JOURNAL OF ECONOMICS TEACHING

TIPS for Teaching: Bridging Macro and Micro Concepts with Inflation-Protected Securities

Treasury Inflation-Protected Securities (TIPS) are useful for teaching how the microeconomic tools of consumer choice are related to key macroeconomic variables like inflation, real interest rates, and monetary policy. This paper applies the contingent-states model of optimal choice to tradeoffs between regular U.S. Treasury bonds and inflation-protected bonds, providing a new application for bridging intermediate micro and macro. As financial data and contemporary policy actions unfold during a semester, students can connect budget constraints and indifference curves to personal financial decisions and the larger macroeconomic environment.

William Grant†

†James Madison University (VA)

1. Introduction

In the study of economics, it is important to connect individual decisions with macro concepts. Treasury Inflation-Protected Securities (TIPS) are useful for teaching how the microeconomic tools of consumer choice are related to key macroeconomic variables like inflation, real interest rates, and monetary policy. This paper applies the contingent-states model of optimal choice to tradeoffs between regular U.S. Treasury bonds and inflation-protected bonds. As financial data and contemporary policy actions unfold during a semester, students can connect budget constraints and indifference curves to personal financial decisions and to the larger macroeconomic environment. This application can be used by intermediate macro instructors to show how key macro variables affect an individual investor's decisions. Alternatively, intermediate micro instructors can use this application to incorporate key macro variables into the topics of indifference curves and budget constraints.

Insurance and intermediate microeconomics textbooks frequently adapt the theory of consumer optimization to portray different outcomes of some uncertain event as being different states of nature. A loss, such as costs from illness, natural disaster, or car accident, distinguishes a bad state of nature from a good state with no loss. Insurance markets allow individuals to trade contingent consumption plans across the different states, with premiums determining the insurance buyer's budget constraint slope. Whether applied to insurance or other contexts involving uncertainty, contingent states theory provides valuable insights regarding preferences over consumption in different circumstances. Inflation uncertainty is a prime topic for demonstrating both the power and the relevance of intermediate-level consumer choice theory. Real wealth is contingent upon inflation that is uncertain at the time an individual buys financial assets, and bond markets are therefore good places to apply the contingent states model.

Contingent states models appear in several intermediate microeconomics textbooks. Nicholson (2010) generalizes the objects of a utility function into "contingent commodities" and compares bundles along the certainty line to those satisfying the tangency condition. Varian's (2014) intermediate micro textbook focuses on states of the financial world that determine whether a risky financial asset earns a positive "good" return or a negative "bad" return. Optimal portfolio allocation in Varian's setup derives from a standard first-order condition concerning the amount invested in the risky asset. In their workbook of intermediate micro problems, Bergstrom and Varian (2009) apply the contingent-states model to a variety of circumstances involving uncertainty. For an individual deciding how much to bet on the Cincinnati Reds making the World Series, students are asked to compute the budget equation and tangency condition involving tradeoffs between Reds-World-Series wealth and no-Reds-World-Series wealth. For an investor allocating wealth between a risk-free asset and stock shares of a defense contractor, optimal wealth bundles correspond to alternative states where a new weapons system is either approved or not approved by Congress. Bergstrom and Varian (2009) also ask students to analyze budget equations and tangency conditions for contingent states models of flood insurance, fire insurance, and sports-injury insurance. In Perloff's (2018) intermediate micro text, states of nature are one of several sources of uncertainty considered in contingent contracts. More advanced treatment of contingent-states applications can be found in insurance economics textbooks like Zweifel and Eisen (2012), who derive marginal rates of substitution and budget slopes for various structures of insurance premiums and consumer risk preferences. They compare optimal wealth bundles across conditions of actuarial fairness, insurer market power, a variety of consumer types, and loss experience.

In the economics pedagogy literature, Hansen (2001) asserts six general proficiencies for economics majors to develop. The topics and exercises that I propose in this paper serve three of those general proficiency goals: accessing, explaining, and interpreting existing economic knowledge. Salemi (1996) articulates four microeconomic competencies that students should master before intermediate macro, two of which are developed in this paper's material: (1) budget-constraint/indifference-curve analysis and (2) the importance of relative versus absolute prices. Perumal (2012) summarizes the debate about whether micro should be sequenced before macro, while this paper asserts that, regardless of sequencing, some material can usefully crossover from macro to micro and vice versa. The application of consumer choice theory to an individual investor's bond portfolio exemplifies Figart's (2012) assertion that the subjects of personal finance and economics are complements.

From the sizeable economic and financial research on TIPS, Bodie (1990) introduced real wealth as the appropriate focus for individual portfolios that include inflation-indexed bonds. More recently, since the original TIPS auction in 1997, Hunter and Simon (2005) analyze tradeoffs and correlations between real and nominal bonds. Dudley, Roush, and Ezer (2009) emphasize the unique benefits of TIPS both for investors and policymakers. Chu, Pittman, and Yu (2011) analyze the timing of inflation effects on TIPS prices and real yields. In an experimental survey analyzed by Armantier et al. (2015), respondents choose between an asset paying nominal interest and an asset paying inflation-adjusted interest, to see how behavior reflects inflation expectations.

In a new teaching application of state-contingent optimization, the next section introduces an inflation-states model of choice between TIPS paying real interest rates and regular Treasury bonds paying nominal interest rates. Comparative statics are covered in Section 3, including bond market effects of the appearance of Coronavirus, the possibility of greater Social Security inflation indexing, and Federal Reserve policy shifts. Section 4 describes the timing and locations of real-time information that students can use during the semester to apply their knowledge of the inflation-contingent states model. Throughout the paper, examples of homework problems and short assignments show how instructors can incorporate TIPS into the consumer choice topic for intermediate microeconomics classes.

