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# *Using Amazon Prime Membership to Teach Compensating and Equivalent Variation*

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## ABSTRACT

This paper uses indifference curve analysis to derive simple theoretical measures of the compensating and equivalent variation from joining (or canceling) a paid subscription service that provides access to lower prices, such as an Amazon Prime membership. The case provided here may be a useful tool for teaching an otherwise abstract concept in an undergraduate microeconomics course, as it extends the standard textbook approach to examine real-world questions of interest facing a well-known company. It is demonstrated that compensating and equivalent variation can serve as an important guide in the price-setting process under a business model of this type.

## Introduction

In teaching microeconomics at the undergraduate level, I have observed that students regularly have difficulty understanding certain topics. The abstract nature of consumer theory, in particular, renders concepts such as compensating (CV) and equivalent (EV) variation especially challenging. My experience has been that many students memorize the textbook diagrams in the hopes that they will be asked to simply reproduce one of the combinations (CV or EV for a price increase or decrease) on a homework assignment or exam. While some students can accurately draw the indifference curves and budget lines, many of the same students cannot correctly answer conceptual questions pertaining to the topic. My discussions with colleagues from other institutions reveal similar concerns. If our aim is for students to truly understand these concepts and develop awareness of the wealth of information that consumer theory has to offer (especially to a firm), then an effective approach is to use relevant real-world examples that are a part of their daily lives (Picault 2019).

In this paper, I offer a simple, real-world instructional example that links these key measures of welfare change to a consumer's decision to join (or cancel) Amazon Prime, a service to which many college students subscribe, or are at least familiar with. In a similar spirit, Sirianni (2017) provides a class activity in which students' own choices lead to isolation of the income and substitution effects of a price change—topics which are closely related to CV and EV. My focus here, however, is on the insights that CV and EV in particular can bring to the *firm*, a topic which is not among the myriad examples surveyed by Picault (2019). The example demonstrates that if Amazon could empirically estimate a consumer's CV and EV, it would acquire relevant information to answer several key questions.

Consider a consumer who does not have Prime: How much would she be willing to pay for it? What other factors are keeping her from signing up? Now consider a current Prime member: What would cause her to cancel the membership? How much is she willing to pay to keep it? To answer these questions, the standard textbook approach to presenting CV and EV (Hicks 1939) is modified to account for the membership fee (Nechyba 2016), thus making the topic more realistic and relatable. The primary aim is to show that CV and EV are not simply abstract theoretical constructs or intellectual curiosities, but that knowledge of them helps guide sound decision-making by the firm. Although we may not know specifics due to non-disclosure agreements, there must be some very good reasons behind the fact that Amazon has been furiously hiring economists, and microeconomic theorists to boot, in recent years.[2] Evidently, Amazon considers economic

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[2] https://www.cnn.com/2019/03/13/tech/amazon-economists/index.html.

analysis to be worth the price, and not "just theory."

The paper proceeds as follows. The next section presents a simple, stylized model of Amazon Prime membership that is suitable for an undergraduate audience. I then demonstrate how CV and EV are linked to prospective and current members' valuations of the service. The final section concludes.

## A Simple Model of Amazon Prime Membership

Suppose a consumer allocates her income to the purchase of Amazon (*A*) and, say, Walmart goods (*W*). The budget constraint is given by either

$$(p_A + S)Q_A + Q_W = M \qquad (1)$$

or

$$p_A Q_A + Q_W = M - f \qquad (2)$$

where $p_A$ is the price of the Amazon good and *S* is the shipping rate, the latter of which is charged only if the consumer does not pay a fee of $f$ to become a Prime member. The consumer uses income $M$ to purchase quantities $Q_A$ and $Q_W$ of the two goods. Because the consumer is concerned only with the relative price of *A* with respect to *W*, assume $p_w$ is equal to 1 for convenience. Note that the budget constraint the consumer actually faces depends upon the choice of whether or not to become a Prime member: nonmembers face budget constraint (1), while Prime members face (2).

Of course, this model makes a number of simplifying assumptions, among them that the consumer spends all her income (say, her "online budget") on a single, homogeneous good from each supplier. The model also does not allow for the bundling of two or more items at a fixed shipping rate; qualifying for free shipping once a spending threshold is reached; or the inclusion of other member benefits such as access to Prime Video. Nevertheless, students should be encouraged not to discount the analysis, as these assumptions are made only for mathematical and graphical tractability. Instead, it is useful to consider this model as a starting point for—or gateway to—a much more sophisticated analysis. I like to tell students that the theory helps us to "organize our thoughts" on the issue at hand. The intent is to highlight the salient features of actual consumer behavior. As mentioned in the introduction, Amazon hires microeconomists and has access to copious amounts of consumer spending data. It is therefore possible for this highly stylized model to be generalized, fine-tuned, and perhaps, with adequate data, operationalized.[3]

The main discussion and figures in the next section characterize a consumer who will always have higher utility with a Prime membership than without. I discuss but do not formally present in figures how the model allows for a consumer to be better off by canceling her membership or not signing up in the first place.

## Compensating Variation

### *The Prospective Prime Member: How Much Is She Willing to Pay for It?*

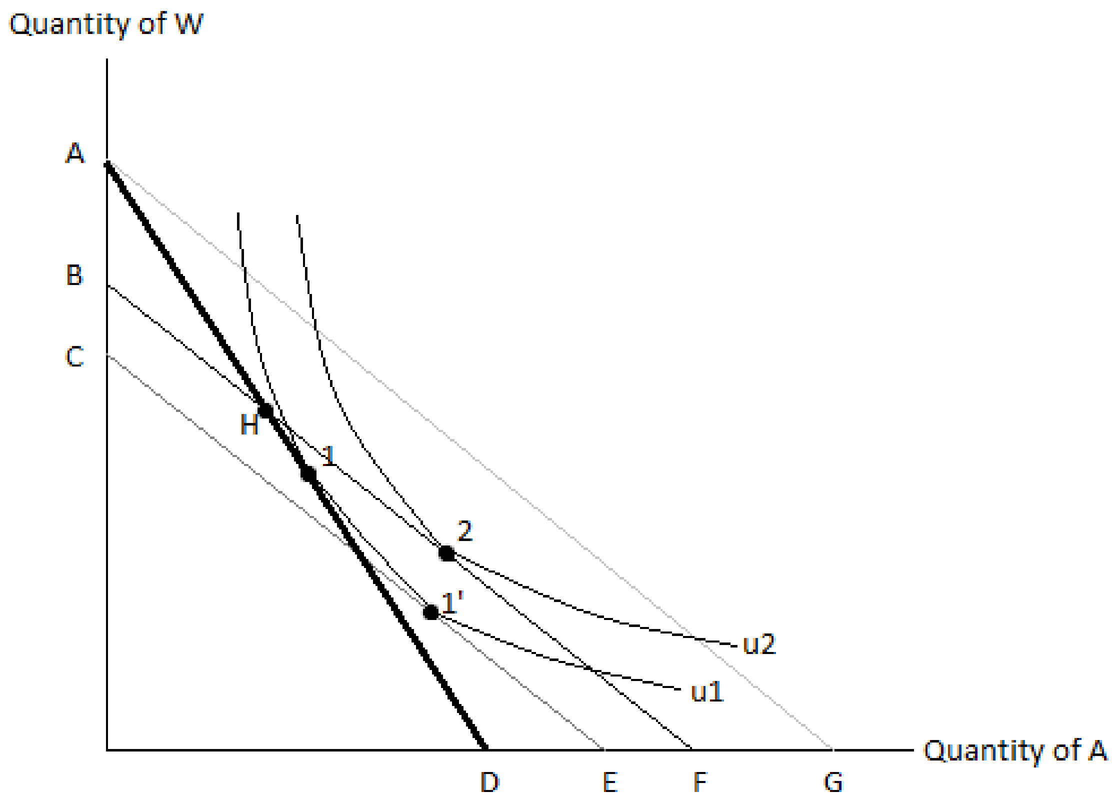
First, suppose that Amazon is interested in knowing how much a consumer who is not currently a Prime member would be willing to pay for membership. In Figure 1 (and all figures that follow), the dark line represents the consumer's current budget constraint (segment AD here). Since $p_w$ is assumed to be 1, distances along the vertical axis will capture the fee as well as the values of CV and EV.

The consumer chooses bundle 1 and receives utility of u1. Note that the budget constraint would be given by equation (1) above. In the standard textbook treatment, if the consumer faces a lower price of the good measured on the horizontal axis, she could choose a bundle along AG. However, access to free shipping on Amazon goods requires that she pay a fixed fee of AB, so her actual budget line will be BF—equation (2). She chooses bundle 2 and receives utility of u2. Note that the consumer's maximum willingness-to-pay for the Prime membership is equal to AC, since any amount greater than AC would result in her being unable to achieve u1 given current prices and shipping fees. If she were required to pay *exactly* AC for Prime, she would choose bundle 1' and be indifferent between this scenario and the no-Prime choice of bundle 1.

[3] I thank the referee for suggesting how to clarify the nature of the simplifying assumptions, and how to reinforce that the analysis can be extended to incorporate actual behavior.

However, since AC > AB and u2 > u1, this consumer will join. Thus, BC represents compensating variation, which, in this case, is the excess of willingness-to-pay over the membership fee.

**Figure 1: Compensating Variation: Non-Prime Members**

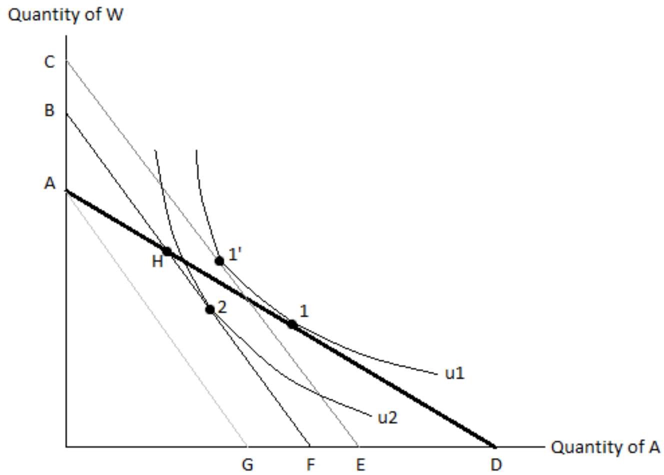



This situation, though, is only by construction. It is also possible for the fee to be larger than the consumer's maximum willingness-to-pay (AB > AC). In such a case, the consumer's Prime budget line BF lies inside of CE, so that no bundles along u1 are affordable. Utility with Prime (u2) would thus be lower than utility without it (u1), so this consumer is better off by not joining in the first place (i.e. keep buying bundle 1). Additionally, note that segment AH of the consumer's budget constraint is only available without Prime. It is therefore possible for u2 to be on BH while u1 is on AH, so that u2 is again below u1. Such a situation depicts a consumer with a strong preference for Walmart goods who does not sign up for Prime given her current options. Amazon goods are occasionally desirable for such a consumer, but she is better off paying the shipping on each individual item.

### *The Current Prime Member: What Will Lead Her to Cancel It?*

Next, consider a consumer who is currently a Prime member. In Figure 2, the starting budget constraint is again AD, and the consumer chooses bundle 1. If she cancels her membership, she will recoup the fee (receiving BA back in money income) and choose along BF (bundle 2). By construction, she would be worse off, and thus retain the membership. However, if her money income increased enough to permit a choice along budget line CE, she would choose bundle 1' and be just as well off without Prime as with it. Note that if such an income subsidy were greater than CA, the consumer will cancel her membership and move to an indifference curve with utility that is higher than u1. Thus, CA represents the minimum amount of additional money income the consumer is willing to accept to forgo her Prime membership, and CB represents compensating variation.

**Figure 2: Compensating Variation: Prime Members**




For this case, note that BH is only affordable without Prime (as was the case with AH above) so it is again possible to have u2 > u1. Furthermore, note that if she is subsidized an amount less than CA, she will retain her membership.

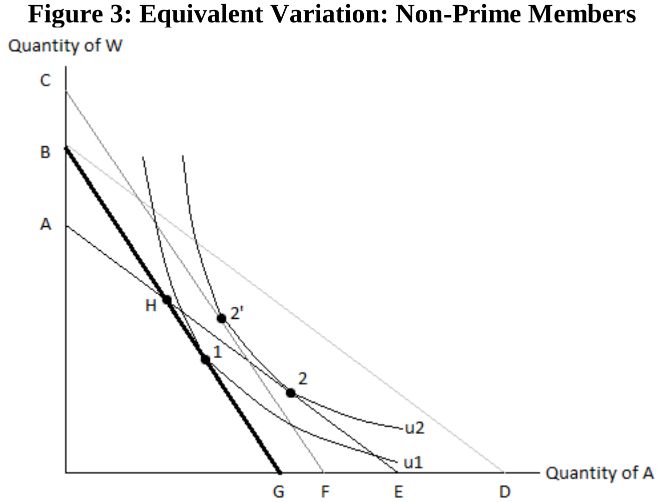
## Equivalent Variation

### *The Prospective Prime Member: What Is Preventing Her from Signing Up?*

In the previous section, compensating variation was linked to the nonsubscriber's willingness-to-pay for the membership. Let us now consider another important question for any subscription service that involves the nonsubscriber's *un*willingness to join.

