real interest rate estimates from 1962-2008 in a recent study by Justiniano and Primiceri (2010, p. 20); their real interest rate estimates are negative during the 1970s and the current decade.
- Figure 4 shows real interest rates estimates from 1831-2004 in a recent study by Weber (2010, p. 8) in which he states that "*… negative real interest rates are a key feature of American business cycle history. The real interest rate was negative in 35 years during the 174 years [shown].*"

NEGATIVE REAL INTEREST RATE *ESTIMATES* ARE FLAWED

There are two reasons why *negative* real interest rate *estimates* are flawed. The first reason, as we have discussed extensively in previous sections, is that Fisher's theory of interest requires positive real interest rates in the world as we know it. As Schwartz (1993, p. 11) notes *"[I]n a market economy, the expected real rate [of interest] cannot be negative…*" Similarly, Brown and Santoni (1981, p. 19) comment that "*Casual observation suggests that the preconditions for a negative ex ante real interest rate do not now exist, nor did they exist in 1974 and 1975.*" If we actually believe that the *negative* real interest rate *estimates* are accurate and useful empirical counterparts to the theoretical real interest rate in Fisher's theory of interest, then economic conditions must also resemble those in Fisher's Imaginary Fig World. Or, more generally, they must resemble conditions that Fisher (1930, p. 191-2) describes as follows:

> " *… [a negative real interest rate] … would be true if there were a world in which the only provisioning of the future consisted of carrying over initial stocks of perishable food, clothing, and so forth and if every unit so carried over into the future were predestined to melt away …*"

Fisher (1930, p. 192) did not envision such economic conditions in the world as he know it.

> "*One reason why we do not encounter such cases, with negative rates of return over costs, negative rates of interest and negative rates of time preference is that we have other income available from the future besides what can be carried over from current stocks. Future figs will come into being from fig trees and even existing stocks of figs and other perishables can be carried over for future use by canning, cold storage, preservation and similar processes.*"

If U.S. economic conditions in the mid-1970s and during this decade did not mimic Fisher's "*Imaginary Figs*" world closely enough to make *estimates* of *negative* real interest rates plausible, then these *estimates* must be spurious.

Several decades ago, two articles demonstrated that the use of *inappropriate* price indices to generate estimates of the expected inflation rate would produce spurious real interest rate estimates. First, Alchian and Klein (1973, pp. 481-2) showed that the price indices used to estimate expected inflation rates were *theoretically* flawed.

> "*Two commonly cited ... price indices [,] the ... Consumer Price Index and the …GNP Deflator [,] ... often ... used ... as measures of inflation and …targets and indicators of monetary and fiscal policy [,] ... are theoretically inappropriate for the purpose to which they are generally put. .... The analysis in this paper bases a price index on the Fisherian tradition of a proper definition of intertemporal consumption and leads to the conclusion that a price index used to measure inflation must include asset prices.*"

Brown and Santoni (1981, p. 21) demonstrated the empirical relevance of Alchian-Klein's theoretical discussion. In response to the initial cluster of published studies that generated negative estimates of the real interest rate in the late 1970s, they explained the reasons for the measurement problem inherent in these published estimates:

> "*First …changes in ... commonly used price indices produce biased estimates of actual changes in the general level of prices when the real interest rate is changing. Second, given that it is the expectations of market participants concerning the general level of prices that is relevant in Fisher's theory of the nominal interest rate, estimates of the real interest rate that employ past changes in a commonly used price index as a proxy for expected inflation will be biased when the real rate is changing.*"

They showed the nature of the bias by comparing the prices of less durable (present) goods to those of more durable (capital) goods. They demonstrated that changes in these proxies for the real interest rate actually moved *inversely* to the published estimates of the real interest rate (pp. 23-26). *Thus, not only were the published estimates of the real interest rate biased, they were biased in the wrong direction*.

Later, Santoni and Moehring (1994) expanded the analysis of the measurement problem discussed in Brown and Santoni (1981) by examining the puzzling inverse relationship between estimated real returns on assets and estimates of the expected rate of inflation. They showed that this puzzling behavior was produced by the use of inappropriately narrow price indices to derive estimates of the Fisherian expected inflation rate.

In the Appendix, we provide a simple example of the differences in the measured inflation rates and estimates of the real interest rate arising from changes in a narrow "*cost of living*" index vs. a broader "*cost of life*" index for alternative economic scenarios. We demonstrate that a change in the real interest rate produces biased estimates of both the inflation rate and the real interest rate for the narrowly-defined cost of living index, but not for the broadly-defined "*cost of life*" index. In particular, we show that an *increase* in the real interest rate will produce both an *increase* in the narrow "*cost of living*" price index and a *decrease* in the estimated real interest rate. In fact, *the estimated real interest rate is triply biased—wrong magnitude, wrong direction of movement and wrong sign.*

GRADUATE ECONOMIC EDUCATION AND THE DUNNING-KRUGER EFFECT

If the negative real interest rate *estimates* used by macroeconomists for decades are theoretically invalid and empirically spurious, how is it possible that macroeconomists have continued to use the

Fisher interest rate theory and negative real interest rate estimates as if both are equally valid and equally useful for macroeconomic policy? One potential explanation that may provide some insight into this macroeconomic conundrum is known as the Dunning-Kruger Effect. As Dunning explains it (Morriss (2010a, p. 7)):

> "*You could think of the Dunning-Kruger Effect as a psychological version of [anosognosia]. If you have, for lack of a better term, damage to your expertise or imperfection in your knowledge or skill, you are left literally not knowing that you have that damage.*"

Thus, the Dunning-Kruger Effect suggests that macroeconomists fail to recognize that their negative estimates of the real interest rate are spurious*because they are ignorant of the Fisherian theory of interest itself*. How could this have happened over the past several decades?