2. A Contingent States Model with Inflation-Protected Securities

<u>Inflation-contingent wealth and the budget constraint</u>

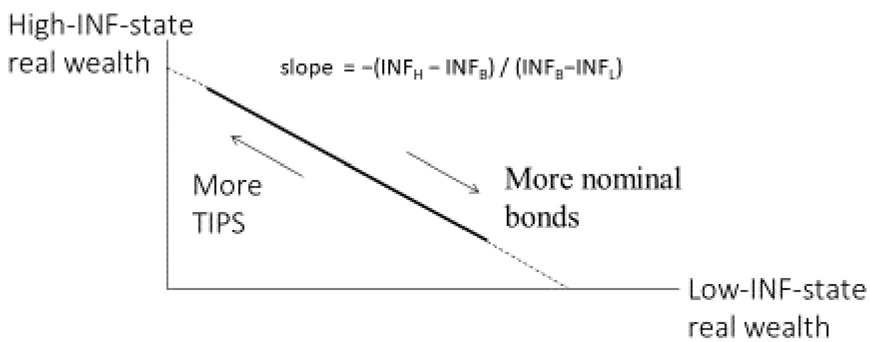
Consider an individual who has allocated some amount of current-period saving to buy and hold bonds to fund consumption in the future year when their bonds mature. Inflation between the present savings year and the future consumption year is uncertain, and the individual considers two possibilities: (1) a low-inflation state where inflation is less than or equal to market expectations and (2) a high-inflation state where inflation exceeds market expectations. If the individual is choosing between regular "vanilla" Treasury bonds and TIPS, then the individual's budget constraint provides a valuable perspective into the difference between nominal and real interest rates. Because the principal on TIPS is adjusted for inflation, the interest rate paid by TIPS is a real interest rate. In the classroom, showing students the real-time TIPS yield allows the current real interest rate to take on a tangible meaning: if you were to buy a TIPS today, your dollars would grow r percent more than inflation. To elucidate the relationship between real and nominal interest rates, ask your students: how much money will you get back if you hold a TIPS to maturity? Most students will take a while to grasp the answer that you do not know how many dollars you get back at maturity when you buy TIPS because the actual inflation that will occur between bond purchase and maturity is uncertain. Student insight about the meaning of real interest rates is aided by emphasizing that a TIPS purchase guarantees the individual a certain amount of growth in the purchasing power of their savings. If a TIPS yields 1%, then your purchasing power rises 1% annually. This is an opportune time for presenting the equation:

(1) $r = i - INF$

where r, i, and INF are the real interest rate, nominal interest rate, and inflation, respectively. TIPS guarantee a value of r, and the growth in nominal dollars will be the value of i determined by equation (1) once inflation occurs. Many students who find nominal growth more intuitive should now be able to grasp how real growth underpins the rationale for buying TIPS. Higher INF causes a TIPS owner to earn a higher i, while lower INF causes a lower i for TIPS owners.

In bond markets, equation (1) takes on a forward-looking nature. Since the actual inflation that will occur after a bond is purchased is uncertain, it is expected inflation that is related to the values of r and i. Of particular interest is *break-even inflation*, denoted INF_B, equal to the amount of inflation causing equal payoffs at maturity of a TIPS and a regular Treasury bond. Pulling up the real-time values of r and i during class allows students to see what kind of break-even inflation, equal to the difference between i and r, is implied by the current day's interest rates. For example, if i = 4% and r = 1% on 30-year regular Treasury bonds and 30-year TIPS bonds, respectively, then average annual inflation of 3% over the next 30 years would result in equivalent returns. For any pair of high-inflation and low-inflation states, the break-even inflation rate gives rise to a contingent-states budget constraint like that shown in Figure 1.

Figure 1: Inflation-Contingent Budget Line



Let INF_H be the value of inflation that an individual anticipates in some particular high-inflation state of the world and let INF_L be the value of inflation that the individual anticipates in some particular low-inflation state. An individual who is allocating some amount of wealth between regular Treasuries and TIPS bonds faces a tradeoff between real wealth in the high-inflation state, W_{HINF}, and real wealth in the low-inflation state, W_{LINF}. Buying more regular Treasury bonds, while buying less TIPS, moves the individual down the budget line and achieves higher W_{LINF} while giving up W_{HINF}. In the other direction, buying more TIPS and less regular Treasury bonds results in higher W_{HINF} and less W_{LINF}. The budget's slope equals

(2) $\Delta W_{HINF}/\Delta W_{LINF} = -(INF_H - INF_B) / (INF_B - INF_L)$

Computing the budget slope allows students to understand the tradeoffs created by market interest rates. Suppose that the individual considers the high-inflation state where INF_H = 8%, the low-inflation state where INF_L = 2%, and suppose the TIPS and regular Treasury bond yields are r = 1% and i = 4%, respectively. Since these yields have break-even inflation equal to 3% (the difference between i and r), the contingent-states budget line has a slope equal to (.08–.03)/(.03–.02) = –5. The individual has to give up $5 of high-inflation-state real wealth for each additional dollar of low-inflation-state real wealth, or moving in the other direction, must give up \$0.20 of W_{LINF} per additional dollar of W_{HINF}.

In developing students' skills for applying the budget slope formula (2), it is important to focus on the way that portfolio reallocations are connected to the slope. Analysis of portfolio reallocations requires students to translate from the general relationships between i, r, INF_H, and INF_L to any particular profile of values for these variables. Given the values of i =4%, r = 1%, INF_H = 8%, and INF_L = 2% from above, an instructive sequence of questions is given in sample problem 1.