Consider Figure 3. The consumer's starting budget constraint is BG, and bundle 1 is chosen. If she signs up for Prime, she will face budget constraint AE and choose bundle 2, where she will be better off. However, if before signing up she receives additional money income that is equal to CB (the equivalent variation), then she will choose bundle 2' and be indifferent to joining and not joining. If this subsidy happens to be greater than CB, then she will not join. The minimum willingness-to-accept is CA, which includes the subsidy as well as the money saved from not having to pay the fee of BA.

**Figure 3: Equivalent Variation: Non-Prime Members**

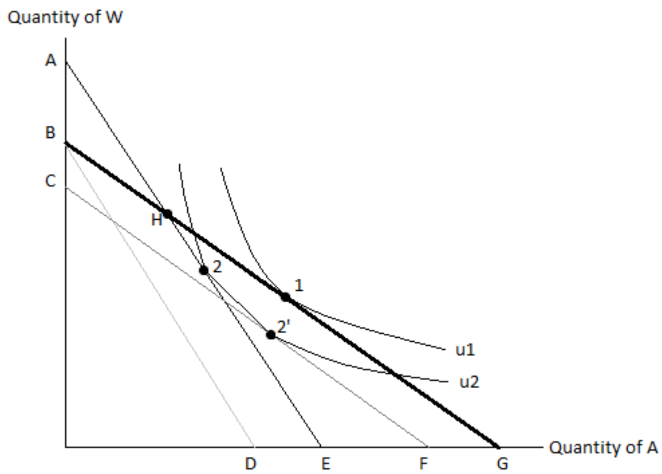



Here, BH is affordable only without Prime, and so again it is possible to have a consumer who consistently assigns more utility to bundle 1 than to bundle 2.

### *The Current Prime Member: How Much Is She Willing to Pay to Keep It?*

Lastly, we turn to the problem of retaining existing customers when subscription fees are raised. In Figure 4, bundle 1 under budget BG represents the starting position. If the consumer cancels her membership, she will recoup the fee and choose bundle 2 on AE. But access to free shipping is valuable, and even if she had to pay an additional membership fee, she would still be better off by retaining the membership as long as the extra charge is less than BC. Thus, AC represents her maximum willingness-to-pay to keep the membership, which can be decomposed into the current fee (AB) and the equivalent variation (BC). This knowledge would be of value to Amazon in predicting the retention rate of existing Prime members when the fee is raised.

**Figure 4: Equivalent Variation: Prime Members**




For completeness, note that AH is affordable only if Prime is abandoned, so it is possible that a different consumer than the one depicted above prefers bundle 2 to bundle 1, and would thus cancel the membership.

## Conclusion

This paper provides a simple, real-world instructional example for undergraduate microeconomics students. The example links compensating (CV) and equivalent (EV) variation to a consumer's decision to join (or cancel) Amazon Prime. It is demonstrated that CV and EV can convey important information to Amazon regarding current and prospective members' valuations of the service. The primary aim of the example is to show that CV and EV are not simply abstract theoretical concepts or academic exercises: consumer theory aims to be descriptive, and with the right data, economists can test its accuracy. It also serves as a guide for firms in making data-driven decisions about price and fee structures, and one would be hard-pressed to find a firm with better access to consumer data than Amazon.

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# A Primer on Teaching Capital Structure Theory: An Intuitive Approach

***Kavous Ardalan[1]***

## ABSTRACT

An adequate understanding of the concept of the optimal capital structure choice of a company requires an intuitive understanding of that concept. The aim of this paper is to provide such an intuitive explanation. It discusses two methods of arriving at the optimal capital structure of a company. The first one is based on the effect of capital structure on the company's share price, and the second one is based on the effect of capital structure on the weighted average cost of capital. The paper notes that the two methods arrive at the same optimal capital structure for the company.

## Introduction

Most current finance textbooks and professors provide a formal discussion of the concept of the optimal capital structure of a company.[2] This approach precludes an intuitive explanation of the concept of a company's optimal capital structure and does not provide an adequate foundation for understanding that concept. The aim of this paper is to fill this void. It discusses two methods of arriving at the optimal capital structure of a company. The first is based on the effect of capital structure on the company's share price, and the second is based on the effect of capital structure on the weighted average cost of capital. The paper also notes that the two methods arrive at the same optimal capital structure for the company.

In illustrating the concept of a company's optimal capital structure, the paper refers to PowerPoint slides which the author uses in his classes. They are reproduced in an appendix at the end of the paper for reference.[3]

Companies finance their business with a mix of debt and equity. This mix is called the capital structure. The optimal capital structure is that capital structure (mix of debt and equity) at which the company's stock price is maximized. Slide 1 shows a subset of capital structure choices open to a company which will be used as the example in this paper.

The paper is organized as follows. First, the paper provides an intuitive explanation of the concept of the optimal capital structure based on the effect of capital structure on the company's share price. Then, it provides an intuitive explanation of the concept of the optimal capital structure based on the effect of capital structure on the weighted average cost of capital. It also notes that the two methods would arrive at the same optimal capital structure for the company. Finally, it sums up in the conclusion.

## Capital Structure and Share Price

This section provides an intuitive explanation of the concept of the optimal capital structure based on the capital structure's effect on the company's share price as shown in slide 2.

Debt has the advantage that it is less costly and the interest paid is tax deductible, which lowers debt's effective cost. However, debt has the disadvantage that if a company falls on hard times and operating

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[2] For the seminal work in this regard, see Modigliani and Miller (1958).

[3] These PowerPoint slides will be made available upon request.

income is not sufficient to cover interest charges, its equity holders will have to make up the shortfall, and if they cannot, bankruptcy will result. The optimal capital structure strikes the proper balance between the higher earnings per share (*EPS)* and the higher financial risk.

The use of more debt in the capital structure of the company generally leads, on the one hand, to a higher *EPS*, therefore higher dividends (*D*s), which lead to a higher stock price. It leads, on the other hand, to a higher risk borne by equity holders, and therefore, a higher equity holders' required rate of return ($r_s$), which leads to a lower stock price. This is shown in slide 3, where it is emphasized that in general the direction of stock price change is not known. The optimal capital structure involves the proper trade-off between risk and return such that the stock price is maximized.

### *Explaining the Advantage of Debt: Rate of Return*

An intuitive example of the way that the increase in the use of debt in the capital structure of the company increases the rate of return, or *EPS* or dividend, to the equity holders is provided in slide 4. Here the project is financed in two different ways, i.e., two different capital structures. The project costs $1,000 and generates a rate of return of 15% per year, i.e., $150 per year. Under the first capital structure, when this project if financed with all equity, then all of the $150 which is generated by the project, belongs to the equity holders of the company, and therefore, equity holders receive a rate of return of 15%. Under the second capital structure, when the project is financed with $500 debt (which is obtained at the interest rate of 10% per year) and $500 of equity, then of the $150 which is generated by the project, $50 would have to be paid to the debt holders and the remainder, which is $100, would belong to the equity holders, and therefore, equity holders receive a rate of return of 20%.

When the rates of return to equity holders under the two capital structures are compared, it is noted that the rate of return with debt financing (i.e., 20%) is higher than the rate of return with no debt financing (i.e., 15%). This happens because any dollar which is invested in this project generates a rate of return of 15%, therefore the $500 borrowed money when invested in the project will generate a rate of return of 15%, but only a rate of return of 10% is paid to the debt holders, and the remaining 5% is retained and paid to the equity holders that increases the rate of return to equity holders. This shows that as long as the company borrows at a lower rate (in our example 10%) and invests it in a project that generates a greater rate of return (in our example 15%), then, the rate of return to equity holders of the company increases. This is the advantage of using debt in the capital structure of the company.

Another intuitive example of the way that the increase in the use of debt in the capital structure of the company increases the rate of return, or *EPS* or dividend, to the equity holders is provided in slide 5. To make this example more relevant to students, it would be a good idea to consider the situation where students have graduated from college and are earning a salary. Then they will be thinking of buying a house, which they expect to increase in price over time. More specifically, the house costs $1,000 (in thousands, i.e., $1,000,000, to make it more interesting to the students) and its price is expected to increase to $1,200 by the end of the year. The example considers the house to have been financed under two different capital structures. Under the first capital structure, when this house (project) is financed with all equity, then the $1,200 (which is the value of the house at the end of the year) belongs to the student, and therefore, his/her rate of return is 20%. Under the second capital structure, when the house is financed with $400 debt (which is obtained at the interest rate of 5% per year) and $600 of equity, then of the $1,200 (which is the value of house at the end of the year), $420 would have to be paid to the debt holders and the remainder (which is $780) would belong to the student, and therefore, his/her rate of return would be 30%.

When the rates of return to the student under the two capital structures are compared, it is noted that the rate of return with debt financing (i.e., 30%) is higher than the rate of return with no debt financing (i.e., 20%). This happens because any dollar which is invested in this house (project) generates a rate of return of 20%, therefore, the $400 borrowed money, when invested in the project, will generate a rate of return of 20%, but only a rate of return of 5% is paid to the debt holders, and the remaining 15% is retained for the student that increases the student's rate of return. This shows that as long as the student borrows at a lower rate (in our example 5%) and invests it in a house (project) that generates a higher rate of return (in our example 20%), then, the student's rate of return increases. This is the advantage of using debt in the capital structure when investing in a house (project).

### *Explaining the Disadvantage of Debt: Risk*

On the other hand, when debt is increased in a company's capital structure, the company becomes riskier. Financial leverage is defined as the use of debt in the financing of a company. Financial risk is the additional risk placed on the equity holders as a result of the decision to finance with debt. If a company uses debt, this concentrates the business risk on equity holders. This concentration of business risk occurs because debt holders, who receive fixed interest payments, bear a smaller business risk relative to the equity holders of the company. This is shown in slide 6.

The following intuitive example shows how the use of debt in the capital structure of a company increases the risk to the equity holders. Consider a company with total assets of $100,000 under two capital structures: the unlevered and the levered. In the unlevered alternative, the company is not issuing debt and it is all-equity financed with 20,000 shares. In the levered alternative, the company is 50% financed with debt (i.e., $50,000 debt at the interest rate of 20%), and it is 50% financed with equity (i.e., 10,000 shares). The company's corporate tax rate is 40%.

Slide 7 shows the company which is financed under two different capital structures. Since a change in the capital structure affects the bottom half of the income statement, slide 7 shows, first, the top half of the income statement (which reflects the business aspect of the company) and then complements it with two financing alternatives (which affect the bottom half of the income statement). Therefore, in slide 7, there are two income statements that have the same top half. For each income statement, there is one net income, as expected. However, the two net incomes under the two financing alternatives are not directly comparable, because they should be distributed among two different number of shares (i.e., 20,000 shares vs. 10,000 shares). This is why at the bottom of each of the two income statements the *EPS*s are calculated as well.

Then, the two financing alternatives can be compared, after the sales of the company change by 10%. As is noted in slide 7, when sales change by 10% then the *EPS* for the unlevered case changes by 20%, but the *EPS* for the levered case changes by 40%.[4] Financial leverage results in a much wider *EPS* swings because of fixed interest charges. Financial leverage widens the probability distribution of *EPS* and increases the probability of a very low *EPS*, thus increasing the risk borne by the common equity holders.

### *Putting the Advantage and the Disadvantage of Debt Together: Risk and Return*

The middle diagram in slide 8 depicts the variations is stock price (which is shown on the vertical axis) corresponding to the variations in the capital structure, as measured by the debt to assets ratio, *D/A* (which is shown on the horizontal axis). Initially, when debt is increased in the capital structure of the company, then the company is relatively lower in risk, and accordingly the debt is relatively cheap, because the debt holders are exposed to a relatively lower risk, and therefore, require a relatively lower rate of return. Consequently, the benefit of debt is high (recall the discussion related to slides 4 and 5, i.e., the difference between the rate of return on the project and the lower cost of debt is large), so that the high benefit of financing with more debt, more than offsets the low risk of financing with more debt, i.e., the advantage of using debt more than offsets the disadvantage of using debt.

However, after a certain point (which is called the optimal capital structure), the increase in debt in the capital structure of the company will have the opposite effect. That is, when debt in increased beyond that certain level (i.e., the optimal capital structure), then, the company becomes relatively much riskier, and the cost of debt becomes relatively much higher, because the debt holders are exposed to a relatively higher risk, and therefore, require a relatively higher rate of return, which translates into a higher cost of debt to the company. Consequently, the benefit of debt is relatively low (recall the discussion related to slides 4 and 5, i.e., the difference between the rate of return on the project and the higher cost of debt is small), so that the small benefit of financing with debt is more than offset by the high risk of financing with debt, i.e., the advantage of using debt is more than offset by the disadvantage of using debt.

At the optimal capital structure, which in this example occurs with 25% debt, the stock price is maximized. At the optimal capital structure, the higher risk of the additional debt is equally offset by the benefit of the additional debt.

[4] The operating income, i.e., *EBIT*, changes by 20% because the company has some operating leverage.

## Capital Structure and Weighted Average Cost of Capital

This section provides an intuitive explanation of the concept of the optimal capital structure based on the effect of capital structure on the weighted average cost of capital.