For one possible explanation of this phenomenon, we look back about 50 years ago, when Enthoven (1963, p. 422) described the requirements for success in economics as follows:

> "*...the tools of analysis that we ... use are the simplest, most fundamental concepts of economic theory, combined with the simplest quantitative methods. The requirements for success in this line of work are a thorough understanding of and, if you like, belief in the relevance of such concepts ... combined with a good quantitative sense. The economic theory we are using is the theory most of us learned as sophomores. The reason Ph.D.'s are required is that many economists do not believe what they have learned until they have gone through graduate school and acquired a vested interest in the analysis.*"

There has been increasing concern that graduate economic education has deemphasized the "*fundamental concepts of economic theory*" over the past decades and that Ph. D.'s no longer have "*a vested interest*" in, or, perhaps, much familiarity with, these concepts. For example, in their article subtitled "*A Dismal Performance from the Dismal Science*", Ferraro and Taylor (2005, abstract) comment that

> "*One expects people with graduate training in economics to have a deeper understanding of economic processes and reasoning than people without such training. However, as others have noted over the past 25 years, modern graduate education may emphasize mathematics and technique to the detriment of economic reasoning.*"

Similar criticisms of graduate economic programs have appeared in recent years. For example, Demsetz (2008, p. 4) remarked that

> "*The work I choose to do is not heavily armored with math and econometrics. It is focused on the empirical and policy problems and on the logic of the theory that bears on these. Cold logic, imagination, and exposition by words, simple geometry, and basic statistics are the tools on which I have mainly relied throughout my career. ... Not many young economists adopt this working methodology today .... Economists in training seem to seek a body of data that is appropriate for the exploitation of technical tools rather than one which offers intrinsic economic interest.*"

Equally critical of graduate economic education, Allen (2010, p. 25) comments that

> "*Economics departments continue to grind out numerous bright Young Scientists who are close substitutes for each other .... Few new grads seem to have a strong sense of, or feel for, or interest in the substance and use of traditional Economics at its best. Few see that ... achievements of high sophistication are resultants of more than learned mechanics and convoluted techniques.*"

Of course, innovations in computer technology and econometric software over the past several decades have encouraged the rise of "*bright Young Scientists*" by making it relatively cheaper to specialize in what Allen might consider "*learned mechanics and convoluted techniques.*" However, these innovations alone should have enabled macroeconomists and others to further extend, develop and test the "*fundamental concepts of economics.*" As Sargent (2010, p. 28) noted in his response to criticisms of macroeconomics:

> "*... it is true that modern macroeconomics uses mathematics and statistics to understand behavior in situations where there is uncertainty about how the future will unfold from*

> *the past. But a rule of thumb is that the more dynamic, uncertain and ambiguous is the economic environment that you seek to model, the more you are going to have to roll up your sleeves, and learn and use some math. That's life.*"

Others, however, have suggested that the attention devoted to these techniques has displaced or crowded out the study of fundamental economic concepts in graduate schools. For example, Demsetz (2008, p. 4) comments that

> "*Today, prospective employers seem to strongly emphasize demonstrable ability in econometrics and mathematics. I suspect that the large degree of specialization across fields of economics explains this, since it is now more difficult to have the knowledge of material in the many fields in which the renderer of judgment is not a specialist. Technical tooling offers a substitute, but heavy attention to these tools often hampers discovering the economist.*"

Similar comments have been made by Allen (2010, p. 233): "*... the [Economics] professional arena now is largely one of gamesmanship in technique*" and Krueger et al., (1991), who observed that economic graduate programs produced "*... too many idiots savants, skilled in technique but innocent of real economic issues.*" Indeed, Allen (2010, p. 219) noted that he once asked Milton Friedman whether he should submit his manuscript on Irving Fisher to the *Journal of Political Economy*. Friedman responded that Allen's "*manuscript would not receive a fair assessment there because it was non-mathematical.*" Friedman suggested that he send it, instead, to the *Journal of Law and Economics*, which did publish it.

It would require a detailed examination of changes in graduate economic program curriculums and dissertation topics over the past several decades to determine whether this specific "*crowding out*" assertion is valid. Unfortunately, we know of no such research to date. However, recent articles by Coelho and McClure (2005, 2008, and 2011) provide indirect evidence that supports this view. They examine the rise of "*mathematical formalism*" and the associated decline in empirical hypothesis tests in the economic articles published in recent decades. Figure 5 [Coelho and McClure (2011, p. 217; their Figure 1)] documents the dramatic rise in the number of articles that emphasize mathematical modeling (i.e., that contain one or more "*lemmas*") in economic journals since 1954. Their research indicates that mathematical models have increasingly crowded out hypothesis tests in published economic articles. A similar criticism was made by a physicist, interested in using advanced computer power to map human economic behavior, who remarked [cited in (Hirsh (2010)] that "*One of the dangerous cultural patterns that economics has fallen into is an excessive emphasis on theorem proof for its own sake rather than what gives you scientific results.*" Coelho and McClure's results are consistent with the Dunning-Kruger explanation applied to the puzzling behavior of macroeconomists who continue to use both Fisher's theory of interest and real interest rate estimates that are inconsistent with this theory.

CAN THEORY AND MACROECONOMIC PRACTICE BE RECONCILED?

Consider the problem challenging macroeconomists who use *estimates* of the real rate of interest as integral components of their models, analysis and policy recommendations. Fisher's theory of interest suggests that, in the world we inhabit, the real interest rate and, by extension, *estimates* of the real interest rate are always positive. In contrast, macroeconomists continue to generate and use empirical *estimates* of the real interest rate that are *negative*over extended time periods. The only way to reconcile theory with macroeconomic practice would be to derive *estimates* of the real rate that are consistent with Fisher's theory. Unfortunately, although four alternative approaches have been suggested, none of them are likely to actually resolve this problem and reconcile theory with macroeconomic practice.

Find a Better Measure of Inflation: "*Cost of Living*" vs. "*Cost of Life*"

Alchian and Klein (1973) argue that the price indices commonly used to calculate inflation rates used as targets or indicators of macroeconomic policy, or employed in macroeconomic models, or used to derive estimates of the real rate, are theoretically inappropriate. Their analysis (pp. 173-4) shows that

> "*A correct measure of the changes in the nominal money cost of a given level of utility level is a price index for wealth. If monetary impulses are transmitted to the real sector of the economy by producing transient changes in the relative prices of service flows and asses (i.e., by producing short-run changes in 'the' real rate of interest), then the commonly used, incomplete, current flow price indices provide biased short-run measures of changes in 'the purchasing power of money.' The inappropriate indices that dominate popular and professional literature and analyses are thereby shown to result in significant errors in monetary research, theory and policy.*"

After deriving a theoretically correct price index that emphasizes intertemporal consumption optimization, they suggest that it could be called the current "*cost of life*" index to distinguish it from the "*cost of living*" labels generally associated with the CPI or PCE indices. Shibuya (1992) derived a similar intertemporal price index, which he called a "*dynamic equilibrium price index*" or DEPI. More recently, Filardo (2000) derived and used an ad hoc Alchian-Klein-type price index for monetary policy purposes.