Sample problem 1 on the inflation-contingent budget line:

a. To gain dollars of low-inflation-state real wealth (W_{LINF}) and give up dollars of high-inflation-state real wealth (W_{HINF}), does the individual buy more TIPS and less regular Treasury bonds or does the individual buy more regular Treasury bonds and less TIPS? **Answer: more regular bonds and less TIPS**
b. To gain a dollar of low-inflation-state wealth (W_{LINF}), how many dollars of wealth does the individual have to move out of TIPS and into Treasury bonds? **Answer: 1 / [(i–INF_L)–r] because, in the low-inflation state, the regular bonds' real growth rate of (i–INF_L) exceeds the TIPS' real growth rate of r. So, for the given parameter values, the individual has to move 1 / [(.04–.02)–.01] dollars (= \$100) out of TIPS and into Treasury bonds to gain a dollar of W_{LINF}.**
c. By moving the amount of money (from your answer in part b) out of TIPS and into Treasury bonds, how much high-inflation-state real wealth (W_{HINF}) will the individual have given up? **Answer: [r–(i–INF_H)]·100 because, in the high-inflation state, the TIPS real growth rate of r exceeds the regular bond's real growth rate of (i–INF_H). So the individual will have given up [.01–(.04–.08)]·100 dollars (= \$5) of W_{HINF}.**

This problem allows students to see how the budget slope formula in equation (2) puts together the answers from parts a, b, and c above. Substituting regular Treasuries in place of TIPS will increase low-inflation-state real wealth because (i – INF_L) > r in the low-inflation state. Transferring x dollars out of TIPS into regular Treasuries will raise W_{LINF} by [(i–INF_L)–r]·x. So for the sample problem part b, transferring \$100 out of TIPS into regular Treasuries will increase W_{LINF} by \$1 = [(.04–.02)–.01]·100. This portfolio reallocation will reduce high-inflation state wealth since (i – INF_H) < r. In particular, the \$100 would have earned a real return of +1% (= r) in the high-inflation state had it not been taken out of TIPS, but it only earns a real return of –4% (= i – INF_H) when it's moved into regular Treasuries. The difference between these real rates of return, equal to 1% minus –4%, is the 5% lower real return on the \$100 that was transferred. This means that the individual will have given up \$5 in W_{HINF}.

Another way for students to derive the budget slope is to compute coordinate values for two different real wealth bundles. As a second example scenario, suppose that the individual considers the high-inflation state involving INF_H = 5%, the low-inflation state involving INF_L = 0%, and suppose the TIPS and regular Treasury bond yields are r = 1% and i = 3%, respectively.

Sample problem 2 on inflation-contingent wealth bundles:

a. For an individual who has decided to invest \$10,000, compute the inflation-contingent real wealth bundles from purchasing all TIPS and from purchasing all regular bonds. **Answer: The all-TIPS bundle is (W_L = 10,100, W_H = 10,100) and the all-regular-bonds bundle is (W_L = 10,300, W_H = 9,800).**
b. Use your answer from part a to compute the slope of the inflation-contingent budget line, $\Delta W_{HINF}/\Delta W_{LINF}$, and interpret the meaning of that slope value. **Answer: slope =**

(9,800 – 10,100)/(10,300 – 10,100) = -1.5. This means that the individual has to give up \$1.50 of W_{HINF} for each additional dollar of W_{LINF}, and the individual has to give up \$0.67 of W_{LINF} for each additional dollar of W_{HINF}.

Expected utility of state-contingent wealth and the optimal bond portfolio

To depict state-contingent preferences, indifference curves can be shown for an expected utility function over alternative bond portfolios. The individual may be assumed to maximize:

(3) $EU(W_{HINF}, W_{LINF}) = prob_{HINF}U(W_{HINF}) + (1-prob_{HINF})U(W_{LINF})$

where $prob_{HINF}$ denotes the probability of the high-inflation state and utility U has positive but diminishing marginal utility of state-contingent wealth. The individual is risk averse if losing a dollar of wealth in any given state causes U to decline by more than gaining a dollar of wealth would cause U to rise in that state. Because a risk-averse individual's marginal utility of wealth diminishes, the individual may seek to avoid wealth bundles where W_{HINF} and W_{LINF} differ greatly. Preferences over the various possible wealth bundles are reflected in the marginal rate of substitution of W_{LINF} in place of W_{HINF} :

(4) $MRS_{WLINF,WHINF} = (1-prob_{HINF})\cdot MU_{LINF} \;/\; prob_{HINF}\cdot MU_{HINF}$

The $MRS_{WLINF,WHINF}$ is the amount of high-inflation-state wealth that the individual is willing to sacrifice per additional dollar of low-inflation-state wealth gained while keeping EU unchanged. Similar to marginal rates of substitution in other contexts with which students are familiar, the $MRS_{WLINF,WHINF}$ in (4) is diminishing, and along any budget line, the individual will compare the budget slope to the $MRS_{WLINF,WHINF}$ to achieve their optimal wealth bundle.

Given risk aversion, the diminishing MU terms in (4) ensure that $MRS_{WLINF,WHINF}$ is diminishing in W_{LINF}, i.e. the slope of any given indifference curve becomes flatter as W_{LINF} rises. The typical convex-to-the-origin shape of an indifference curve reveals the risk-averse individual's incentive for bond portfolio diversification. If a risk-averse individual considers a portfolio containing a relatively large share of regular bonds and a relatively small share of TIPS, such as the bundle shown in Figure 2a, then they are relatively reluctant to substitute low-inflation-state wealth in place of high-inflation-state wealth. Bundle A in Figure 2a has relatively high W_{LINF} and low W_{HINF}, causing a low numerator and a high denominator in $MRS_{WLINF,WHINF}$. In contrast, if the individual considers a TIPS-heavy portfolio such as bundle B in Figure 2b, then expected utility is maintained by giving up a relatively large amount of W_{HINF} since the dollars gained of low-inflation-state wealth have high marginal utility. Mathematically, the low W_{LINF} and high W_{HINF} in the bundle B portfolio means a high numerator and a low denominator in $MRS_{WLINF,WHINF}$.