Debt has the advantage that debt holders get a fixed return, so equity holders do not have to share the profits if the business is extremely successful. However, debt has the disadvantage that the higher the debt ratio, the riskier the company, hence the higher will be the cost of both debt and equity of the company. The optimal capital structure strikes the proper balance between the advantage and the disadvantage of debt.

When companies want to choose their optimal capital structure they go to investment bankers who offer them a list of alternative capital structures and their corresponding cost of debt and cost of equity. Slide 9 provides this information with respect to the company under consideration in this paper. Note that as the level of debt increases in the capital structure of the company then: (1) the cost of debt increases, (2) the cost of equity increases, and (3) the cost of equity is always greater than the cost of debt. There is some logic underlying each one of these three relationships, as follows.

1. Why does the cost of debt increase as the amount of debt increases? As the company borrows more, the likelihood that in bad economic times the company cannot meet its debt (interest and principal repayment) obligations and goes bankrupt increases. Therefore, as the amount of company's debt increases the debt holders are exposed to a higher level of risk of not receiving their interest and principal repayment, and therefore, the debt holders would require higher compensation, i.e., a higher interest rate, which means a higher cost of debt to the company.

2. Why does the cost of equity increase as the amount of debt increases? As the company borrows more, the likelihood that in bad economic times the company cannot meet its obligations to the company's equity holders (dividend payment and equity value protection) and goes bankrupt increases. Therefore, as the amount of company's debt increases the equity holders are exposed to a higher level of risk of not receiving their dividend and losing the value of their equity, and therefore, the equity holders would require a higher compensation, which would translate into a higher cost of equity for the company.

3. Why is the cost of equity always higher than the cost of debt? This is because the equity holders receive their cash flows from the company after debt holders have received their cash flows from the company. This holds true when the company is in operation or is in the state of bankruptcy. When the company is in operation, equity holders receive their dividends after debt holders have received their interest from the company, as in slide 10. When the company is in the state of bankruptcy and the assets of the company are liquidated, the equity holders receive any of their equity after debt holders have received most of their principal amount they lent. So, whether the company is a going concern or is bankrupt, the equity holders receive their cash flows from the company after debt holders have received their cash flows from the company. Therefore, the equity holders are exposed to a higher level of risk than the debt holders. Consequently, equity holders require a higher rate of return than debt holders, which means a higher cost of equity than the cost of debt to the company.

An intuitive example can be provided by subjecting the company presented in slide 7, to more severe economic fluctuations. That is, rather than limiting the change in sales to 10%, let us subject the company to more drastic changes in sales, e.g., 25% and 30%. The case of a severe economic downturn is shown in slide 11 and the case of a large economic upturn is shown is slide 12. In the severe economic downturn case, slide 11, the consequences of the two different capital structures can be compared.

In slide 11, first, note that as the economy moves further and further into recession then the levered company gets into financial distress much sooner. This is because the company has to meet its fixed interest obligations. The unlevered company does not have this obligation, and therefore, can weather the recession with little difficulty, in this respect. This is why when a company borrows more it becomes riskier, and therefore its debt holders and equity holders are exposed to a higher level of risk and thereby requiring a higher rate of return, which translates into a higher cost of debt and a higher cost of equity to the company.

Second, note that when the company is levered and the company moves further and further into recession then the equity holders get into financial trouble sooner than debt holders. This is because debt holders get their share of the cash flows of the company before equity holders get theirs. This is why the equity holders are exposed to a higher level of risk compared to debt holders, and therefore, equity holders require a higher rate of return than debt holders, which translates into a higher cost of equity to the company than the cost of debt to the company.

In slide 12, when the economy enjoys a very favorable economic upturn then the sales and operating income of the company increase correspondingly, and since the debt holders get a fixed interest payment, then the benefit of economic upturn accrues to the equity holders of the company. This is the advantage of using debt in the company's capital structure.

The foregoing analysis is depicted in slide 13. It shows that as the amount of debt in the company's capital structure increases, then, (1) the cost of debt increases, (2) the cost of equity increases, and (3) the cost of equity is always greater than the cost of debt. The implication of these three relationships with respect to the weighted average cost of capital (*WACC*) is as follows. As the company substitutes lower-cost debt for higher-cost equity, the *WACC* declines. However, as the debt ratio increases, the costs of both debt and equity rise, at first slowly, but then at a faster and faster rate, as a result of the increases in financial risk. Eventually, the increasing costs of the two components offset the fact that more low-cost debt is being used, and the *WACC* rises with further increases in the debt ratio. Initially the company benefits from the lower-cost debt, and its favorable effect on earnings, and the consequent favorable effect on its stock price. However, after a certain point (the minimom of *WACC*), the further use of debt increases the risk of both debt and equity such that they more than offset the benefit of the use of debt.

## Capital Structure, Share Price, and Weighted Average Cost of Capital

The capital structure that minimizes the *WACC*, as shown in slide 13, is also the capital structure that maximizes the company's stock price, which is shown in slide 14.

More specifically, Table 1 demonstrates that, for the company under consideration, the capital structure that maximizes the share price also minimizes the *WACC*. In Table 1, the first two columns show a sample of possible capital structures for the company. The next two columns show the corresponding cost of debt and the cost of equity at those capital structures. The next column shows the number of shares outstanding at each capital structure. For instance, when the company is all equity financed, there are 1,000 shares outstanding; and when the company is 50% equity financed, there are 500 shares outstanding. The next column calculates net income (*NI*) based on the way the income statement is constructed. That is, $NI = (EBIT - I)(1 - t)$. The next column calculates *EPS* as $EPS = NI \,/\, No.\ of\ Shares\ Outstanding$. The next column calculates share price as $Share\ Price = EPS / r_s$. That is, since the company is on its steady state and is not growing, all its earnings are paid out as dividends to the company's common shareholders, and, therefore, dividend per share (*DPS*) equals earnings per share, i.e., $DPS = EPS$ and $Growth\ Rate = 0$. The final column calculates *WACC* as $WACC = w_c\ r_d\ (1 - t) + w_{ce}\ r_s$. As can be noted, when the company is financed with 75% equity and 25% debt, the share price is maximized and the *WACC* is minimized.

**Table 1: A Firm Financed with 75% Equity/25% Debt Maximizes Share Price and Minimizes WACC**

| Equity % | Debt % | $r_d$ % | $r_s$ % | No. of Shares | NI | EPS | Share Price | WACC % |
|---|---|---|---|---|---|---|---|---|
| 100.00 | 0.00 | 10.00 | 15.00 | 1,000 | 12,000 | 12.00 | 80.00 | 15.00 |
| 87.50 | 12.50 | 10.00 | 15.50 | 875 | 11,250 | 12.86 | 82.97 | 14.31 |
| 75.00 | 25.00 | 11.00 | 16.50 | 750 | 10,350 | 13.80 | 83.64 | 14.00 |
| 62.50 | 37.50 | 13.00 | 18.00 | 625 | 9,078 | 14.53 | 80.72 | 14.18 |
| 50.00 | 50.00 | 16.00 | 20.00 | 500 | 7,200 | 14.40 | 72.00 | 14.80 |

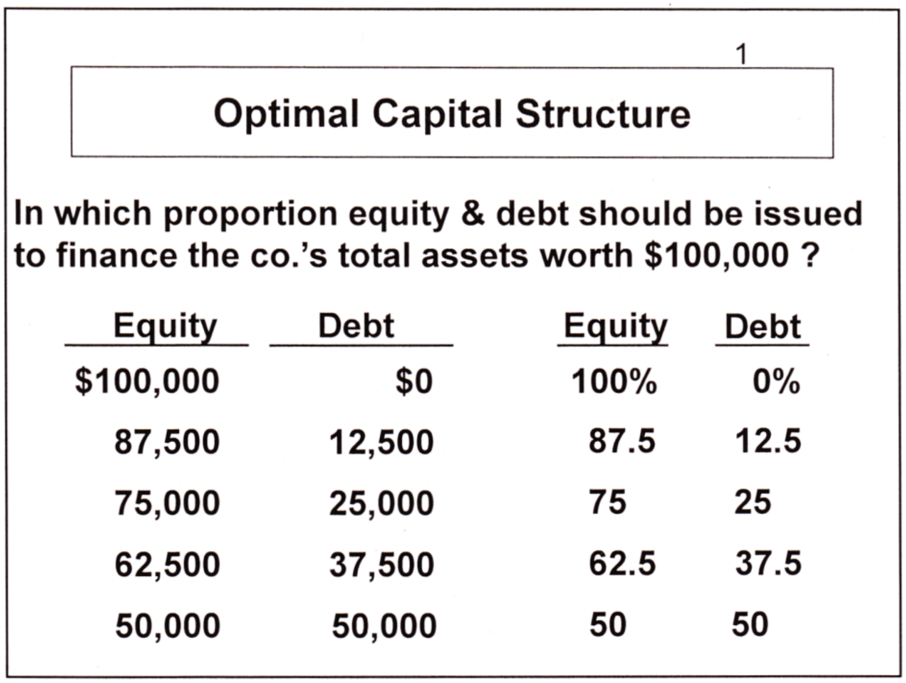
## Conclusion

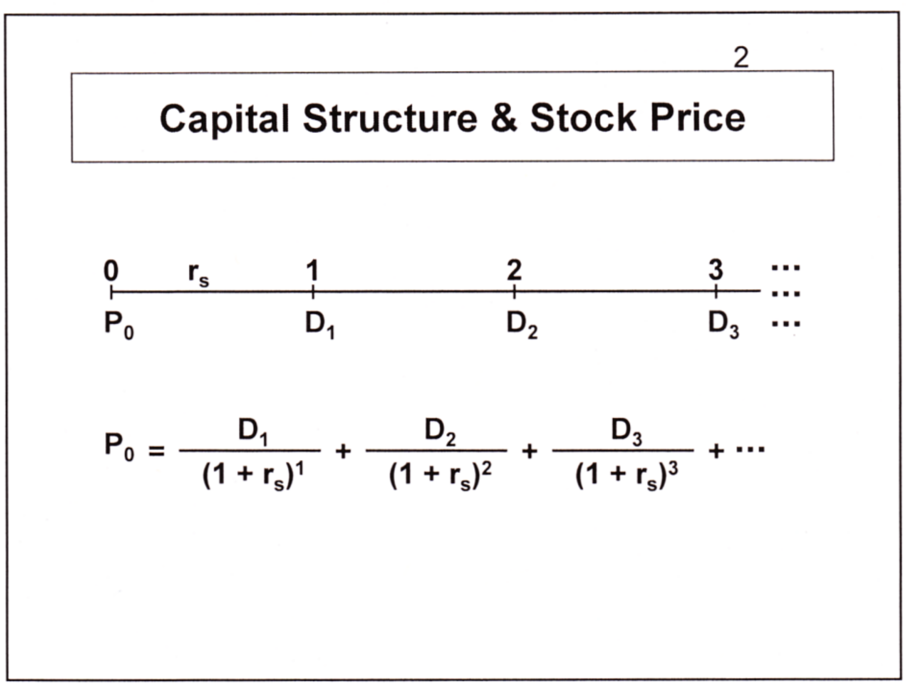
An adequate understanding of the concept of a company's optimal capital structure choice requires an intuitive understanding of that concept. The aim of this paper is to provide an intuitive explanation of the concept of the optimal capital structure of a company. It discusses two methods of arriving at the optimal capital structure of a company. The first one is based on the effect of capital structure on the company's share price; and the second one is based on the effect of capital structure on the weighted average cost of capital. The paper also notes that the two methods arrive at the same optimal capital structure for the company.

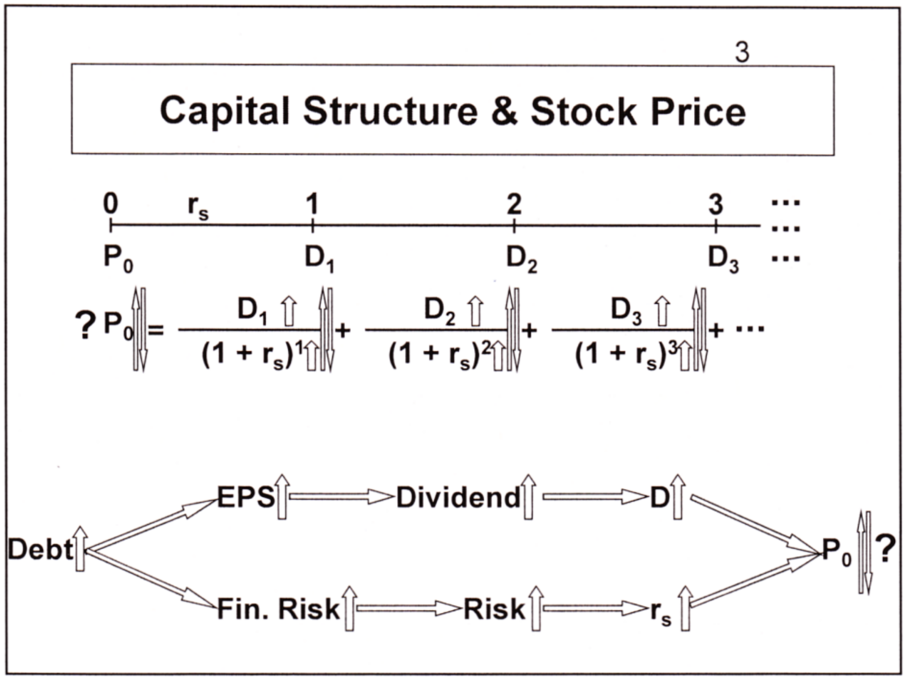
## Reference

Modigliani, Franco, and Merton H. Miller. 1958. "The Cost of Capital, Corporation Finance and the Theory of Investment." *American Economic Review* 48: 261-297.