Although the "*cost of life*" price index avoids the biases in inflation and real interest rates estimates associated with the use of the usual "*cost of living*" price indices, it is extremely unlikely that an Alchian-Klein "*cost of life*" price index will be developed and widely used for two related reasons. First, acquiring the additional information required to compile this index is extremely expensive. In a review of the Alchian-Klein approach, Goodhart (2001, p. F335) states that

> "*The argument that an analytically correct measure of inflation should take account of asset price changes was made most forcefully by Alchian and Klein in 1973, and has never, in my view, been successfully refuted on a theoretical plane, though … their particular proposals have severe, perhaps incapacitating, practical deficiencies.*"

Similarly, Shibuya (1992, p. 105) notes the practical and theoretical problems associated with calculating and using his DEPI measure of the "*cost of life*" price index include "*reliable and promptly available data on a comprehensive range of asset prices … [and adjustments] in the effects of long-term productivity changes…*" As Alchian and Klein (p. 187-9) acknowledged, after describing the information necessary to compile a "*cost of life*" index, "*The empirical problems are enormous.*"

Recently, however, Nakamura (2011, abstract) has argued that

> " *… a potentially large macro-micro database for the U.S. based on an extended version of the Flow of Funds … would have been of material value to U.S. regulators in ameliorating the recent financial crisis and could be of aid in understanding the potential vulnerabilities of an innovative financial system in the future. I also suggest that making the data available to the academic research community … would enhance the detection and measurement of systemic risk.*"

So, perhaps some of the additional data necessary to compile a "*cost of life*" index may be available in the future should financial market regulators decide that it would provide better financial market regulation and incur the costs of acquiring this data.

The second reason why an Alchian-Klein-type price index is unlikely to be compiled and used is the apparent lack of demand for it by macroeconomists specifically or by the public in general. As Alchian and Klein note (p. 186)

> "*… an individual … attempting to determine how much money wealth he now needs for a particular level of present and future consumption [should] use our index. But why, then, isn't there a demand for a price index that includes asset prices and why do movements in the CPI appear to be politically important?*"

Carlson (1989, p. 14) suggests that the lack of interest in the Alchian-Klein price index may also reflect the preferences of monetary policymakers who want "*measures of price movements [that make] the inflationary effects of their actions … readily identifiable. This means that the price measure most relevant to them differs from that most relevant to individuals.*"

Estimate the Real Rate of Interest From the Real Rate of Return on Capital

Hosek and Zahn (1985) derived estimates of the real interest rate without using estimates of the expected inflation rate and the Equation (3) approach. Instead, they generated them from their estimates of the real rate of return on capital. They described their approach (p. 212) as follows:

> "*Quarterly data for the U.S. are used … to estimate the real rate [of interest] implied in the neoclassical theory of capital formation where the value of the marginal product of capital equals its service price. Since the real rate [of interest] is an argument in the service price of capital, we can derive an expression for it in terms of factors shaping equilibrium in the aggregate capital market.*"

Their estimated real interest rates were *positive* throughout their 1954-81 sample period.

For comparison, they generated two alternative (adaptive vs. rational expectations) estimates of the real interest rate using the usual Equation (3) approach described above. They note the key difference between their approach and the widely-used approach for estimating the real interest rate: "*… unlike our estimate, both the adaptive and rational estimates [of the real interest rate] show negative values during the sample period, a factor which is difficult to reconcile with economic theory.*" (p. 219). They conclude that

> "*A comparison of the statistical properties of our estimate with both adaptive and rational estimates of the real rate based on the Fisher Equation indicates substantial differences between our estimate and the others …The dissimilarities in the statistical properties of the estimates raise serious questions about the appropriate measure of the real rate used to evaluate the impact of economic policy on … aggregate demand. Although the accuracy of our [real interest rate] estimate relative to the other estimates can not be determined, its reliability as an explanatory variable in the appropriate structural equations of a model, which explains the interactions between the real and monetary sectors, is the subject of our continuing research.*" (pp. 220-1).

The Hosek-Zahn approach seemingly offers estimates of real interest rates that are consistent with economic theory, free from the measurement problems discussed by Alchian-Klein and Brown-Santoni, and avoid the possibly large data costs associated with calculating the "*cost of life*" index.

However, there are three problems with their approach that argue against its widespread adoption by macroeconomists. First, Hosek-Zahn's approach does generate *negative* estimates of the real interest rate, as they show in their Table 3 (p. 217-8).

> "*Noting the high elasticity of the real rate with respect to the value of the marginal product of capital and given that our estimate of the output elasticity with respect to capital β plays an important role in that regard, we estimated the real rate with β varying between plus and minus one standard error. … Clearly the estimates of the real rate are sensitive to the value of β.*"

Their "*sensitivity*" analysis produces *negative* estimates of the real interest rate for 1970s for a β value that is one standard deviation below the estimate they use for their analysis. Thus, their approach does not avoid real interest rate estimates that are, as they described it, "*difficult to reconcile with economic theory*."

Second, their approach suffers from data problems similar to those faced by Alchian-Klein. In an article emphasizing the importance of accounting for maintenance and repair to properly measure a nation's capital stock, McGrattan and Schmitz, Jr. (1999, p. 3) note that "*For many countries, like the United States, it is not possible to determine the size of the maintenance and repair in the aggregate given current data collection procedures.*" Therefore, the capital stock estimates necessary for Hosek-Zahn's approach are erroneous and the real interest rate estimates derived from their approach are misspecified.

Third, Hosek and Zahn's article has failed the academic "*market test*"—it has essentially been ignored by the profession for a quarter of a century. A Scholar-Google literature search for the number of studies that have cited it since its publication in 1985 yields a count of exactly *one* citation—an unpublished working paper. Apparently, macroeconomists remain unconvinced of the usefulness of this approach for estimating the real interest rate—perhaps because it is considerably more difficult to use than the widely-used, albeit error-prone, estimated inflation-Fisher Equation approach that uses inexpensive, publicly-available price indices.