Figure 2a: A Wealth Bundle with Low Willingness to Substitute Regular Bonds in Place of TIPS

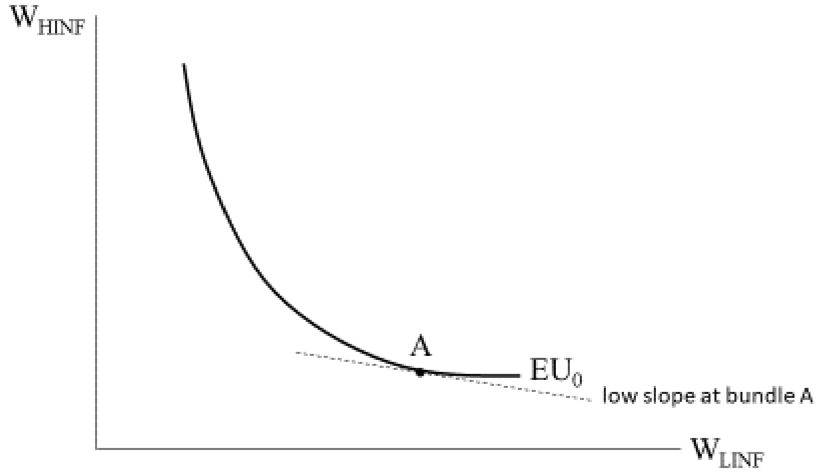
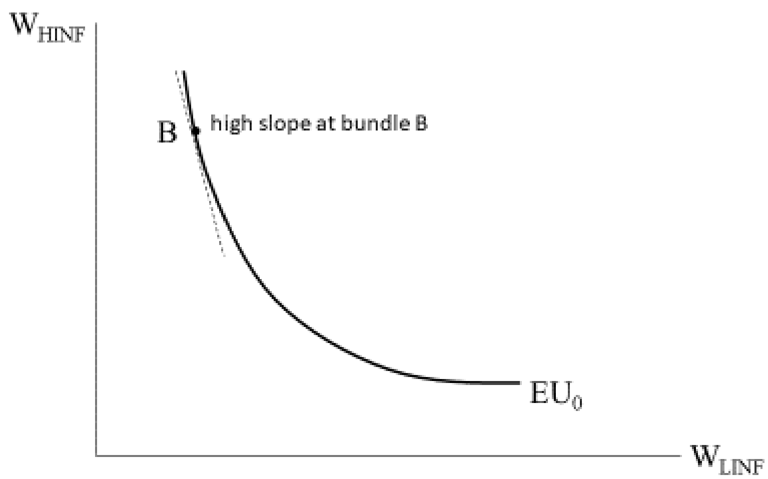


Figure 2b: A Wealth Bundle with High Willingness to Substitute Regular Bonds in Place of TIPS

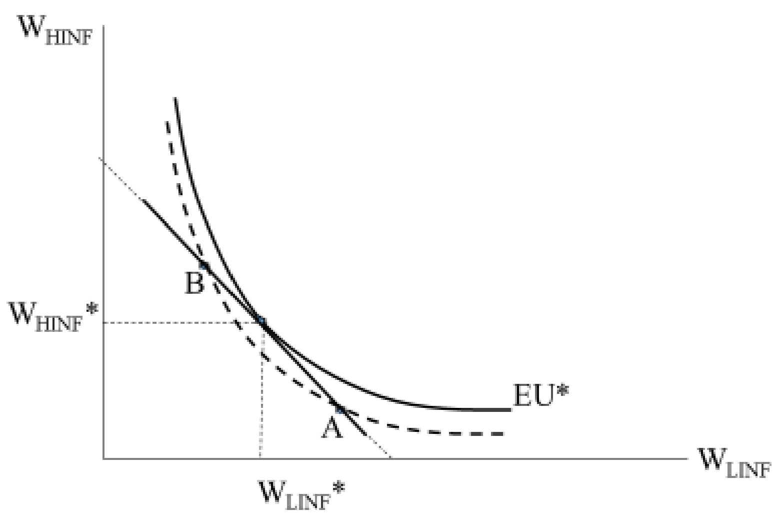


Risk aversion, and the associated $MRS_{WLINF,WHINF}$, mean that expected dollars in the high-inflation-state are not perfect substitutes for expected dollars in the low-inflation-state. Starting from portfolios that have insufficient inflation protection, or starting from bundles with excessive inflation protection, the substitution of dollars across the two different states can increase the individual's expected utility. The optimal bond portfolio is achieved by exploiting those EU-enhancing substitutions to the maximum extent possible. Graphically, the individual chooses whichever portfolio along the budget line that lies on the most preferred indifference curve.

An interior optimum will achieve tangency between the budget line and the indifference curve, such as the bundle W_{LINF}*,W_{HINF}* shown in Figure 3. There is no portfolio change that would raise the individual's expected utility since the amount of W_{HINF} that the individual is willing to give up in exchange for one more dollar of W_{LINF} and maintain constant expected utility is exactly equal to the amount of W_{HINF} that market interest rates require the individual to give up to gain a dollar of W_{LINF}. Sub-optimal wealth bundles along the budget line are less preferred than W_{LINF}*,W_{HINF}* since the individual's expected utility rises from moving towards W_{LINF}*,W_{HINF}* and moving away from any other possible bundle. Rather than choose bundle A in Figure 3, for instance, the individual would substitute TIPS in place of regular bonds since they are willing to give up more W_{LINF} per dollar of W_{HINF} gained than the opportunity cost that is actually required. Graphically, the reciprocal of the budget slope equals the amount of W_{LINF} that the individual has to give up per dollar of W_{HINF} gained according to the market interest rates. Incurring the required opportunity cost indicated by the budget line thus causes a favorable tradeoff for the individual: they give up some W_{LINF} by buying fewer regular bonds, but the resulting increase in W_{HINF} more than offsets that sacrifice so the net result is an increase in EU.

The $MRS_{WLINF,WHINF}$ running through Bundle B, on the other hand, exceeds the budget slope's magnitude. Rather than choose bundle B, the individual would substitute regular bonds in place of TIPS because they are willing to give up more W_{HINF} per dollar of W_{LINF} gained than what's required by market interest rates. The budget line's slope equals the amount of W_{HINF} that must be given up per dollar of W_{LINF} gained, and the high-inflation-state EU loss is more than offset by the additional EU in the low-inflation state. With the optimal portfolio, consisting of W_{LINF}* and W_{HINF}*, no substitutions between TIPS and regular bonds can raise expected utility.