## Appendix: PowerPoint Slides Used in Class



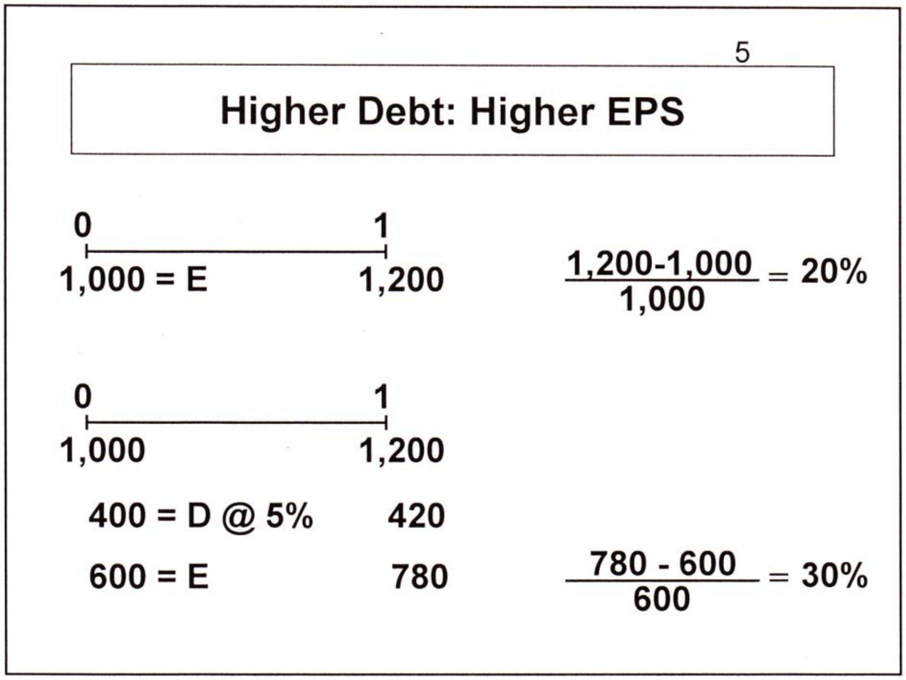



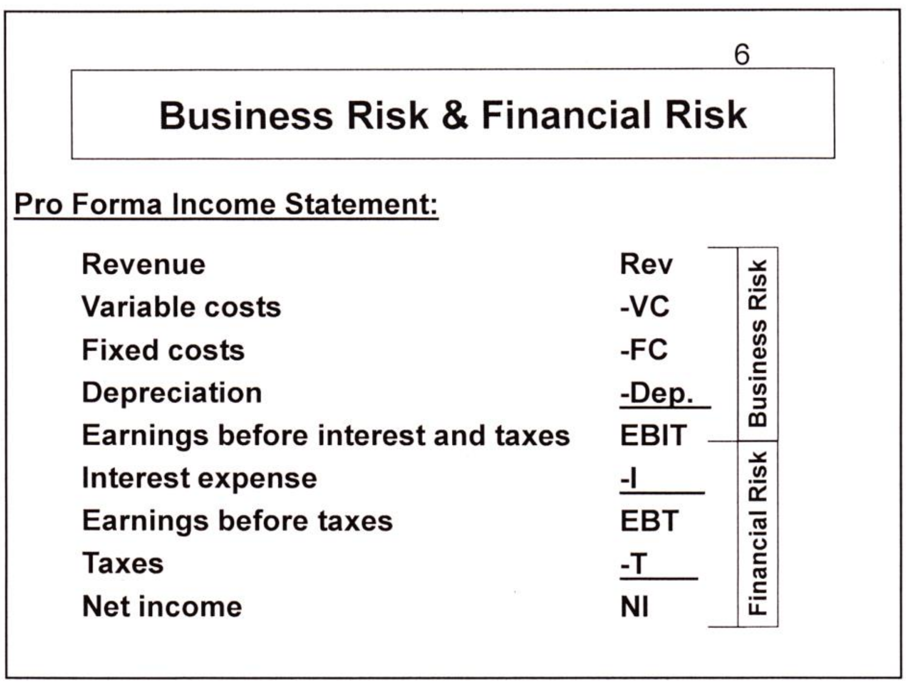



4

## Higher Debt: Higher EPS

| Assets | Rate of Return on Assets | Dollar Return on Assets | Financing | Payment to Debt Holders & Equity Holders | Rate of Return to Equity Holders |
|---|---|---|---|---|---|
| $1,000 | 15% | $150 | Debt = $0 | $0 | |
| | | | Equity = $1,000 | $150 | 15% |
| $1,000 | 15% | $150 | Debt = $500@10% | $50 | |
| | | | Equity = $500 | $100 | 20% |

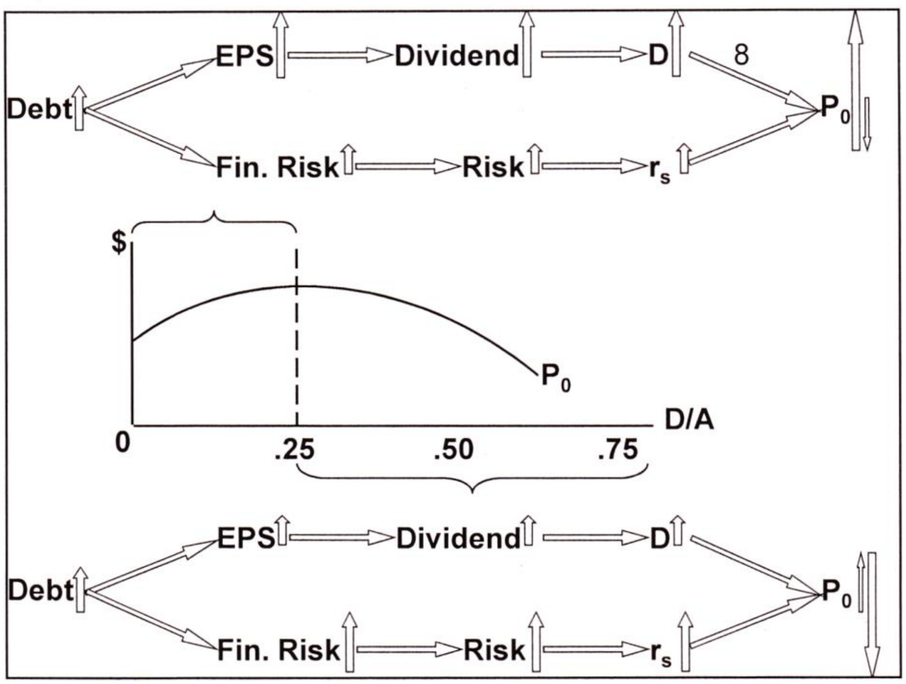

5
Higher Debt: Higher EPS
0
1
1,000 = E
1,200
1,200-1,000
1,000
= 20%
0
1
1,000
1,200
400 = D @ 5%
420
600 = E
780
780 - 600
600
= 30%


6
Business Risk & Financial Risk
Pro Forma Income Statement:
Revenue
Rev
Variable costs
-VC
Fixed costs
-FC
Depreciation
-Dep.
Earnings before interest and taxes
EBIT
Interest expense
-I
Earnings before taxes
EBT
Taxes
-T
Net income
NI
Business Risk
Financial Risk

7

## Higher Debt: Higher Financial Risk

| | | Base Case | Sales+10% | Sales-10% | Sales+-10% |
|---|---|---|---|---|---|
| Intrmdt O.L. | Sales | 100,000 | 110,000 | 90,000 | |
| | VC | 60,000 | 66,000 | 54,000 | |
| | FC | 20,000 | 20,000 | 20,000 | |
| | EBIT | 20,000 | 24,000 | 16,000 | EBIT+-20% |
| Unlevered | EBIT | 20,000 | 24,000 | 16,000 | |
| | I | 0 | 0 | 0 | |
| | EBT | 20,000 | 24,000 | 16,000 | |
| | T (40%) | 8,000 | 9,600 | 6,400 | |
| | NI | 12,000 | 14,400 | 9,600 | |
| | EPS | 0.6 | 0.72 | 0.48 | EPS+-20% |
| Levered | EBIT | 20,000 | 24,000 | 16,000 | |
| | I | 10,000 | 10,000 | 10,000 | |
| | EBT | 10,000 | 14,000 | 6,000 | |
| | T (40%) | 4,000 | 5,600 | 2,400 | |
| | NI | 6,000 | 8,400 | 3,600 | |
| | EPS | 0.6 | 0.84 | 0.36 | EPS+-40% |



9

**Estimated costs of debt and equity for the company:**

| Equity | Debt | $r_d$ | $r_s$ |
|---|---|---|---|
| $100,000 | $0 | 10.0% | 15.0% |
| 87,500 | 12,500 | 10.0 | 15.5 |
| 75,000 | 25,000 | 11.0 | 16.5 |
| 62,500 | 37,500 | 13.0 | 18.0 |
| 50,000 | 50,000 | 16.0 | 20.0 |

10

**Pro Forma Income Statement**

**Pro Forma Income Statement:**

| | |
|---|---|
| Revenue | Rev |
| Variable costs | -VC |
| Fixed costs | -FC |
| Depreciation | -Dep. |
| Earnings before interest and taxes | EBIT |
| Interest expense | -I |
| Earnings before taxes | EBT |
| Taxes | -T |
| Net income | NI |

11

### Economic Cycle: Risk of Equity vs. Debt

| | | Base Case | Sales-10% | Sales-25% | Sales-30% |
|---|---|---|---|---|---|
| Intrmdt O.L. | Sales | 100,000 | 90,000 | 75,000 | 70,000 |
| | VC | 60,000 | 54,000 | 45,000 | 42,000 |
| | FC | 20,000 | 20,000 | 20,000 | 20,000 |
| | EBIT | 20,000 | 16,000 | 10,000 | 8,000 |
| Unlevered | EBIT | 20,000 | 16,000 | 10,000 | 8,000 |
| | I | 0 | 0 | 0 | 0 |
| | EBT | 20,000 | 16,000 | 10,000 | 8,000 |
| | T (40%) | 8,000 | 6,400 | 4,000 | 3,200 |
| | NI | 12,000 | 9,600 | 6,000 | 4,800 |
| | EPS | 0.60 | 0.48 | 0.30 | 0.24 |
| Levered | EBIT | 20,000 | 16,000 | 10,000 | 8,000 |
| | I | 10,000 | 10,000 | 10,000 | 10,000 |
| | EBT | 10,000 | 6,000 | 0 | -2,000 |
| | T (40%) | 4,000 | 2,400 | 0 | 0 |
| | NI | 6,000 | 3,600 | 0 | -2,000 |
| | EPS | 0.60 | 0.36 | 0 | -0.20 |

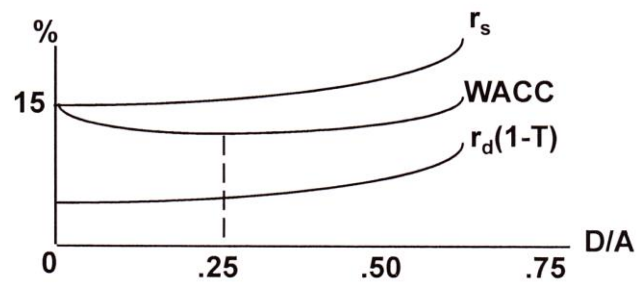
12

### Economic Cycle: Benefit of Equity vs. Debt

| | | Base Case | Sales+10% | Sales+25% | Sales+30% |
|---|---|---|---|---|---|
| Intrmdt O.L. | Sales | 100,000 | 110,000 | 125,000 | 130,000 |
| | VC | 60,000 | 66,000 | 75,000 | 78,000 |
| | FC | 20,000 | 20,000 | 20,000 | 20,000 |
| | EBIT | 20,000 | 24,000 | 30,000 | 32,000 |
| Unlevered | EBIT | 20,000 | 24,000 | 30,000 | 32,000 |
| | I | 0 | 0 | 0 | 0 |
| | EBT | 20,000 | 24,000 | 30,000 | 32,000 |
| | T (40%) | 8,000 | 9,600 | 12,000 | 12,800 |
| | NI | 12,000 | 14,400 | 18,000 | 19,200 |
| | EPS | 0.60 | 0.72 | 0.90 | 0.96 |
| Levered | EBIT | 20,000 | 24,000 | 30,000 | 32,000 |
| | I | 10,000 | 10,000 | 10,000 | 10,000 |
| | EBT | 10,000 | 14,000 | 20,000 | 22,000 |
| | T (40%) | 4,000 | 5,600 | 8,000 | 8,800 |
| | NI | 6,000 | 8,400 | 12,000 | 13,200 |
| | EPS | 0.60 | 0.84 | 1.20 | 1.32 |