Estimate the Real Rate of Interest Using Commodity Futures Market Data

Mishkin (1987, 1988) considers yet another potential alternative method to estimate the real interest rate. He uses spot and futures market prices for selected commodities to provide estimates of expected inflation rates for specific commodities. These expected inflation rate estimates are then subtracted from nominal interest rates to obtain estimates of the real rate of interest for these specific commodities. Then, an estimate of the general real interest rate is obtained from a weighted average of these commodity-specific real interest rate estimates.

Unfortunately, there are several problems with this approach. First, as Mishkin (1988, pp. 1064-5) points out, it is difficult to filter the data econometrically to derive estimates of the real rate of interest.

> **"…** *own-commodity real rates constructed using futures market data contain information not only about the real interest rate for the aggregate economy or for a particular sector but also about ex ante relative price movements for the particular commodity. Since, as demonstrated in Mishkin (1987), these ex ante relative price movements (which can be thought of as noise) are far greater in magnitude than movements in the aggregate real interest rate (the signal), then the noise-to-signal ratio in own-commodity real rates will be very high. Own-commodity real rates constructed using futures market data will thus contain little information about the aggregate real interest rate of primary concern to economists.*"

In part, this problem may be the result of increased volatility of the underlying commodity prices in recent decades. Although Calvo-Gonzonez et al.'s (2010, abstract) recent study finds that *"… there is no upward or downward trend in volatility [in commodity prices] over time*", they note that *"… the timing and number of breaks in volatility [of commodity prices] vary considerably across individual commodities, cautioning against generalization based on the use of commodity price indices…*"

Moreover, because this approach incorporates only selected commodity prices, it involves an even narrower set of goods than the "*usual suspects*" used to generate expected inflation estimates. Thus, it would still produce biased and theoretically unacceptable estimates of the real interest rate for reasons discussed in Alchian and Klein (1973), Brown and Santoni (1981), and the Appendix to this paper.

Estimate the Real Rate of Interest Using Inflation-Indexed Securities

Inflation-indexed securities are financial instruments whose principal and interest payments are tied to movements in some designated price index. A number of countries have issued inflation-indexed government bonds over the past 65 years—e.g., Finland introduced them in 1945, the U.K. in 1981 and Canada in 1991.[7] The U.S. began issuing TIPS (Treasury Inflation-Protected Securities) in 1997. The yields on TIPS have been used in macroeconomic studies in two ways. First, it has been argued that the yield spread between the interest rates on nominal and inflation-indexed securities provide estimates of expected inflation. For example, Craig (2003, p. 1) notes that

> "*Treasury inflation-indexed securities are just like nominal Treasury securities, except that their coupon and principal payments are indexed to inflation. The yield spread between the two types of securities should serve as a daily measurement of the market's perception of expected inflation, modified to reflect of the cost of inflationary risk.*"

Similarly, Campbell and Shiller (1996, p. 160) comment that inflation-indexed bonds "*… may have some informational value because they make it easier for the monetary authority and other observers to impute the inflation expectations of bond-market investors.*"

Second, interest rates on indexed securities could be interpreted directly as estimates of the real rate of interest. Craig (2003, p. 1) explains that:

[7] See the table and discussion in Campbell and Shiller (1996, pp. 156-8).

> "*Economic theory separates the yield of a nominal Treasury [bill or bond] at its market equilibrium into several components: a real return, the expected rate of inflation and an inflation-risk premium … A TIIS [another term for TIPS] holder does not have to worry about the inflation component but only about the real return. Thus, at first glance, the TIIS yield should equal the nominal Treasury rate minus the expected inflation rate and minus a risk-aversion premium.*"

In other words, the TIPS yield might be used to provide a direct estimate of the real rate of interest. This is precisely what some analysts did when the recent TIPS auction yielded *negative* interest rates. For example, D'Altorio (2010) commented that "*Investments that promise negative yields don't sound very sexy. But scores of people "went negative" this week, snapping up $10 billion worth of [TIPS] … [with] an astonishing negative 0.55% yield.*" So, contrary to economic theory, did this result actually represent a financial market-based *negative* estimate of the real interest rate?

Unfortunately, there are several problems with interpreting and using the yields on inflation-indexed securities as estimates of the real rate of interest. First, a number of articles have shown that the yields on these securities cannot be directly interpreted as estimates of the real interest rate, chiefly due to the peculiarities of the indexing scheme used. Arak and Kreicher (1985) explain this problem with respect to U.K indexed securities:

> "*Yields on price-linked securities, which provide nominal returns in line with inflation, could, in principle, provide a measure of the real rate of interest directly. … Most indexing schemes, however, are imperfect. For example, a time delay between computation of interest and its payment—a common feature—makes the payment worth less and requires that the investor be compensated by a yield which is greater than the real rate of interest. The observed yield on indexed securities cannot, therefore, be assumed to be a good estimate of the real rate of interest.*"

Similarly, Barr and Campbell (1996, p. 3) point out that

> "*This feature of index-linked bonds creates technical difficulties in extracting implied real interest rates from index-linked bond prices. Observed changes in the price of an index-linked bond may reflect changes in inflation expectations, albeit with a sensitivity well below that of a purely nominal bond …*"

They then go on (pp. 3-4) to explain that various attempts to address this problem are, themselves, subject to theoretical, technical and econometric problems that make the derived estimates of the expected inflation rates and real interest rates problematic.

A second problem with the estimates of the real interest rates derived from yields on indexed securities, over and above the estimation problems cited above, is that these securities are indexed to narrow price indices (e.g., the CPI) rather than the Alchian-Klein-type price indices discussed earlier. Therefore, the real rate estimates derived from these indexed securities are subject to the same errors of bias and mismeasurement discussed earlier. Consequently, it is not surprising that negative estimates of the real interest rate arise periodically, even from TIPS yields.