Figure 3: Optimal Wealth Bundle from TIPS and Regular Bonds

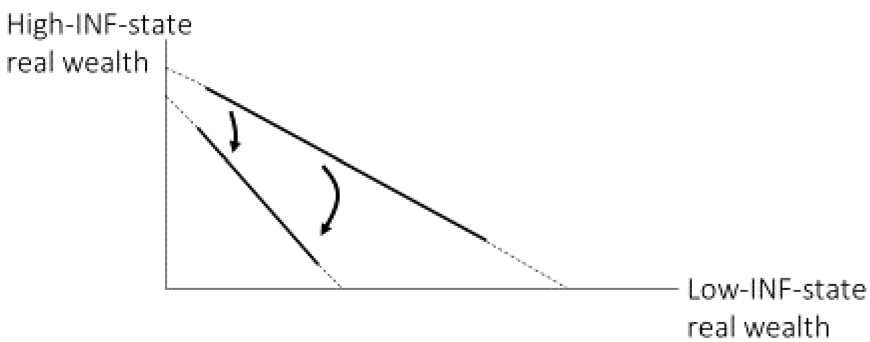


3. Comparative Statics

Immediate Impact of Coronavirus

Changes in the macroeconomic environment and/or in the individual's microeconomic circumstances can be demonstrated in the contingent-states framework. For an individual buying bonds to hold to finance future consumption at maturity, the optimal choice is affected by other bond market participants' behavior. As the coronavirus news unfolded, the rush into lower-risk assets in March 2020 increased demand for both TIPS and regular Treasury bonds by investors seeking speculative gains. However, regular T-bonds saw a relatively greater influx of short-term traders than TIPS bonds as a shelter from the breaking storm because the regular T-bond market is more liquid and therefore easier to buy into and later sell out of, while TIPS are less so (Andreasen & Christensen, 2016; Fleming & Krishnan, 2012). This partly reflects how, on the secondary market, there are markedly fewer TIPS for sale with fewer than 50 different maturities, whereas regular T bonds are available in markedly greater volume and nearly continuous maturity date choices (more than 500). The budget constraint for hold-to-maturity bond investors, therefore, steepened as the increase in demand for regular bonds outpaced the increase in TIPS demand, causing the break-even inflation rate to markedly drop. Between March 9 and March 20, for example, the ten-year break-even inflation rate fell by more than one percent, from 1.46% to 0.43%. For an individual considering the contingent states involving $INF_H = 4\%$ and $INF_L = 0\%$, the resulting budget slope steepened from $-(.04-0.0146)/(.0146-0.0)$ to $-(.04-0.0043)/(.0043-0.0)$, which comes from plugging the values of INF_B, INF_H, and INF_L into equation (2). The budget slopes on March 9 and March 20 were, respectively, -1.74 and -8.30. After this drop in break-even inflation, \$8.30 of high-inflation-state real wealth had to be given up per dollar of low-inflation-state real wealth gained. Substituting regular bonds in place of TIPS became much more expensive. Conversely, the relative price of TIPS (relative to regular Treasuries) dropped to a historic low. On March 9, for an individual considering the contingent states involving $INF_H = 4\%$ and $INF_L = 0\%$, the individual had to give up \$0.57 of W_{LINF} per dollar of W_{HINF} gained, while on March 20, only \$0.12 of W_{LINF} had to be given up to gain a dollar of W_{HINF}. All else equal, for buy-and-hold bond investors, this change in relative prices created substitution effects for TIPS over regular Treasuries. However, the overall effect on a buy-and-hold investor's bond bundle is undetermined because lower real returns for both assets created an uncertain income effect.

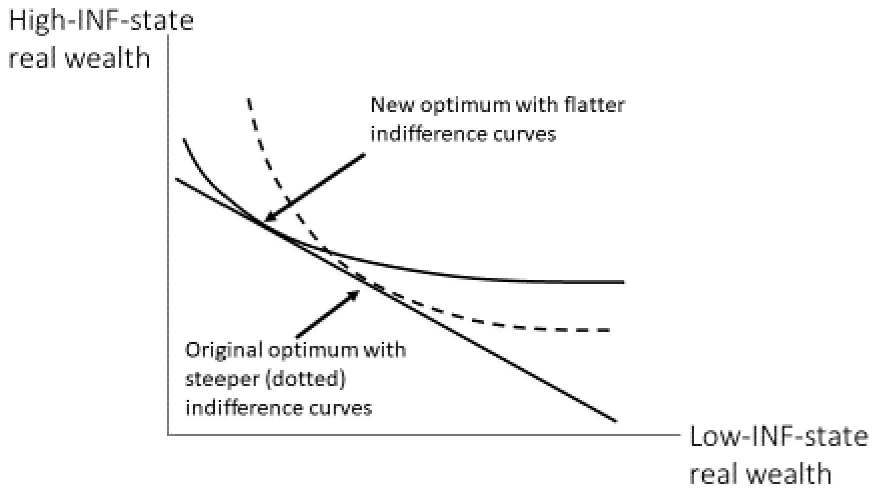
Figure 4: Effects of Coronavirus Flight to Liquidity