13

**Optimal Capital Structure**




14

**What is WACC at D = 0, D = $25,000, D = $50,000?**

$$WACC = w_d r_d(1-T) + w_{ce} r_s$$

***D = 0:***

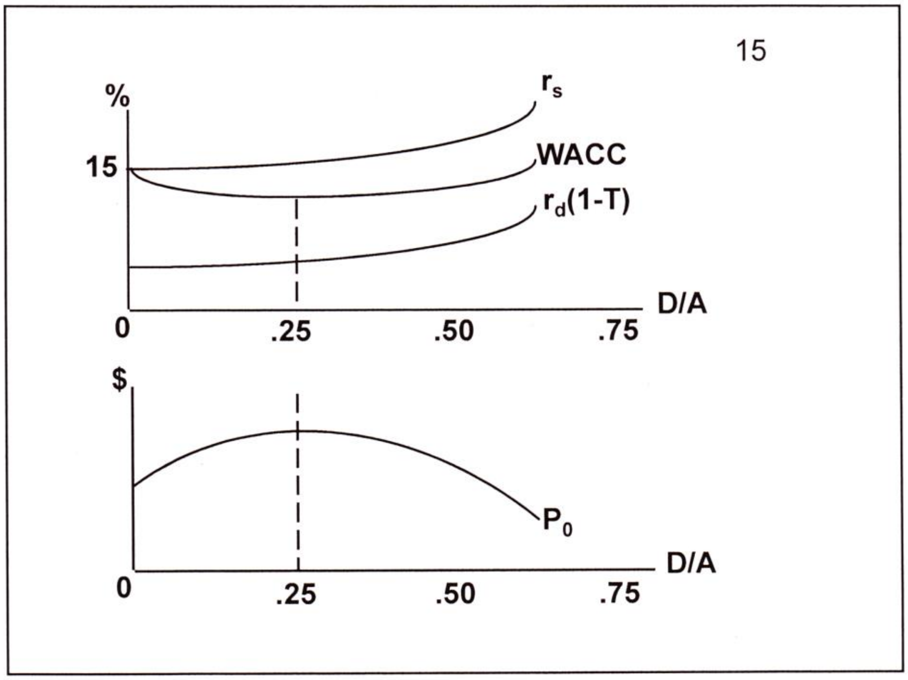
**WACC = 0 + 1.0(15%) = 15.0%**

***D = 25,000:***

**WACC = .25(11)(.6) + .75(16.5) = 14.0%**

***D = 50,000:***

**WACC = .50(16)(.6) + .50(20.0) = 14.8%**


15
%
$r_s$
15
WACC
$r_d(1-T)$
D/A
0
.25
.50
.75
$
$P_0$
D/A
0
.25
.50
.75

# Modeling Bond Immunization Outcomes with User-Defined Functions

**Christi R. Wann[1]**

## ABSTRACT

This paper presents a new assignment that teaches students how to create user-defined functions in Visual Basic for Application (VBA) to model bond immunization outcomes. Students learn how to create five user-defined functions that calculate bond price; duration; the number of bonds required for immunization; the future value of semi-annual coupon payments reinvested at six-month Treasury rates; and the "street" price of a bond at duration using the daily compounding method for accrued interest between bond payments. This assignment helps students understand the effects of monetary policy on bond immunization strategies and strengthens Excel skills, which is desirable to employers.

## Introduction

This paper presents a new spreadsheet assignment that helps Finance students understand the effects of monetary policy on bond immunization strategies and strengthens Excel Visual Basic for Application (VBA) skills for employment. The Excel assignment has eight multi-part questions that contain specific color-coded cells where data and formulas must be entered. At the option of the instructor, students either learn how to create five user-defined functions using VBA scripting, or the instructor can provide the Excel Add-In for students to use to complete the assignment. The user-defined functions allow students to model actual and predicted bond immunization of a future liability for any yield curve shape and shift, bond type, and target horizon. The completed spreadsheet allows students to quickly analyze and understand how the historical, current, or forecasted interest rate environment affects the ability to achieve bond immunization. This assignment is suitable for upper-level courses with an emphasis on economic and financial modeling. The completion of the following assignment could take place in a computer lab or as a take-home project. The assignment will work best if broken up into sections to complete during the semester as a project.

The instructor resources include three Excel files and six YouTube videos. The three Excel files include an instructor version (answer key) and a student version of the assignment, as well as an Excel Add-in file. The instructor version of the spreadsheet is a completed version of the assignment and the Excel Add-in has a working version of all the user-defined functions. The student version of the spreadsheet does not contain the answers or the user-defined functions. The Excel files are available by request from the author. The YouTube videos illustrate how to create each user-defined function required by the spreadsheet assignment. The website links to the YouTube videos are available in Appendix 1 and within the instructor and student Excel files.

The instructor can opt-out of having students create user-defined functions. To allow students to use a working version of the user-defined functions, simply install the provided Excel Add-in. The Excel Add-in file contains all the user-defined functions needed for the assignment and can be added to any Excel workbook. Please note that the three Excel files are macro-enabled and cannot be used in Google Sheets. Instead, each file should be downloaded to a computer with Microsoft Excel installed.

The student version of the spreadsheet is equipped with an automatic grading system that assigns half of the points per question to using cell-referenced equations and functions and the other half to obtaining the correct numerical answer. This grading feature helps instructors to deny full credit to students who simply type in the correct answer (hard coding) without using Excel equations. Once students turn in their

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assignments, instructors can unhide all the columns in the "Grade" tab to see the specific errors in students' equations.

The student spreadsheet provides reading materials that discuss the role of the Federal Open Market Committee from 2014 to 2020 in shaping the Treasury yield curve. Discussion questions requiring students to observe and comment on how the yield curve shifts from 2014 to 2019 are also available for instructors to use if there is sufficient class time. Students will then work through a historically based bond immunization assignment that illustrates the difficulty of achieving perfect immunization due to unpredictable yield curve shifts. Students are instructed to use formulas and cell references to perform calculations. Hard-coding of answers should be discouraged because the student will be unable to view how an answer changes in response to a variable change. The student version of the Excel file allows students to check their awarded points on the "Grade" tab. Due to the complexity of the assignment, this tab should not be hidden from students.

The YouTube videos teach students how to create five user-defined functions in Excel with VBA scripting. First, students create the function *BondPrice* to calculate the price of a semi-annual bond. The purpose of creating this function is to allow students to get used to the logic of VBA coding. Next, the *BondPrice* code can be adapted to create the second user-defined function, *MacDurationAdj*, which calculates Macaulay duration in years. Third, students create the *NumberBonds* function to compute the required number of bonds to immunize a future liability. Fourth, students create the *FVCouponPmts* function to calculate the future value of reinvested coupon payments. This function requires students to learn more difficult VBA scripting (i.e., nested "For, Next" loops) to allow for a different reinvestment rate at each coupon payment. Fifth, the *StreetPrice* function is created to calculate the transaction price of a bond using the daily periodic rate to accrue interest earned between coupon payments. This assignment takes students through a step-by-step process to obtain the final bond portfolio value at the target immunization date and check if the future liability is overfunded or underfunded.

This new assignment addresses two shortcomings to traditional textbook approaches in teaching Macaulay (1938) duration. First, bond immunization examples are frequently illustrated in Investments textbooks as achieving the exact value of the needed future cash flow to pay the liability. Exact bond immunization is unlikely to be achieved unless the bond portfolio is rebalanced every time interest rates change so that the average duration continues to equal the target time horizon. Second, bond immunization textbook examples assume a flat-shaped yield curve. However, actual yield curve shapes shift each day in their level, slope, and curvature. The most common yield curve shifts are parallel, twisted, or shifts with humpedness. In this assignment, the likelihood of achieving the minimum future liability is related to the types of yield curve shifts over the immunization period.

## Motivation and Literature Review

Excel-based assignments can improve learning by requiring students to actively participate in the lecture as they learn how to work through a spreadsheet assignment. This approach is known as the "constructivist" learning approach to problem-solving because they allow students to be part of the learning process (Boethal and Dimock 1999; Maddux et al. 2001). The constructivist learning approach is associated with higher learning achievements because it forces students to actively create knowledge (Tynjala 1998; Clements and Battista 1990). As knowledge is created in a way that makes sense to each student, students feel empowered and more confident (Boethel and Dimock 1999; Maddux et al. 2001). The use of Excel-based assignments leads to better student understanding of complex formulas, increased self-competence, greater self-actualization, and increased logical thinking skills (Ghani and D'Mello 1993; Kruck et al. 2003). The use of Excel also captures student's attention in what otherwise might be considered a boring topic (Barreto 2015). When educators and students concurrently participate in a learning activity, as is the case when using Excel, more successful learning occurs (Rovai 2004).

Traditional financial education is theoretical, leaving students with a "skills gap" when trying to obtain jobs that demand hands-on experience. Today, Excel skills increase employability (Hess 2005) because many companies expect Finance graduates to use Excel for financial reports and forecasts (Weber 2015). An article from CNBC lists Microsoft Excel as the most in-demand skill for the year 2020 (Liu 2019). The Wall Street Journal featured an article that reiterates how entrenched Excel remains in today's business world after receiving hundreds of comments from a prior article (Shumsky 2017a) that talked about a few companies' efforts to reduce the use of Excel (Shumsky 2017b). One comment received stated that asking finance professionals to give up Excel is "like asking whether we've given up drinking" (Shumsky 2017b). Further, Microsoft reports that greater than "90% of Fortune 500 financial companies now have the cloud-powered Office 365 and that the product has 120 million corporate monthly users globally" (Shumsky 2017b).

Excel VBA skills are useful for automating repetitive tasks. For example, a significant part of economic or financial analyst jobs includes finding, assembling, and processing data. VBA programming can be used to create complex calculations that require loops, conditional logic, and repetition. Further, learning how to use VBA in Excel helps students to become familiar with programming logic, which can help students acquire other programming languages (i.e., Python, JavaScript) that may be required in their careers.

Knowing how to use software such as Excel has become so critical to businesses that educators must demonstrate the many functions and capabilities of Excel to students (Maddux, et al. 2001). Further, educators must emphasize a more professional approach to Excel programming that facilitates an in-depth understanding of a problem rather than just learning simple features and functions (Garrett 2015). Thus, given the continued demand for Excel in the workplace, it is apparent that universities and educators need to offer students the opportunity to acquire this important skill. Using more advanced Excel-based assignments in the classroom is one way to meet this challenge.

## Excel Assignment Pedagogy

### *Step 1: Setup Excel Files and Introduce Macaulay Duration*

Before beginning this assignment, obtain the Excel files from the author and add the Developer tab to the ribbon in Excel. On the File tab, go to Options and choose Customize Ribbon. Under Customize the Ribbon and under Main Tabs, select the Developer checkbox. If you only want to use the Add-in, it must be installed. To install the Add-in, Go to Developer -- Add-ins -- Excel Add-ins. In the Add-ins dialogue box, browse and locate the saved file and click OK. Students must also follow the steps to add the Developer tab if they are required to create user-defined functions. Instead, if students are required to use the Add-in, then students must install the Add-in in the same manner as mentioned above.

Before using the Excel assignment in class, the instructor should introduce the term structure of interest rates, Macaulay duration, and properties of duration. Macaulay (1938) first introduced the duration formula to measure the average or effective maturity of a bond's cash flows. Duration can be used in a target date bond immunization strategy to hedge against interest rate and reinvestment rate risks. This is achieved by matching the duration of a bond or a portfolio of bonds with a target time horizon when a future liability must be paid. The assignment uses historical Treasury data to illustrate how well a target date bond immunization strategy would have worked based upon the yield curve shifts from January 2014 to January 2019.

The next sections describe three tabs in the student and instructor versions of the Excel assignment file. The three tabs include the pre-assignment reading tab, the Treasury yield curves tab, and the target date immunization tab.

### *Step 2: Pre-Assignment Reading Tab*

The student and instructor Excel files contain a tab called "Pre-Assignment Reading" that should be reviewed by students before starting the assignment. This tab contains the same information as the Federal Reserve's website that discusses open market policy ("Policy Tools" 2020). The website provides historical information for the Federal Open Market Committee's (FOMC) target federal funds rate changes. A link to the Federal Reserve website is provided in Excel.