A third problem with using estimates of the real interest rate derived from the yields on U. S. TIPS is that they have existed only since 1997. The relatively brief time period since their introduction makes it difficult to use TIPS yields to provide estimates for expected inflation or real interest rates for macroeconomic research and analyses. Consequently, studies of inflation-indexed securities use either U.K. indexed securities [Barr and Campbell (1996); Evans (1998)] or econometric models designed to estimate the movement of stylized (hypothetical) inflation-indexed bond yields for longer time periods [Campbell and Shiller (1996)].

SUMMARY AND CONCLUSIONS

Keynes (1921, p. v) stated that "*The theory of economics is a method rather than a doctrine, an apparatus of the mind, a technique of thinking, which helps its possessor to draw correct conclusions.*"

McGrattan (2010) corroborates Keynes' assertion in her recent article on the use of different statistical representations to the same prototypical business cycle model. She asks the question: "*How much can business cycle theorists learn from actual time series if they impose very little theory when applying their statistical methods?*" Her answer was "*very little.*" (p. 12). Without relevant theories to guide their analyses, economists are extremely unlikely to arrive at correct conclusions about the economy.

This same problem arises when economists misuse or, even worse, ignore the theories that, presumably, are guiding their analyses. Fisher's theory of interest is a cornerstone of macroeconomic analysis, so universally accepted and extensively used in macroeconomics and finance that Bullard (2010, pp. 340-1) maintains that "*Practically speaking, any macroeconomic model of monetary phenomena will have a Fisher relation as a part of the analysis…*" Similarly, as Taylor (2001) noted, the *ex ante* real rate of interest, as defined in Fisher's theory of interest, is widely recognized as being one of the most important variables in economics and is used in virtually all macroeconomic and monetary models. Yet, without relevant measures of key macroeconomic variables to guide their analyses, economists are extremely unlikely to arrive at correct conclusions about the economy.

In this article, we first reviewed Fisher's theory of interest rates and demonstrated that the *ex ante* real interest rate is *positive* in the world as we know it. We then pointed out that virtually all *estimates* of the *ex ante* real rate of interest used in macroeconomic analyses over the past 35 years are theoretically invalid and empirically flawed because they contain *negative* values for extended time periods. We noted that this problem was recognized and discussed in several published articles over 30 years ago—and then subsequently ignored when estimates of real interest rates were derived. We attempted to explain how this wide divergence between economic theory and macroeconomic practice might have arisen by invoking the Dunning-Kruger Effect and citing research on economic publication rates that is consistent with this explanation. Finally, we reviewed four alternative methods to the one most commonly used to derive estimates of the real interest rate. We pointed out that three of them—those that estimate the real rate of interest from the real return on capital, futures prices for selected commodities and yields on inflation-indexed securities—are unlikely to provide real interest rate estimates consistent with Fisher's theory of interest. On the other hand, although the use of an Alchian-Klein-type price index to derive the expected inflation rate is likely to produce theoretically-consistent estimates of the real interest rate, the cost of generating this price index appears to be prohibitive at present.

Is there a solution to the real interest rate morass? Unfortunately, not at the present time. In our opinion, the best way to proceed would be, first, to recognize that the procedures used to generate the real rate estimates currently used in macroeconomic models and policy recommendations yield estimates that are theoretically invalid and empirically spurious for the reasons presented in this article. Consequently, macroeconomic predictions and policy recommendations should be treated with somewhat more caution.

Second, increased data collection and research efforts to generate Alchian-Klein-type price indices should be considered. Nakamura's (2011) discussion that financial market regulation would benefit from the availability of similar data provides an new justification for collecting the data necessary to construct the cost-of-life price index.

Finally, increased attention to the "*fundamental concepts of economic theory*" might improve our ability to recognize problems and anomalies when they arise rather than later when they become more problematic. Thoreau once remarked that "*Some circumstantial evidence is very strong, as when you find a trout in the milk*." Finding *negative estimates* of the real rate of interest should be considered just as fishy by macroeconomists.