<u>Changes in an individual's exposure to inflation</u>

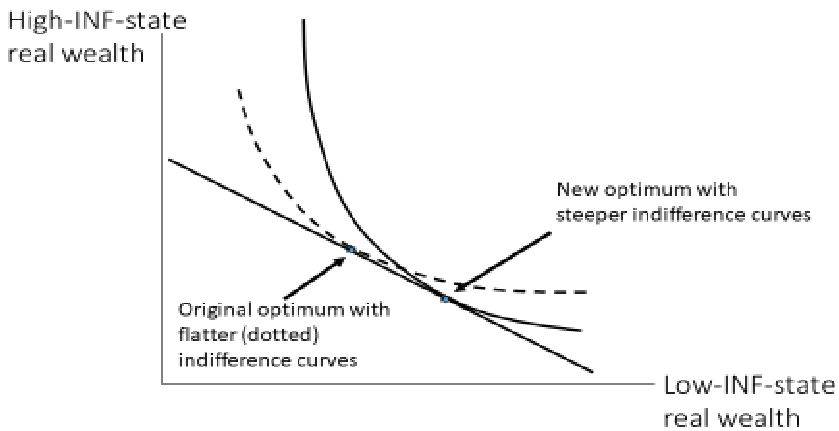
The contingent-states model elucidates how important changes in the investor's circumstances affect his or her portfolio choices. Such effects could arise from changes in the individual's subjective inflation-state probabilities, or changes in the individual's marginal utilities, or both. Consider an individual who expects higher inflation is more likely due to increased government debt. Like all contingent-states models, preferences over alternative wealth bundles reflect the relative likelihoods that an individual attaches to different states. Figure 5 shows how the indifference curves become flatter if the individual believes high inflation is more likely, as the marginal rate of substitution of W_{LINF} in place of W_{HINF} falls. Mathematically, a higher value of $prob_{HINF}$ reduces the value of equation 4, meaning that the individual is willing to give up less high-inflation-state real wealth per additional dollar of low-inflation-state real wealth when they perceive high inflation's likelihood has risen. By substituting TIPS in place of regular bonds, the individual moves to a new indifference curve and a new optimum.

Figure 5: Greater Government Debt Raising the Individual's Subjective Probability of High Inflation



Even if there are no changes in the individual's perceived likelihood of inflation, external factors could lead the individual to value wealth in one of the inflation states relatively more or less. That is, a change in MU_{LINF}/MU_{HINF} could cause a change in the $MRS_{WLINF,WHINF}$ even if $prob_{HINF}$ is unchanged. If, for instance, policymakers were to enhance the Cost-of-Living Adjustment (COLA) to create greater inflation indexing for social security benefits, then the individual would gain wealth in the high-inflation state from non-bond sources. This would cause a decrease in the marginal utility of high-inflation-state wealth and therefore an increase in the MRS. With more of the inflation risk covered by future Social Security income, the individual would be more willing to give up W_{HINF} to gain dollars of W_{LINF} in order to gain the greater nominal rates of return from regular Treasury bonds without suffering as much exposure to the high-inflation state risk. Figure 6 represents this scenario with a steepening of the indifference curves leading to a new optimum with less TIPS and more regular bonds.

Figure 6: Effects of Greater Inflation Indexing of Social Security Payments



Monetary Policy Effects

Many markets move at the whim of Federal Reserve policy redirection, but TIPS markets, in particular, respond in interesting and varied ways when the Fed indicates greater tightening or loosening in their stance. If Fed reveals a tighter monetary future, secondary TIPS markets participants have to compare the direct effects of higher interest rates on TIPS demand versus the indirect effects on TIPS demand from changes in inflation expectations. It could be that demand for TIPS will fall because interest rates moving higher signals a time to sell your TIPS (sell now before rates rise and bond prices fall), or alternatively, the very risk of higher inflation that led the Fed to tighten could stimulate TIPS demand (buy now before higher inflation materializes and TIPS' principal appreciates). Regular Treasury bond markets respond in a perfectly predictable direction from monetary policy moves because both the interest rate risk and the inflation risk cause the same kind of change in regular Treasury bond demand. The Fed tightening unequivocally reduces secondary market regular bond demand because investors should sell before rates rise and because the root cause of the Fed tightening (higher potential inflation) makes nominal bonds less valuable. But the inflation-adjusted nature of inflation-protected bonds means that TIPS prices sometimes rise and other times fall from contractionary monetary policy announcements.

On the other hand, a shift towards more expansionary monetary policy will affect TIPS demand via the resulting anticipation of lower interest rates. All else equal, this encourages TIPS (and other bonds) buying as traders anticipate the coming rise in bond prices. However, there can be a simultaneous change in inflation expectations coinciding with a shift to more expansionary policy. If the Fed's announcement or data indicates that they are making the shift because their predictions concerning future inflation have been lowered, then there would be a negative effect on TIPS demand as investors substitute towards other kinds of assets (including regular bonds) from lower inflation expectations. The net effect on TIPS demand in a scenario like this could be positive or negative depending on whether the interest rate effect or the inflation expectations effect dominates.

Sample problem 3 on Federal Reserve effects on real and nominal interest rates

a. How and why will demand for TIPS and demand for regular bonds be affected when the Fed indicates a tighter monetary policy direction?
b. As a result of your answer in part a, how will the real interest rate r, the nominal interest rate i, and the break-even inflation rate INF_B change?

Table 1: Monetary Policy Possibilities for Sample Problem 3

	Federal Reserve shift:	
	more contractionary / less expansionary	more expansionary / less contractionary
Market forms lower inflation expectation	Interest rates rise with $\lvert +\Delta i \rvert < \lvert +\Delta r \rvert$ so break-even inflation falls (Fed move is big enough and early enough to reduce INF expectations)	Interest rates fall with $\lvert -\Delta i \rvert > \lvert -\Delta r \rvert$ so break-even inflation falls (Fed move is too small or too late to thwart disinflationary expectations)
Market forms higher inflation expectation	Interest rates rise with $\lvert +\Delta i \rvert > \lvert +\Delta r \rvert$ so break-even inflation rises (Fed move is too small or too late to head off INF expectations)	Interest rates fall with $\lvert -\Delta i \rvert < \lvert -\Delta r \rvert$ so break-even inflation rises (Fed move is big enough or early enough to fuel higher inflation expectations)

4. Classroom connections to bond market events and personal finance

TIPS auctions during an academic semester present opportunities for writing assignments requiring students to apply the inflation contingent-states framework. New issue auctions occur for 5-year TIPS in April and October; for 10-year TIPS in January and July; and for 30-year TIPS in February. Immediately after an auction, students can play the role of economic reporter by writing about the auction results in terms of interest rates, bond prices, and break-even inflation expectations. For a hold-to-maturity investor, explaining whether a recent auction was a good buying opportunity serves as a useful writing assignment.