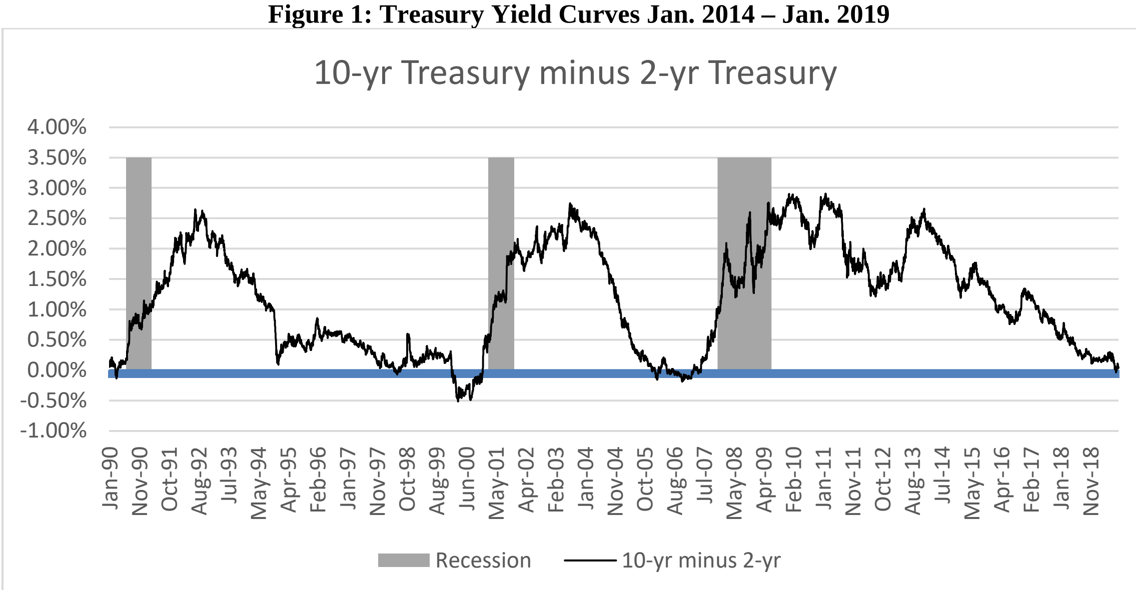
Information about inverted Treasury yield curves is provided at the bottom of the "Pre-Assignment Reading" tab. For example, Figure 1 plots the 10-yr minus the 2-yr Treasury along with NBER defined recessions. Figure 1 illustrates to students how the Treasury curve inverts prior to a recession. This tab also includes summary information about the average time until a recession after a yield curve inversion.

### *Step 3: Treasury Yield Curves Tab (Question 1)*

**1.a Look at Figure 1. What is the initial shape of the yield curve? What happens to the shape of the yield curve over time? Does the yield curve shift in a parallel fashion?**

**1.b Does the 2019 pattern of the yield curve give cause for concern about the health of the economy?**
**1.c What did the Federal Open Market Committee (FOMC) do from 2015 to 2019 that affected the changing yield curve shape?**
**1.d Prior to 2015, when was the last time the FOMC took significant action to affect interest rates? Why was this done?**

**Figure 1: Treasury Yield Curves Jan. 2014 – Jan. 2019**




*Note*: Federal Reserve data and authors' calculations. The shaded area represents the National Bureau of Economic Research (NBER) recessions.

The information and questions in the "Treasury Yield Curves" tab can be used by the instructor to introduce the assignment during class. The purpose of this tab is for students to realize that yield curves do not always shift in a parallel fashion as is assumed for examples in several Investments textbooks. Figure 2 provides an overview of how the Treasury yield curve shifted in January 2014, 2017, and 2019. The questions in this tab ask students to describe the changing shape of the yield curve (1.a), learn about the warning implied by a flat yield curve (1.b), learn how the FOMC actions affected the yield curve (1.c), and learn about the FOMC actions during the credit crisis which began in 2008 (1.d). Later in the Excel assignment, students will learn how the changing yield curve shape can affect efforts to achieve perfect bond immunization. The answers to Questions 1.a through 1.d are in the instructor file in the "Answers-Treas. Yield Curve Ques" tab.

## *Step 4: Target Date Immunization Tab (Questions 2 – 8)*

The next portion of the assignment requires students to use the historical Treasury yield curve data from Question 1 to immunize a bond portfolio to meet a \$5,000,000 future liability. The bond immunization questions are located on a separate tab in the Excel file called "Target Date Immunization." Questions 2 through 8 are located on this tab and specific spaces for answers are provided according to a color-coded guide. The guide is located at the top of the spreadsheet. In yellow-shaded cells, students must use cell-referenced equations, Excel functions, user-defined functions, or text answers. In orange-shaded cells, students type in or hard-code data. Gray-shaded cells are to be left "as is."

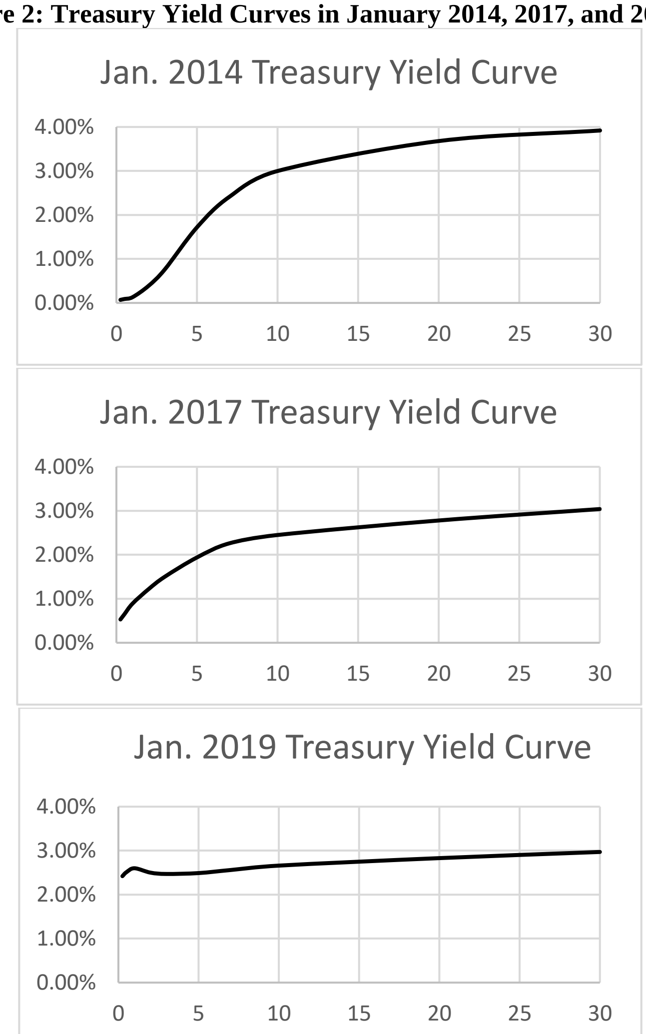
***Use of Cubic Splines to Interpolate Treasury Yields (Question 2.a)***

**2. Assume that it is January 2, 2014, and your company is deciding how to pay a \$5,000,000 future liability. Your company has decided that a Treasury bond, which was issued January 2, 2009, is a suitable investment. The Treasury bond is semi-annual, has 5 years remaining until maturity, a 2.46% annual coupon rate, and a par**

**value of $100. The table below provides Treasury Yield spot rate data from January 2014 to January 2019.**

In Question 2, students are given data for a 2.46% coupon rate, $100 par value Treasury bond[2] (issued January 2, 2009) which has 5 years left to maturity as of January 2, 2014. The goal of Question 2 is to obtain the Macaulay duration for the Treasury bond.

**Figure 2: Treasury Yield Curves in January 2014, 2017, and 2019**




*Note:* Federal Reserve data.

**2.a Use the custom function called *Spline* that is provided in this Excel file. The format of the *Spline* function is Spline(periodcol,ratecol,x). "Periodcol" is the range of the Treasury maturities (t) in the table above. "Ratecol" is the range of the Treasury rates available for each half-year (i.e., Jan. 2014). Finally, "x" is the needed Treasury maturity to interpolate the Treasury rate. Use the *Spline* function and the historical Treasury yield data in the table above to interpolate the values of the needed Treasury rates in the highlighted table below. For example, the first equation for a half-year Treasury in January 2014 should be: =Spline($E$15:$E$19,F$15:F$19,$E37) A quick illustration for using this formula is provided in the following YouTube link below.**

The first issue that must be addressed in Question 2.a is the absence of historical daily data for treasury rates at half-year points, such as 1.5 years. Also, there is no reported value for the Treasury rate on a 4-year

[2] For the purpose of this assignment, the Treasury note will be referred to as a bond since “note” is specific to Treasury securities. This allows for a more commonly understood naming feature in the creation of the user-defined functions.

bond. Since students are working with a Treasury bond with 5 years remaining to maturity, interpolated rates on a 1.5-, 2.5-, 3.5-, 4-, and 4.5-year bond are needed for each semi-annual coupon payment date.

The quasi-cubic Hermite spline model is used by the Office of Debt Management in the Department of the Treasury to derive the Treasury yield curve. Unfortunately, the Treasury does not provide its exact methodology:

> "The Treasury does not provide the computer formulation of our quasi-cubic Hermite spline yield curve derivation program. However, we have found that most researchers have been able to reasonably match our results using alternative cubic spline formulas" (U.S. Department of the Treasury: Office of Debt Management, 2018, Treasury Yield Curve Methodology section, para. 5).

A simple Google search produced an accurate VBA script for use in this project (2007, Cubic Spline Function in VBA). This VBA script is included in the instructor and student Excel files as a user-defined function named *Spline*. Therefore, the students do not have to create this particular user-defined function due to its complexity.

Students will use the *Spline* function and the provided historical Treasury yield data to interpolate the needed values of the Treasury rates at half-year periods. A video (https://youtu.be/vQnZOoctubM) is provided in the Excel spreadsheet that shows how to use the *Spline* function. The interpolated Treasury yields are computed from January 2014 to January 2019 for each date of the semi-annual coupon payment (January and July). The completed answer to Question 2.a can be found in the instructor version of the Excel file.

***Bond Price (Question 2.b – 2.c)***

> **2.b Compute the current price of the bond based upon the yield curve for 2014. Use Excel's PV function.**

Question 2.b asks students to calculate the current price of the Treasury bond using Excel's "PV" (present value) function as of January 2014. The Treasury bond price is $103.53. In Question 2.c, students create their first user-defined function called *BondPrice* using VBA scripting. To create a user-defined function, students must add Excel's Developer tab to the ribbon. On the File tab, go to Options and choose Customize Ribbon. Under Customize the Ribbon and under Main Tabs, select the Developer checkbox. Students must create the user-defined function in the Developer tab by selecting the Visual Basic button. A new window pops up and students are to locate the Modules folder. Two modules have already been created and named "CubicSpline" and "MyFunctions." Students will work in the "MyFunctions" module. A detailed explanation of the *BondPrice* function is provided in the instructor version of Excel. A video (https://youtu.be/iKL9C_sr_Nk) has been created to illustrate how to write the first function, called "BondPrice."

> **2.c Create a new custom function in Excel called "BondPrice." First, add Excel's Developer tab to the ribbon by following these steps: 1) On the File tab, go to Options and choose Customize Ribbon. 2) Under Customize the Ribbon and under Main Tabs, select the Developer check box.**

Figure 3 provides the VBA script answer to Question 2.c. An effort was made to use clear variable names within the functions such as "YearsToMaturity." The emphasis in the *BondPrice* function is to incorporate flexibility in the formula by adding the variable "CompoundingPeriods" which allows the calculation of bond prices with semi-annual, quarterly, monthly, or daily compounding.

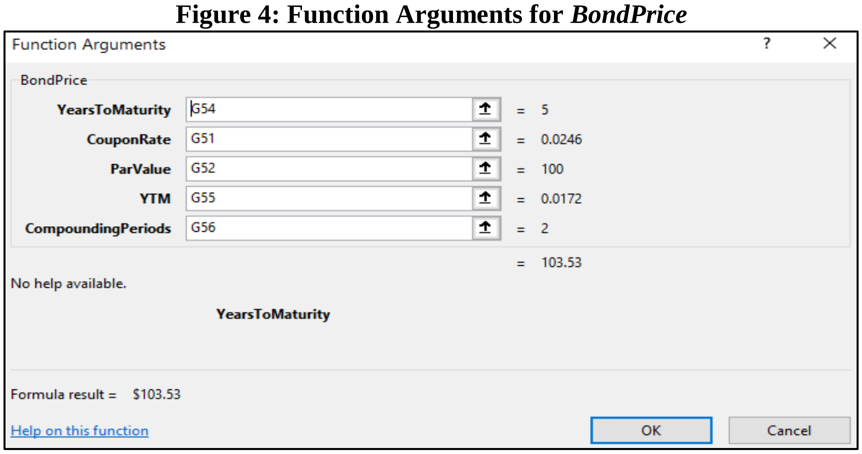
The "For, Next" statement allows each cash flow to be discounted. However, since a bond has a final payout that returns the par value and the last coupon payment, an "If, Then, Else" statement is also needed. The first equation in the "If, Then, Else" statement calculates the present value of the tenth and final coupon payment plus the par value. The second equation within the "If, Then, Else" statement calculates the present value of coupon payments one through nine. The variable "Price" accumulates the present values of each cash flow until it equals the final bond price of $103.53.

The final "If, Then" statement calculates the bond price on the day of expiration (t=0). This is needed because the other statements do not account for a maturity of t=0. When the Macaulay duration of the bond occurs between the last coupon payment and the bond maturity, the bond price at t=0 must be estimated. Finally, since VBA scripting does not round numbers, students will utilize Excel's "Round" function to obtain two decimal places for the final bond price. For example, to round in VBA students must use "Application.WorksheetFunction.Round" to call the Excel function "Round." The *BondPrice* function arguments dialog box is illustrated in Figure 4 to allow the instructor to see the outcome of the VBA scripting process.