Figure 1: Yohe and Karnosky's Real Interest Rate Estimates: 1961-69

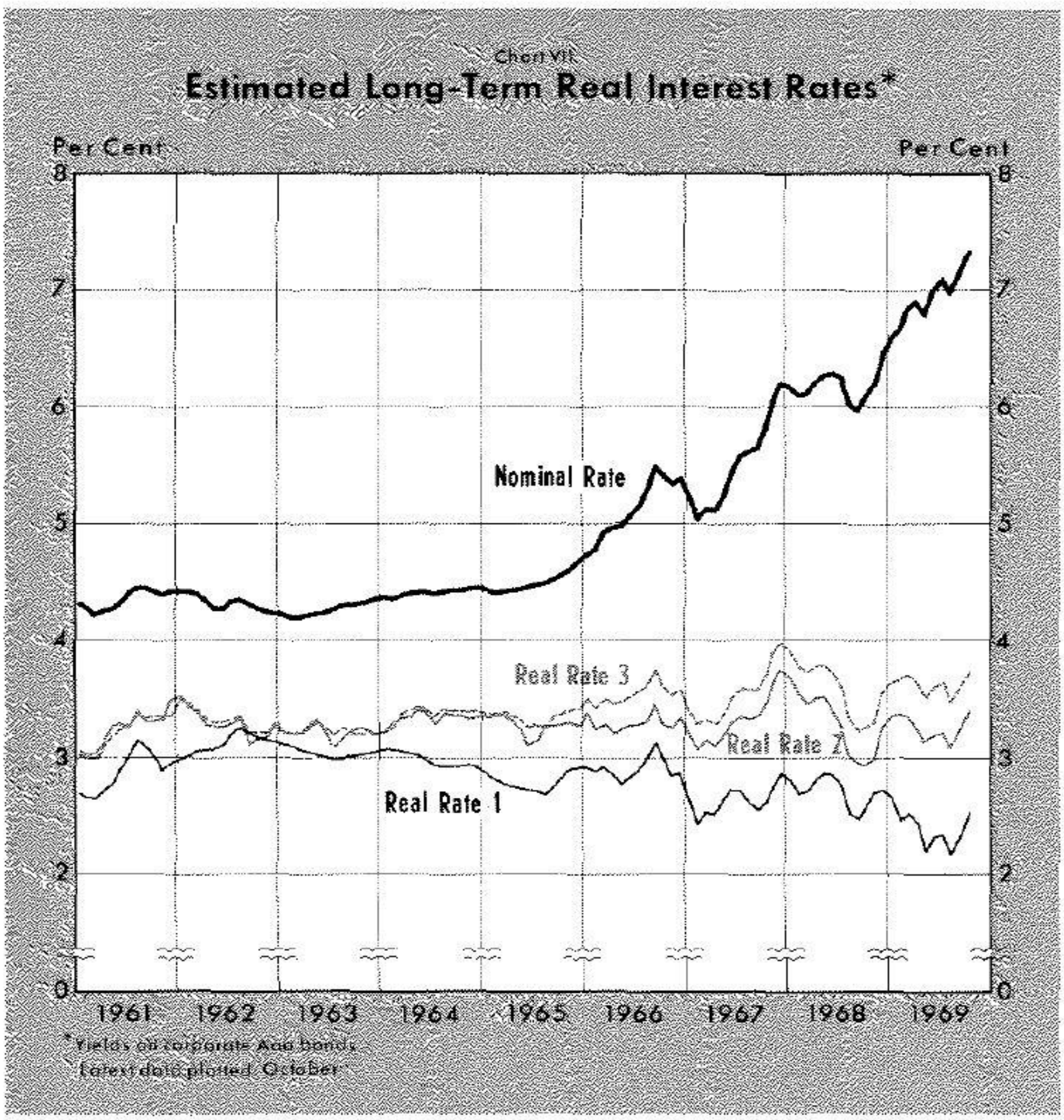


Figure 2: Interest Rates and Inflation: 1954-2010

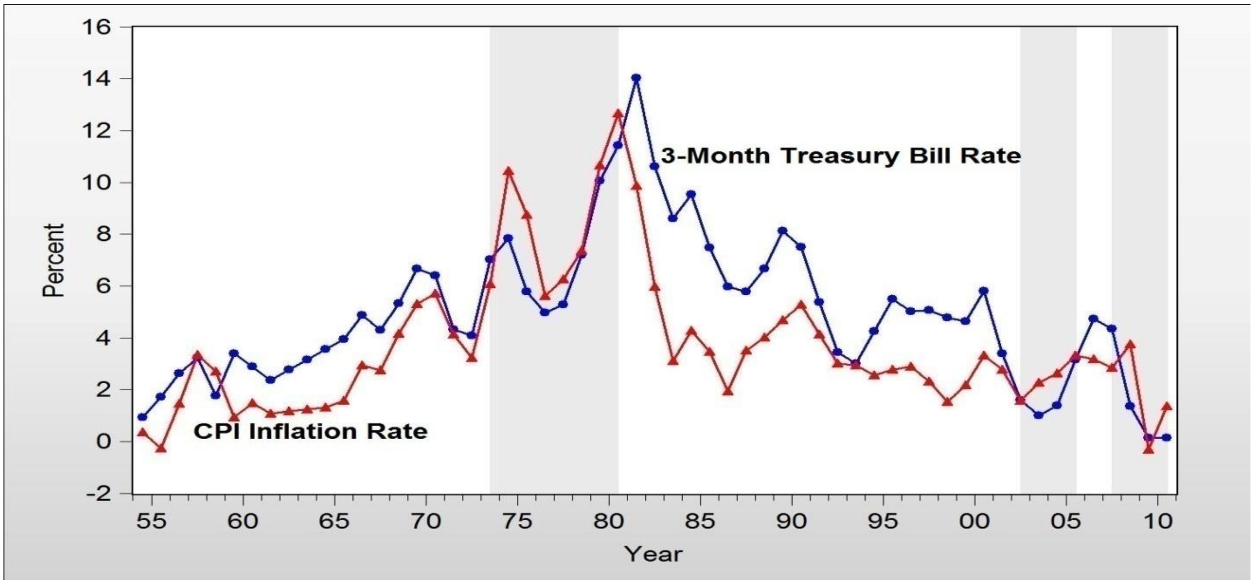