Sample writing assignment for analysis of real-world TIPS auctions
How did the recent TIPS auction compare to prior auctions' outcomes and what does this mean for the individual's budget constraint and optimal choice? What long-term and short-term macroeconomic factors affected the auction results? What predictions about a buy-and-hold investor's future bond market opportunities can you make based on the auction results?

Table 2: Data and Information Sources

Resource	Key Content
https://tipswatch.com	
TIPSwatch by David Enna	Best source for analysis before and after auctions, with links to all of the U.S. Treasury auction result press releases. Contains intelligent analysis of economic conditions that are relevant for trends in break-even inflation (INF_B). Great for provoking students' thoughts for purposes of short-essay assignments like Assignment 4.
https://www.treasurydirect.gov/indiv/research/indepth/tips/res_tips_faq.htm	
Treasury Direct TIPS FAQ (2021)	This is the Treasury's site for buying TIPS at auction. Explains in clear terms how TIPS' principal is calculated based on Consumer Price Index inflation.
https://www.bloomberg.com/markets/rates-bonds/government-bonds/us	
Bloomberg United States Rates & Bonds	Best source for r and i. "Yield" column 4 in TIPS table shows minute-by-minute values of the real interest rate r for the most recently traded TIPS by maturity. "Yield" column 4 in Treasury Yields table shows minute-by-minute values of the nominal interest rate i for the most recently traded regular bonds by maturity.
https://www.wsj.com/market-data/bonds/tips	
Wall Street Journal Current Yields (2021)	More detailed source for r and i. Lists real interest rate (r) for each particular previously issued TIPS that is currently trading on the secondary bond market, as of the most recent calendar date. "Yield" in column 6 equals r.

Auctions that are re-openings of previously issued TIPS present opportunities for students to see the relationship between bond prices and interest rates in action (reopenings are in June and December for 5-year TIPS; in March, May, September, and November for 10-year TIPS; and in August for 30-year TIPS). When a TIPS is re-opened, a buyer receives the same coupon interest rate and the same maturity date as the original issue but usually a different price according to market conditions. For TIPS re-openings, students can demonstrate their understanding of the relationship between bond prices and interest rates to explain how and why the re-opening real yield compares to the original issue real yield. How and why has demand for the TIPS changed; how has break-even inflation changed; how has the budget slope changed? Between the original issue and re-opening, what kind of indifference curve shifts may be representative of the market-level TIPS demand? Has a typical investor attached greater or less probability to high-inflation versus low-inflation in the time since the original TIPS issue, and has this caused steepening or flattening in indifference curves?

Since auctions occur only sporadically throughout a semester, it may be useful to have students examine and interpret TIPS prices on the secondary market. Websites provide up-to-the-minute secondary market data on 5-, 10-, and 30-year TIPS, such as Bloomberg Rates & Bonds (2021). Students can see the effects of any day's economic news on yields, such as real yields turning more negative as the COVID-19 crisis emerged. Exchange-traded funds like iShares TIP ETF offer inter-auction evidence on demand, as well as a way for students to connect ETF prices immediately following a TIPS auction to gauge how the auction result compared to market expectations.

More liquid and more volatile vehicles for TIPS investing, like mutual funds and ETFs, allow students to see the nature of market risk as separate from interest rate risk and inflation risk. Investment- and finance-minded students will be interested in the personal financial details of TIPS portfolio building. Financial media like David Enna's (2021) TIPSwatch or Michael Ashton's (2021) Inflation Guy regularly post economically insightful analyses for inflation-protective investing. A comprehensive discussion of the pros and cons of constructing a ladder of many individual TIPS is provided by Bodie and Taqqu (2012). Unexpected needs may not coincide with maturity dates and individual TIPS may be harder to sell than shares in a mutual fund or ETF. Individual TIPS purchases may not be allowed by some 401k plans or other tax-efficient savings vehicles whereas inflation-protected mutual and exchange-traded funds usually are. Individual TIPS held in after-tax accounts suffer the disadvantage of "phantom tax" due to increases in the inflation-adjusted principal when that inflation occurs prior to maturity. These details help students understand how TIPS could form a part of their personal financial future, as well as how the inflation-contingent micro model could be affected by these details.

5. Conclusions

Students will be better motivated to learn consumer optimization if they find the choice variables relevant and interesting. Once the basics of budget lines and indifference curves have been established, inflation-contingent states provide a fascinating context for mastering choice theory. Learning to compute budget line slopes connects personal finance to real-world data on interest rates and break-even inflation. Understanding indifference curve shapes connects inflation uncertainty with risk preferences. To integrate across economics classes, TIPS take the core microeconomic tools out of the micro textbook and into the macro news headlines. The model explains how a Fed policy shift alters the set of inflation-contingent wealth bundles available to a buy-and-hold bond investor. Inflation-state probabilities cause a different marginal rate of substitution when government fiscal decisions foretell of the rising national debt. And when bond market data reveal a change in break-even inflation, students see the similarity to changes in price tags at the grocery store. Tradeoffs between TIPS and regular bonds involve some of the most important variables covered in macroeconomics courses: inflation, real and nominal interest rates, and macroeconomic policy. TIPS demonstrate the teaching and learning complementarities between these macroeconomic variables and the workhorse microeconomic model of optimal choice.

References

Andreasen, M.M., & Christensen, J. 2016. TIPS liquidity and the outlook for inflation. *Federal Reserve Bank of San Francisco Economic Letter, 35*: 1-5.

Armantier, O., Bruine de Bruin, W., Topa, G., Van Der Klaauw, W., & Zafir B. 2015. Inflation expectations and behavior: Do survey respondents act on their beliefs? *International Economic Review, 56*(2): 505-537.

Ashton, M. 2021. *The inflation guy* https://twitter.com/inflation_guy.
Bergstrom, T.C., & Varian, H.R. 2009. *Workouts in intermediate microeconomics*. New York, NY: W.W. Norton & Company.