**Figure 3: VBA Script for *BondPrice* Function**

```
Function BondPrice(YearsToMaturity, CouponRate, ParValue, YTM, CompoundingPeriods)
AdjCouponRate = CouponRate / CompoundingPeriods
AdjYTM = YTM / CompoundingPeriods
NumPayments = YearsToMaturity * CompoundingPeriods
Price = 0
  For CFTime = 1 To NumPayments
      If CFTime = NumPayments Then
      Price = (AdjCouponRate * ParValue + ParValue) / (1 + AdjYTM) ^ CFTime + Price
    Else
      Price = (AdjCouponRate * ParValue) / (1 + AdjYTM) ^ CFTime + Price
    End If
  Next CFTime
If YearsToMaturity = 0 Then
Price = ParValue
End If
BondPrice = Application.WorksheetFunction.Round(Price, 2)
End Function
```

**Figure 4: Function Arguments for *BondPrice***




***Macaulay Duration (Question 2.d – 2.f)***

**2.d Calculate the Macaulay duration of the Treasury bond in 2014 using the formula approach shown in class. bond: Your answer will be based on semi-annual periods.**

To immunize the Treasury bond position, students must calculate the Macaulay duration in Question 2.d by completing a table in Excel. This first method of calculating Macaulay duration allows students to better visualize the mechanics of the equation. Macaulay duration is calculated using Equation (1). Equation (2) contains a portion of the manual calculation which is often demonstrated in class.

$$D = \frac{\sum_{t=1}^{n} t(CF_t)(1+i)^{-t}}{P_B} \quad (1)$$

$$D = \frac{(1)\left(\frac{\$2.46}{2}\right)\left(1+\left(\frac{.0172}{2}\right)\right)^{-1} + \ldots + (9)\left(\frac{\$2.46}{2}\right)\left(1+\left(\frac{.0172}{2}\right)\right)^{-9} + (10)\left(\$100+\frac{\$2.46}{2}\right)\left(1+\left(\frac{.0172}{2}\right)\right)^{-10}}{\$103.53} = 9.482 \quad (2)$$

In the Excel file, students complete a table to obtain the numerator of Equation (1). Then, students divide \$981.66 by the price of \$103.53 to obtain 9.482 as the answer to Question 2.d.

**2.e Adjust the Macaulay duration answer in 2.d to annual periods.**

The duration of 9.482 found in Question 2.d refers to semi-annual periods. Therefore, in Question 2.e, students must divide the previous answer by two to obtain the duration in annual periods of 4.741.

**2.f Calculate the Macaulay duration (in years) by creating a new custom function in Excel called *MacDurationAdj***

In Question 2.f, students create their second user-defined function called *MacDurationAdj* using VBA scripting which calculates the duration of a bond in years. Figure 5 provides the VBA script that calculates the Macaulay duration of the Treasury bond in years. The only difference between the *MacDurationAdj* function and the *BondPrice* function is the addition of the variable "Numerator." This new variable captures the value of the numerator in the Macaulay duration formula. "Numerator" and "Price" are defined similarly, except "*CFTime" is added to multiply each cash flow by the time period of the cash flow. An explanation of the *MacDurationAdj* function is provided in the instructor version of Excel. A video (https://youtu.be/7S37HJ4MEeM) has been created to illustrate how to write the second function, called "MacDurationAdj." The "If, Then, Else" statement calculates the present value of each coupon payment and the par value. The duration is equal to 4.741 as is found in Question 2.e.

**Figure 5: VBA Script for *MacDurationAdj* Function**

```
Function MacDurationAdj(YearsToMaturity, CouponRate, ParValue, YTM, CompoundingPeriods)
AdjCouponRate = CouponRate / CompoundingPeriods
AdjYTM = YTM / CompoundingPeriods
NumPayments = YearsToMaturity * CompoundingPeriods
Price = 0
Numerator = 0
  For CFTime = 1 To NumPayments
      If CFTime = NumPayments Then
      Price = (AdjCouponRate * ParValue + ParValue) / (1 + AdjYTM) ^ CFTime + Price
      Numerator = ((AdjCouponRate * ParValue + ParValue) * CFTime) / (1 + AdjYTM) ^ CFTime +
                  Numerator
    Else
      Price = (AdjCouponRate * ParValue) / (1 + AdjYTM) ^ CFTime + Price
      Numerator = ((AdjCouponRate * ParValue) * CFTime) / (1 + AdjYTM) ^ CFTime + Numerator
    End If
  Next CFTime
If YearsToMaturity = 0 Then
Price = ParValue
End If
MacDurationAdj = Numerator / Price / CompoundingPeriods
End Function
```

***Immunization Funding Strategy (Question 3.a – 3.e)***

**3. Show the funding strategy that should be used with the 5-year 2.46% coupon Treasury bond to immunize the portfolio.**

Question 3 requires students to create an immunized funding strategy with the 5-year treasury bond to achieve a target balance of $5,000,000 in exactly 4.741 years.

**3.a Calculate the interpolated yield to maturity on a Treasury in January 2014 with a time to maturity that matches the Macaulay duration found in the previous question. (Hint: Use the *Spline* user-defined function.)**

First, students must use the *Spline* function to calculate the interpolated yield to maturity on a bond with 4.741 years to maturity (Question 3.a). This value is needed to find the required present value of the Treasury bonds needed to immunize the future liability. The interpolated yield for a 4.741-year Treasury is 1.59% as of January 2014.

**3.b Calculate the needed current value of the bond in today's dollars. Construct a portfolio of bonds that will accumulate in value to $5,000,000 (V) at time T (Macaulay duration) at the current market interest rate. Set the Macaulay duration equal to the targeted date of the liability T. The current value of the portfolio of bonds is: P = V/[1+(i/m)])^(T*m). "m" equals the number of compounding periods. "i" is the interpolated Treasury yield at time T.**

Second, students compute the needed present value of the Treasury bonds that must be purchased in January 2014 (Question 3.b). In Excel, students will use Equation (3) to calculate the needed investment amount. In Equation (3), $V$ equals the needed future value of the liability, $i$ equals the current interpolated spot rate on a 4.741-year Treasury bond in January 2014, $m$ is the number of compounding periods, and $T$ is equal to the investment horizon. To immunize the portfolio, the investment horizon must equal the Macaulay duration of 4.741 years. The answer to Question 3.b is $4,638,977.

$$P = \frac{V}{\left(1+\frac{i}{m}\right)^{(T\,x\,m)}} = \frac{\$5{,}000{,}000}{\left(1+\frac{0.0159}{2}\right)^{(4.741\,x\,2)}} = \$4{,}638{,}977 \qquad (3)$$

**3.c How many bonds should you purchase today? Use the "ROUND" function to avoid purchasing fractional bonds. Round to the nearest whole number of bonds.**

Third, students calculate the required number of Treasury bonds to purchase (Question 3.c) to invest $4,638,977. The bond in this example has a $100 par value. Students are also instructed to use Excel's "Round" function to avoid buying fractional bonds. In Excel, students find that they must purchase 44,808 Treasury bonds by using Equation (4).

$$Number\ of\ bonds\ purchased = \frac{P}{Current\ Market\ Price} = \frac{\$4{,}638{,}977}{\$103.53} = 44{,}808 \qquad (4)$$

**3.d Calculate the number of bonds needed by creating a new custom function in Excel called *NumberBonds***

Fourth, students are asked to create the third user-defined function, called "NumberBonds," in Question 3.d. Figure 6 provides the VBA script that calculates the number of bonds that should be purchased now to immunize the payment of the future liability. A detailed explanation of the *NumberBonds* function is provided in the instructor version of Excel. A video (https://youtu.be/cbDNr-8wFlY) has been created to illustrate how to write the VBA script for "NumberBonds."

**Figure 6: VBA Script for *NumberBonds* Function**

```
Function NumberBonds(FutureLiability, Duration, InterpolatedI, YearsToMaturity, CouponRate,
ParValue, YTM, CompoundingPeriods)
ValueBondNeeded = FutureLiability / (1 + InterpolatedI / CompoundingPeriods) ^ (Duration *
CompoundingPeriods)
Price = -Application.WorksheetFunction.PV(YTM / CompoundingPeriods, YearsToMaturity *
CompoundingPeriods, CouponRate / CompoundingPeriods * ParValue, ParValue)
NumberBonds = Application.WorksheetFunction.Round(ValueBondNeeded / Price, 0)
End Function
```

**3.e Calculate the total semi-annual coupon payment received based upon the number of Treasury bonds purchased. Use the ROUND function to round to two decimal places.**

Fifth, the total semi-annual coupon payment amount is calculated to aid in computing the future value of reinvested coupons (Question 3.e). Students are instructed to use the "Round" function to obtain two decimal places. Based upon the number of Treasury bonds purchased, the semi-annual coupon payment is $55,113.84 as shown in Equation (5).

$$Total\ semi\ annual\ payments = 44{,}808\ x\ \left(\frac{2.46}{2}\right) = \$55{,}113.84 \qquad (5)$$

***Future Value of Reinvested Coupons (Question 4.a – 4.b)***

**4.a. Use the yield curve data from Jan. 2014 to Jan. 2019 to find the future value of the reinvested semi-annual coupon payments at the time of Macaulay duration. Assume that you reinvest each semi-annual coupon payment received at the actual 6-month T-bill rate that occurs over time. For example, the first coupon payment will be reinvested every 6 months until Macaulay duration in semi-annual periods is reached. The final reinvestment period might be a fractional time period. (Hint: The July 2014 coupon payment will be reinvested for how many six-month periods? Take the Macaulay duration in six-month periods in Question 2.d and subtract 1. See the equation below which shows the future value of the first semi-annual coupon payment.)**

In Question 4, students must use the yield curve data from January 2014 to January 2019 to find the future value of all received and reinvested semi-annual coupon payments at the time of Macaulay duration. To simplify the assignment, students assume that each semi-annual coupon payment is reinvested at the 6-month T-bill rate each half-year. For example, the first coupon payment will be reinvested every 6 months until Macaulay duration in semi-annual periods is reached. The final reinvestment period might be in between coupon payments unless the Macaulay duration occurs exactly on a coupon payment date. Since the Macaulay duration in this example is 4.741 years, the final reinvestment period is 0.241 years (87.94 days).

The format of the Excel spreadsheet forces students to calculate the future value of each received semi-annual coupon payment (payments one to nine). The sum of the reinvested coupon payments is the answer to Question 4.a. For example, the first coupon payment is received in July 2014 and is reinvested for 8.482 6-month periods. Since the original Macaulay duration in years is 9.482 semi-annual periods and the first coupon payment occurs after 1 semi-annual period, 8.482 semi-annual periods (4.241 years) are left to reinvest coupon payments. For example, the future value of the first coupon payments is $56,660.96 (partial answer to Question 3.d) and is illustrated in Equation (6). It is important to note that the quoted six-month Treasury bill rates are annualized. Therefore, each six-month T-bill rate is divided by two in Equation (6).

$$FV_{t=4.741}^{PMT\ 1} = \$55{,}113.84\left(1+\frac{i_{JUL\ 2014}}{2}\right)\left(1+\frac{i_{JAN\ 2015}}{2}\right)\left(1+\frac{i_{JUL\ 2015}}{2}\right)\left(1+\frac{i_{JAN\ 2016}}{2}\right)\left(1+\frac{i_{JUL\ 2016}}{2}\right)\left(1+\frac{i_{JAN\ 2017}}{2}\right)\left(1+\frac{i_{JUL\ 2017}}{2}\right)\left(1+\frac{i_{JAN\ 2018}}{2}\right)\left(1+(0.482)\left(\frac{i_{JUL\ 2018}}{2}\right)\right) = \$56{,}660.96 \quad (6)$$

The total future value of all reinvested coupon payments is equal to $506,692.01. The interest rates for 6-month T-bills are found in the table named "Treasury Yield Data from Jan. 2014 -Jan. 2019" at the top of the Excel tab named "Target Date Immunization." This table was also used to create the interpolated yields for Question 2.a.

**4.b Calculate the future value of the semi-annual coupon payments by creating a new custom function in Excel called *FVCouponPmts***

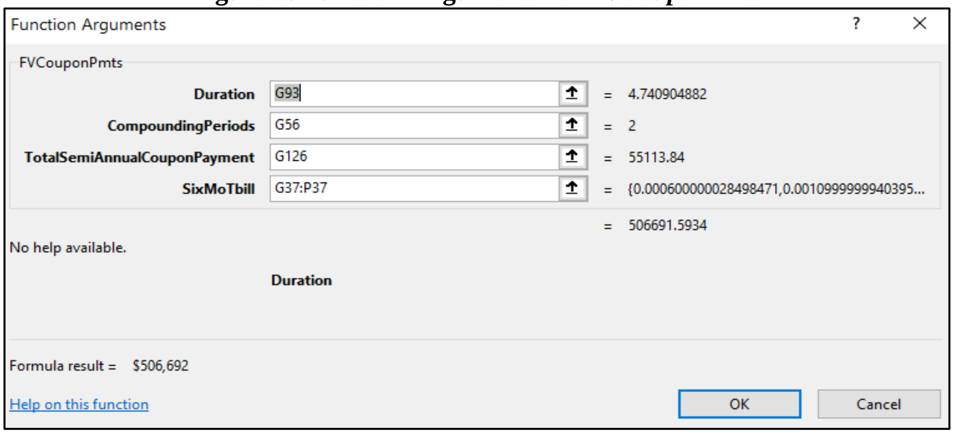
Next, students are asked to create the fourth user-defined function, called "FVCouponPmts," in Question 4.b. Figure 7 provides the VBA script that calculates the future value of the total semi-annual coupon payment received. A detailed explanation of the *FVCouponPmts* function is provided in the instructor version of Excel. A video (https://youtu.be/cBt3T9_Pv4Y) has been created to illustrate how to write the VBA script for "FVCouponPmts."