Figure 3: Justiniano and Primiceri's Estimates of the Real Interest Rate

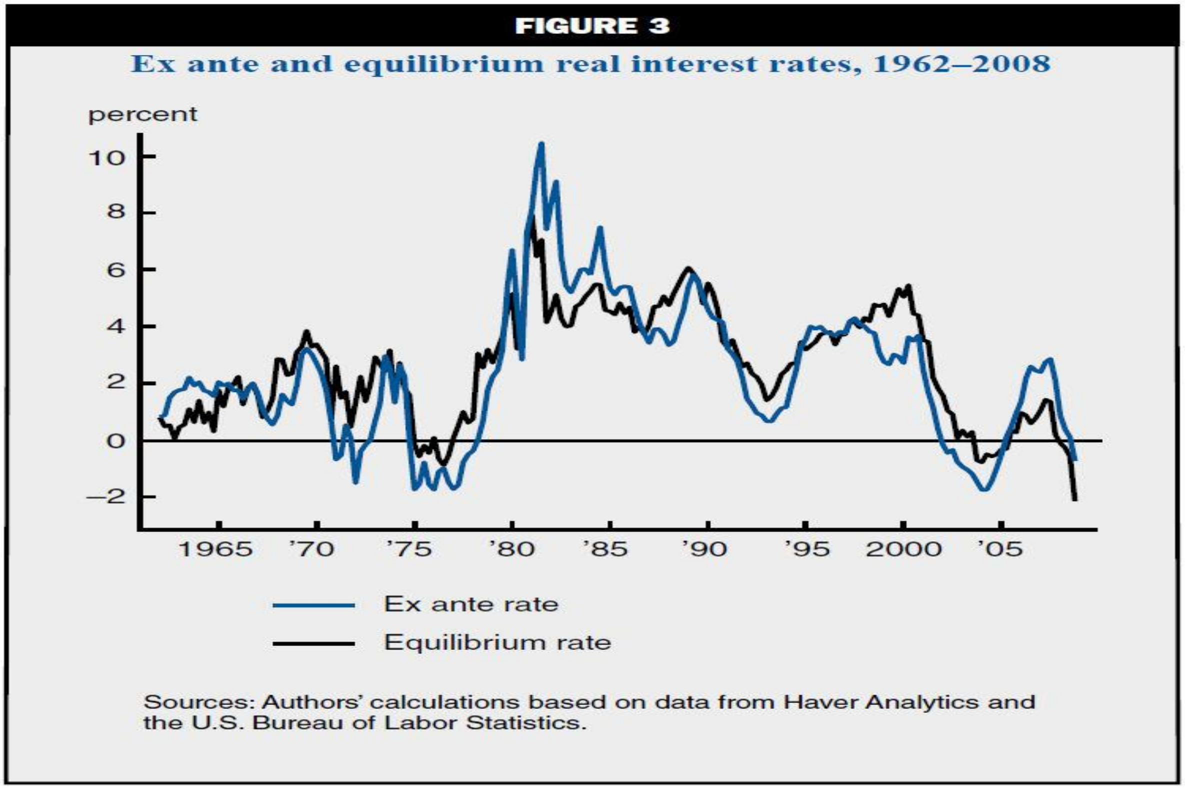


Figure 4: Weber's Real Interest Rate Estimates

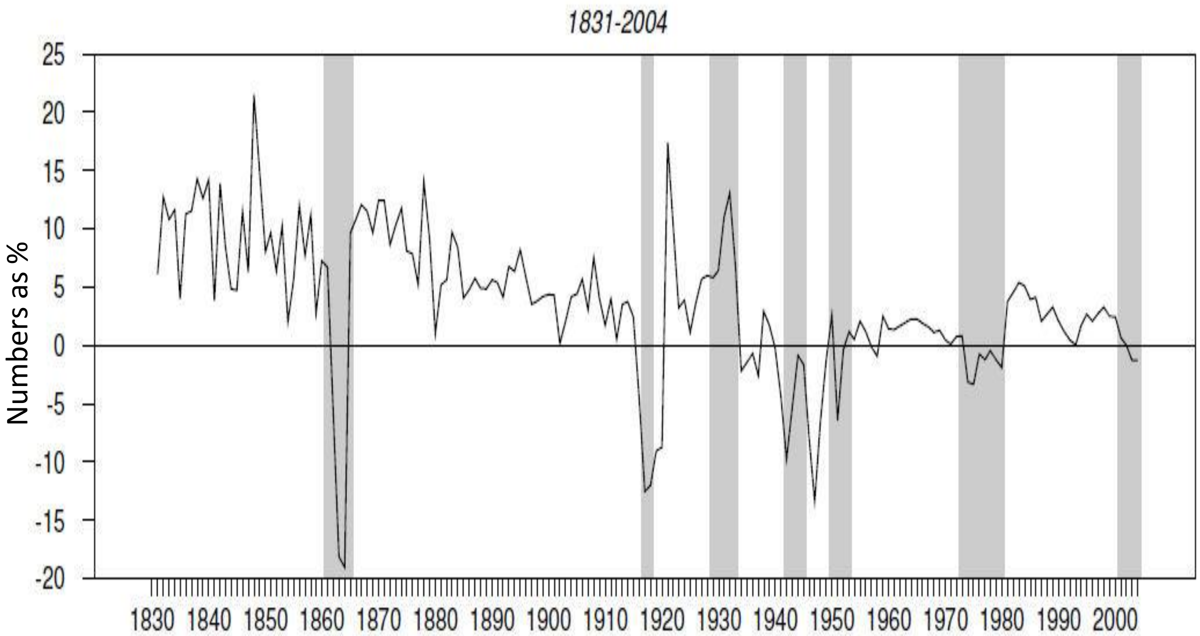
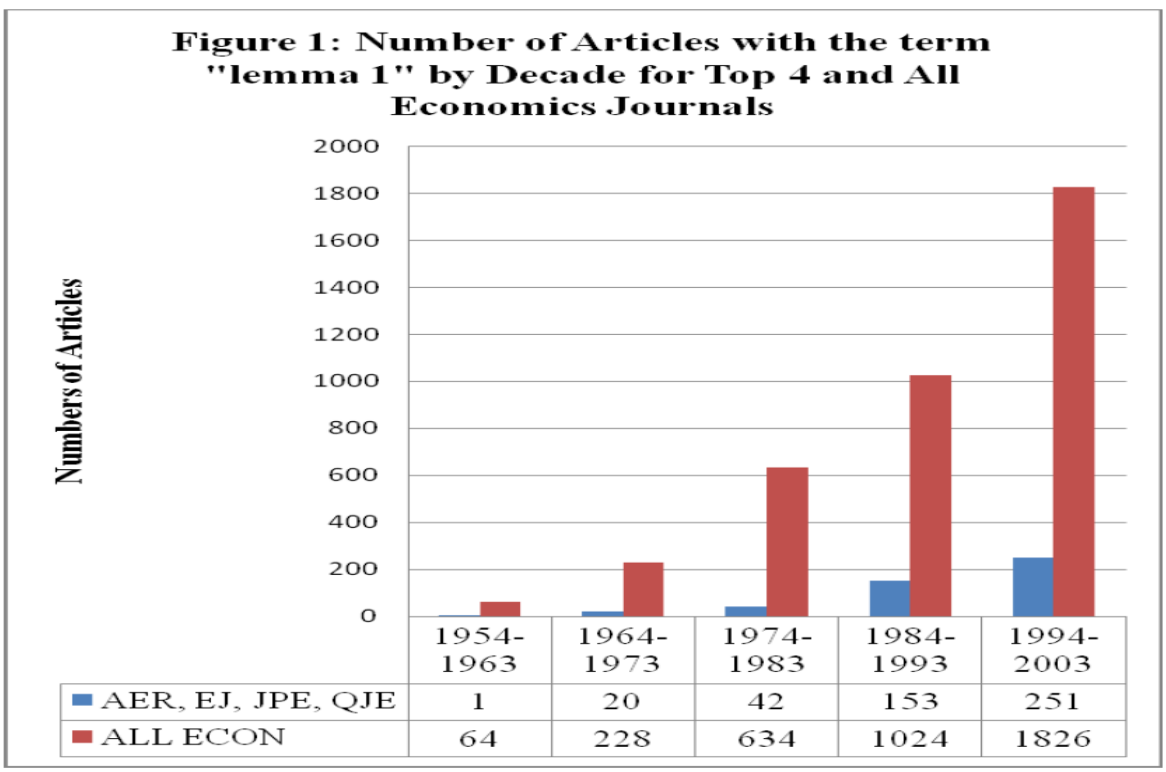