Bloomberg. 2021. https://www.bloomberg.com/markets/rates-bonds/government-bonds/us.

Bodie, Z. 1990. Inflation, index-linked bonds, and asset allocation. *Journal of Portfolio Management*, *16*(2): 48-53.

Bodie, Z., & Taqqu, R. 2012. *Risk less and prosper: Your guide to safer investing*. John Wiley & Sons.

Chu, Q.C., Pittman, D.N., & Yu, L.Q. 2011. When do tips prices adjust to inflation information? *Financial Analysts Journal, 67*(2): 59-73.

Dudley, W.C., Roush, J., & Ezer, M.S. 2009. The case for TIPS: An examination of the costs and benefits. *Economic Policy Review of the Federal Reserve Bank of New York, 15*(1): 1-17.

Enna, D. 2021. *TIPSwatch*. https://tipswatch.com.

Figart, D.M. 2012. Economics and personal finance education are complements, not substitutes. *International Journal of Pluralism and Economics Education, 3*(4): 354-360.

Fleming, M.J., & Krishnan, N. 2012. The microstructure of the TIPS market. *Economic Policy Review of the Federal Reserve Bank of New York, 18*(1): 27-45.

Hansen, W.L. 2001. Expected proficiencies for undergraduate economics majors. *The Journal of Economic Education, 32*(3): 231-242.

Hunter, D.M., & Simon, D.P. 2005. Are TIPS the real deal? A conditional assessment of their role in a nominal portfolio. *Journal of Banking and Finance, 29*: 347-368.

Nicholson, W., & Snyder, C. 2010. *Intermediate microeconomics and its applications*. Mason, Ohio: South-Western, Cengage Learning.

Perloff, J.M. 2018. *Microeconomics*. New York, NY: Pearson Education.

Perumal, M. 2012. Should we teach microeconomics before macroeconomics? Evidence from an Australian university. *Australasian Journal of Economic Education, 9*(2): 1-14.

Salemi, M.K. 1996. Microeconomic concepts students should learn before intermediate macroeconomics. *The Journal of Economic Education, 27*(2): 116-125.

Treasury Direct. 2021. https://www.treasurydirect.gov/indiv/products/prod_tips_glance.htm.

Varian, H.R. 2014. *Intermediate microeconomics: A modern approach*. New York, NY: W.W. Norton & Company.

Wall Street Journal Current Yields. 2021. https://www.wsj.com/market-data/bonds/tips.

Zweifel, P., & Eisen, R. 2012. *Insurance economics*. Heidelberg, Germany: Springer.

Appendix 1

This appendix reviews the topics of indifference curves, budget-constrained optimization, and risk aversion for instructors who have not recently taught Intermediate Microeconomics. The bond wealth applications in this paper build upon these concepts. To represent preferences over good x and good y, an **indifference curve** shows bundles of x and y that provide the same level of total utility (i.e., the consumer is indifferent between all bundles on a given indifference curve). For any particular good, the **marginal utility** is the change in total utility resulting from a change in the consumption of that good, holding constant quantities of other goods consumed. The ratio of MU_x/MU_y is the **marginal rate of substitution of x in place of y** (denoted $MRS_{x,y}$), where MU_x and MU_y are the marginal utilities of x and y, respectively. For typical preferences, $MRS_{x,y}$ equals the negative of the slope of the indifference curve. The $MRS_{x,y}$ quantifies how much good y the consumer is willing to give up in exchange for an additional unit of x and maintain constant utility.

The **hypothesis of diminishing marginal utility** states that additional units of consumption of a good provide successively smaller increments to utility. When there is diminishing marginal utility, the marginal rate of substitution of x in place of y will diminish, the more x (the less y) the consumer has along any given indifference curve. This gives rise to a convex-to-the-origin curvature of each indifference curve.

Different indifference curves correspond to different levels of utility. For typical preferences (where both x and y have positive marginal utility), along any line from the origin, a further-from-the-origin indifference curve has higher utility than a closer-to-the-origin curve. Consumer choice is constrained by some **budget line**, which is the set of bundles that are affordable, given unit prices p_x and p_y and exhausting income I. The budget line slope is $-p_x/p_y$. The negative of this budget line slope quantifies how much good y the consumer has to give up in order to afford an additional unit of x. The consumer's goal is to choose the bundle that maximizes the consumer's utility, while still being affordable with the consumer's income and the goods' prices. Graphically, the consumer picks the bundle which lies on the budget line and reaches the highest-utility indifference curve. For an interior optimum, this results in a bundle where $p_x/p_y = MRS_{x,y}$. This is the **tangency condition**, meaning that the consumer's willingness to give up y to gain x exactly matches how much y the marketplace requires the consumer to give up to gain x.

The bond wealth context described in this paper, as well as other contingent states applications, use indifference curves to show risk preferences regarding state-contingent amounts of wealth. Typical shaped curves, with negative slope and convex to the origin, indicate risk aversion. Because of uncertainty over which state will occur, an individual may face uncertain wealth. A risk-averse individual has a lower **certainty-equivalent wealth** than the expected wealth from the gamble, where certainty-equivalent wealth equals how much wealth the individual would have to receive with certainty in order to be indifferent to taking the gamble. Risk aversion can also be defined in terms of the expected utility dimension. For a risk-averse individual, the expected utility from the gamble is less than the utility if they were to receive the expected wealth from the gamble with certainty. Graphically, with alternative state-contingent wealth amounts on the axes, the typical indifference curve shape shows how risk aversion is equivalent to diminishing marginal rate of substitution of wealth across states. When an individual has more wealth in a given state of the world, they are less willing to give up wealth in the alternative state, if expected utility is to remain constant. In a contingent-states framework, the convex-to-the origin shape implies risk aversion because a mixture between any two points on an indifference curve will lie on a more preferred indifference curve. That is, for any two bundles of state-contingent wealth between which the individual is indifferent, a weighted average of those two bundles will be preferred over each of those two bundles.