Figure 5: Coelho and McClure's Analysis of Mathematical Model-based Articles in Economics Journals: 1954-2003



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APPENDIX: USING ANARROWLY-DEFINED PRICE INDEX VS. AN ALCHIAN-KLEIN-TYPE PRICE INDEX TO ESTIMATE THE *EX ANTE* REAL INTEREST RATE

Consider the following example of very simple economy that contains people who hold money and apples and who own apple trees. In this economy, each apple tree produces 100 apples per year and lasts forever. The apples must be consumed during the year because they cannot be stored or otherwise carried over to future periods (e.g., as applesauce or apple wine). Table A1 depicts the prices of two goods (apples and apple trees) and the cost of two specific bundles of these goods in Periods 0 and 1 for two alternative*ex ante* real interest rates and a general inflation rate of 5%. One bundle consists of 100 apples, which we interpret as representative of the usual bundle of current consumption goods that make up the CPI and other commonly used price indices. The other bundle consists of 100 apples and an apple tree, which we interpret as an extremely simplified version of the "*cost of life*" index, the broad-based price index including both current consumption and long-lived assets discussed by Alchian-Klein. We have arbitrarily assigned a value of $2100 to the "*cost of life*" bundle in Period 0.

Table A1: Apples, Apple Trees and the "*Cost of Life*"

Period	0		1	
Panel 1: Ex Ante Real Interest Rate = 5%; Expected Inflation Rate = 5%				
	Nominal Interest Rate = 10%		Nominal Interest Rate = 10%	
	Price	Cost of Bundle	Price	Cost of Bundle
Apples	$1	$100	$1.05	$105
Apple Trees	$2000	-----	$2100	-----
"*Cost of Life*"		$2100		$2205
Panel 2: Ex Ante Real Interest Rate = 8%; Expected Inflation Rate = 5%				
	Nominal Interest Rate = 13%		Nominal Interest Rate = 13%	
	Price	Cost of Bundle	Price	Cost of Bundle
Apples	$1.56	$156	$1.64	$164
Apple Trees	$1994	-----	$2041	-----
"*Cost of Life*"		$2100		$2205
Panel 3: Ex Ante Real Interest Rate **Unexpectedly** Changes from 5% to 8% Expected Inflation Rate = 5%				
	Nominal Interest Rate = 10%		Nominal Interest Rate = 13%	
	Price	Cost of Bundle	Price	Cost of Bundle
Apples	$1	$100	$1.64	$164
Apple Trees	$2000	-----	$2041	-----
"*Cost of Life*"		$2100		$2205

Panels 1 and 2 in Table A1 show the individual prices of apples, apple trees, the cost of a bundle of 100 apples and the "*cost of life*" (100 apples and 1 apple tree) in Periods 0 and 1. The relative prices of an apple tree in terms of the cost of the bundle of 100 apples in both periods in Panels 1 and 2 reflect the relevant real interest rate, and the changes in the costs of the two bundles from Period 0 to Period 1 reflect the inflation rate of 5%.

Panel 3 in Table A1 shows the individual prices of apples, apple trees, the cost of a bundle of 100 apples and the "*cost of life*" in Periods 0 and 1 when the real interest rate rises unexpectedly between Periods 0 and 1, while the overall inflation rate remains at 5%. The increase in the real interest rate directly affects the nominal interest rate, the individual prices of apples and apple trees and, of course, the *relative* price of apples to apple trees. However, it does not affect the rise in the "*cost of life*" from Period 0 to Period 1, which increases solely due to the general inflation rate.

Table A2 shows the observed (*ex post*) inflation rates for the cost of the two bundles depicted in Panels 1 – 3 of Table A1. It also shows two *estimates* of the *ex ante* real interest rate (Estimates A and B in columns 5 and 6) when the observed inflation rates are subtracted from the nominal interest rates in Period 0 and Period 1.

Table A2: Inflation Rates and *Ex Ante* Real Interest Rate Estimates

Bundle	Cost of Bundle in Period 0	Cost of Bundle in Period 1	Inflation Rate from Period 0 to Period 1	Real Rate Estimate A: Interest Rate in Period 0 Minus Inflation Rate	Real Rate Estimate B: Interest Rate in Period 1 Minus Inflation Rate
Panel 1: Ex Ante Real Interest Rate = 5%; Expected Inflation Rate = 5%; Nominal Interest Rate = 10%					
100 Apples	$100	$105	5%	5%	5%
"*Cost of Life*"	$2100	$2205	5%	5%	5%
Panel 2: Ex Ante Real Interest Rate = 8%; Expected Inflation Rate = 5%; Nominal Interest Rate = 13%					
100 Apples	$156	$164	5%	8%	8%
"*Cost of Life*"	$2100	$2205	5%	8%	8%
Panel 3: Ex Ante Real Interest Rate *Unexpectedly* Increases from 5% to 8%; Expected Inflation Rate = 5%;Nominal Interest Rate Increases from 10% to 13%					
Panel 3					
100 Apples	$100	$164	64%	-54%	-51%
"*Cost of Life*"	$2100	$2205	5%	5%	8%

Note that the inflation rates in the cost of both bundles from Period 0 to Period 1 (column 4) in Panels 1 and 2 equal 5% regardless of the level of the real interest rate. However, as Panel 3 indicates, the *unexpected* rise in the ex ante real interest rate produces a sharp increase in the inflation rate for the consumer goods bundle (100 apples) but leaves the inflation rate for the "*cost of life*" equal to 5%.

The impact of an *unexpected rise* in the *ex ante* real interest rate on *estimates* of the *ex ante* real interest rate derived from changes in the costs of both bundles is clearly shown in the last two columns of Panel 3. The *estimated ex ante* real interest rate using the inflation rate for the bundle of 100 apples has *declined* to *negative* values. In sharp contrast, the *ex ante* real interest rate *estimates* using the inflation rate for the "*cost of life*" index correctly capture both the levels of the *ex ante* real interest rate in each period and the *rise* in the *ex ante* real interest rate from Period 0 to Period 1.