**Figure 7: VBA Script for *FVCouponPmts* Function**

```
Function FVCouponPmts(Duration, CompoundingPeriods, TotalSemiAnnualCouponPayment,
SixMoTbill As Excel.Range)
Duration_UnAdj = Duration * CompoundingPeriods
nBeforeDur = Application.WorksheetFunction.RoundDown(Duration_UnAdj, 0)
'Obtain Future Value of Coupon Payments.
EachCoupPmtFV = 0
For k = 1 To nBeforeDur
IntFactor = 1
  For i = k To nBeforeDur
    If i = nBeforeDur Then
      IntFactor = IntFactor * (1 + ((Duration_UnAdj – nBeforeDur) * (SixMoTbill(i) /
      CompoundingPeriods)))
      EachCoupPmtFV = TotalSemiAnnualCouponPayment * IntFactor + EachCoupPmtFV
    Else
      IntFactor = IntFactor * (1 + (SixMoTbill(i) / CompoundingPeriods))
    End If
  Next i
Next k
FVCouponPmts = EachCoupPmtFV
End Function
```

The *FVCouponPmts* function arguments dialog box is illustrated in Figure 8. The last function argument, "SixMoTbill," is input as a range of cells. Using a range of cells allows the function to adapt to bonds with any number of years to maturity and to allow for different reinvestment rates over time. The final answer to Question 4.b is $506,692.

**Figure 8: Function Arguments for *FVCouponPmts***




***Transaction Price of a Bond between Coupon Payments (Question 5.a – 5.e)***

**5. Calculate the "Street value" of the Treasury bond at the time equal to the Macaulay duration when the liability will be paid. The "Street" price is the transaction price of a bond between coupon payments, not the quoted price of a bond. Therefore, we must consider that accrued interest will be earned.**

Question 5 walks students through the calculation of the final transaction price of the Treasury bond at Macaulay duration. Since the Macaulay duration is equal to a time (t=4.741) that is between coupon payments nine and ten, accrued interest must be included to obtain the "street" price of the Treasury bond. The "street" price is the transaction price of a bond between coupon payments, not the quoted price of a bond.

The best approach is the daily compounding of interest proposed by Boyles et al.(2005). This bond pricing method produces the same transaction price as the financial market method used by the "Street" (Fabozzi and Fabozzi 1989). A common textbook approach to computing accrued interest assumes that a discrete amount of daily interest is earned (Boyles et al. 2005). However, the "Street" calculates accrued interest on a daily compounding basis. Questions 5.a through 5.d precisely guide the student to calculate the "street" price which accrues interest on a daily basis.

**5.a Calculate the price of the Treasury bond right after the last coupon payment that occurs before Macaulay duration. This should be the price of the bond after the 9th coupon payment.**

In Question 5.a, students must first calculate the price of the Treasury bond after the last coupon is paid but before the Macaulay duration time of 4.741 years is reached (t=4.5). Since the Macaulay duration is greater than 4.5 years, then nine coupon payments (4.5 x 2 = 9) will occur before time is equal to duration. The price of the Treasury bond is calculated in Excel as of July 2018 when the rate on a Treasury with a half-year left to maturity is equal to the annualized T-bill rate of 2.14%. In Excel, students should obtain a price of $100.16.

**5.b Calculate the price of the Treasury bond right after the last coupon payment that occurs after Macaulay duration. This should be the price of the bond at the 10th coupon payment. Remember to add the coupon payment to the price obtained by the BondPrice function to get the "Street" price.**

In Question 5.b, students calculate the price of the Treasury bond right after the last coupon payment that occurs after the Macaulay duration time (t=5). For this example, the bond price should be calculated at the $10^{th}$ coupon payment to get the transaction or "street" price. At the $10^{th}$ coupon payment, the bond is worth the par value amount plus the last coupon payment. The bond price after duration is $101.23.

**5.c Calculate the daily periodic rate of return assuming a 182.5-day half-year. Use the July 2018 price of the bond as the PV. Use the Jan. 2019 price of the bond as the FV.**

Next, students calculate the daily periodic rate of return assuming a 182.5-day half-year (Question 5.c). Students are instructed to use the July 2018 price of the bond as the PV (obtained in Question 5.a). This is the quoted price of the bond right after the 9th coupon payment. Since the 10th coupon payment occurs at the Treasury bond maturity of 5 years, students use the January 2019 price of the bond (obtained in Question 5.b). Also, students are instructed to use the "Round" function to obtain ten decimal places for the daily rate of return. The daily periodic rate is equal to 0.00582277%.

**5.d Use the daily periodic rate of return found in Question 5.a as the interest rate to compute the "street" price of Bond A at the day of Macaulay Duration. N will equal the fractional time left to liability payoff times 365 days. You will be solving for the future value.**

Now, students can use the daily periodic rate of return to find the future "street" price of the bond at Macaulay duration in Question 5.d. The present value of the bond is $100.16, which was the price of the bond right after the ninth coupon payment. "N" is equal to 182.5 days times 0.482, or 87.9 days. The number 0.482 is the last portion of the semi-annual period before Macaulay duration. This is the same number that would be obtained by multiplying 365 days by 0.241 years. Finally, students are instructed to round the obtained future value to two decimal places. Students find the transaction price of the bond is $100.67 at Macaulay duration. This number includes the daily compounding of accrued interest.

**5.e Calculate the "street" price of the Treasury bond by creating a new custom function in Excel called *StreetPrice***

In Question 5.e, students create the fourth user-defined function called *StreetPrice* using VBA scripting. Appendix 2 provides the VBA script that calculates the transaction or "street" price. A detailed explanation of this function is provided in the instructor version of Excel. A video (https://youtu.be/kNso3oHGQ-g) has been created to illustrate how to write the function "StreetPrice."

***Was Immunization Achieved? (Question 6.a – 6.d)***

**6.a Using your answer from Question 5.d, calculate the proceeds from the sale of the Treasury bonds plus the future value of the received coupon payments at the duration-matched time to maturity.**

In Question 6.a, students calculate the total proceeds from the sale of the Treasury bond at Macaulay duration and add it to the future value of the reinvested coupon payments. This will allow students to see the effectiveness of bond immunization based upon the historical Treasury yields from January 2014 to January 2019. The final immunized portfolio balance at Macaulay duration is calculated in Excel according to Equation (7).

$$Portfolio\ Value = (Number\ of\ Notes\ x\ Transaction\ Price) + FV\ of\ Reinvested\ Coupons = (44{,}808\ x\ \$100.67) + \$506{,}692 = \$5{,}017{,}513 \quad (7)$$

**6.b Is the portfolio immunized? Is the portfolio underfunded or overfunded? Why or why not?**

Next, students must answer if the portfolio is immunized and reflect upon why the outcome is achieved or not achieved (Question 6.b). The target portfolio balance to cover the future liability is $5,000,000. Therefore, the liability is immunized and overfunded by $17,513. The traditional textbook approach would have assumed a flat yield curve and therefore, perfect immunization of exactly $5,000,000 would have been achieved. However, in this realistic case problem, "perfect" immunization does not occur for two reasons. The first and main reason is that the bond sells for a premium at duration ($100.67), causing an overfunded liability. The second reason is the availability of increasingly higher reinvestment rates for coupon payments. The T-bill rates rose from 0.06% to 2.14% from July 2014 to July 2018 as a result of the FOMC's actions to raise the federal funds rate.

**6.c Using the previously created user-defined functions, calculate the "estimated" portfolio value at duration, assuming that you only have the yield curve information for January 2014. Remember to hard code cells highlighted in orange, use equations or functions for cells highlighted in yellow, and do not alter cells highlighted in gray. The best estimate of future 6-month T-bill reinvestment rates is today's (Jan. 2014) 6-month T-bill rate. These are used to find the future value of the semi-annual coupon payments as in Question 4.b.**

So far, known historical Treasury data has been used to obtain the final bond investment value. However, at the time of immunization, future interest rates are not known. Question 6.c puts students in the realistic position of not knowing future interest rates or yield curve shifts. Therefore, they must use the January 2014 yield curve and assume that it remains unchanged for the next five years.

In Question 6.c, students use the previously created user-defined functions to calculate the estimated portfolio value at duration. Students calculate the new "street" price and future value of coupon payments under the assumption that the January 2014 yield curve does not change during the bond immunization period. Under the assumption of an unchanged January 2014 yield curve, the estimated portfolio value at duration is $5,031,596.

**6.d Is the "estimated" portfolio immunized? Is the "estimated" portfolio underfunded or overfunded? Why or why not?**

Next, students must answer if the portfolio is immunized and reflect upon why the outcome is achieved or not achieved (Question 6.d). The future liability is immunized and overfunded by $31,596. The estimated portfolio balance results in a higher overfunded status than the actual real-world outcome that occurs in Question 6.a ($31,596 vs. $17,513). The difference is primarily because the bond is predicted to sell at a larger premium at duration. The overestimated "street" price of $101.20 resulted from assuming that the yield to maturity before duration was 0.9% (t=4.5). Also, note that the estimated future value of the coupon payments is $497,026 which is only slightly lower than the future value obtained in Question 6.a. Therefore, the higher calculated "street" price accounts for the estimation of a larger overfunded amount.

***Achieving Immunization from January 1990 to January 1995 (Question 7.a – 7.b)***

**7. Repeat the process in Question 6.c and 6.d to calculate the actual (7.a) and estimated (7.b) outcomes of immunization. The coupon rate and the historical time period are different for this problem. The coupon rate for this Treasury bond is 2% and provided interest rates are from January 1990 to January 1995. You should get the same Macaulay duration answer as you did in the main example. This will allow you to see how target date immunization works if you were in a different historical time period. During this time period, interest rates were much higher at first and the yield curve was relatively flat. Then interest rates fell until 1995 when they rose close to 1990 levels.**

Question 7 asks students to repeat the process in Question 6. These questions allow students to see how bond immunization works when the Macaulay duration is the same number as in Question 6, but the historical period, yield curve shifts, and coupon rate are different. In Question 7.a, the historical period covers January 1990 to January 1995. During this period, interest rates were much higher (i.e., 6-month Treasury yield of 8.42%) and the yield curve was relatively flat. Interest rates fell until 1994, but in 1995, interest rates rose back to 1990 levels.

The Excel template for Question 7.a and 7.b can be modified for other uses beyond the assignment. For example, if you need to analyse a semi-annual bond with a duration of 9.1 years, more rows should be added to the "T-bill Reinvestment Rates" section. If the duration is 9.1 years, then the yield to maturity rates before and after duration should be estimated with data from a yield curve at year 9 and 9.5, respectively.

In Question 7.a, students will find that the portfolio value will equal $4,991,695 at the targeted future date. This means that the portfolio value is underfunded by $8,305. This is not particularly concerning given that it represents an underfunded percentage amount close to negative 0.16%. In Question 7.b, students assume that they do not know future interest rates beyond January 1990. In this case, the estimated portfolio value at duration is $4,998,040 which is underfunded by $1,960.

***Differences in Immunization Outcomes (Question 8)***

**8. Comment on the target date immunization results for questions 5, 6, and 7. Compare the "Actual Outcome" and "Estimated Outcome (with no yield curve change)" results. Which immunization example was the least expensive? Why? Hint: Multiply the initial bond prices in Question 2.b and Question 7 times the number of bonds required for immunization. Also, consider the premium or discount status of the two different bonds.**

Question 8 is the final question. Students are to comment on the bond immunization results from Questions 6 and 7. Students must compare the "Actual Outcome" (Part "a") with the "Predicted Outcome"

(Part "b") column results. Students should answer that the bond in Question 6 results in an overfunded liability, where the bond in Question 7 results in a slightly underfunded liability.

Students also determine which immunization example was the least expensive. In Questions 6 and 7, the initial bond prices are $103.53 (premium) and $76.12 (discount), respectively. The total cost of immunizing the future liability when the bond sells at a premium is $4,638,977 ($103.53 times 44,808 bonds). In Question 7, the total cost of immunization is $3,465,820, which is the result of multiplying $76.12 times 45,531 bonds. Therefore, the deep discount bond in Question 7 was less expensive. As time passes, the price of a discount bond rises to its par value, while the price of a premium bond falls to its par value. The street price of the discount bond in Question 7 at duration was $99.76, which represented an increase of $23.64 per bond. The premium bond, however, decreased in price from $103.53 to $101.21 over the immunization period. This point can be used to illustrate how premium and discount bond prices revert to par value as the maturity date approaches.

## Conclusion

The overarching goal of this new spreadsheet assignment is to strengthen students' Excel skills. Using Excel-based assignments in the classroom is one way to meet this challenge. Thus, as previously mentioned, Excel can offer two major benefits for the student. First, Excel can provide an interactive, hands-on method of constructive learning of complex problems. Second, by improving their knowledge, skill, and expertise in VBA scripting, students may improve their employment prospects in the job market. VBA scripting is a useful tool in many finance jobs.

Treasury yield spot rate data from January 2014 to 2019 is provided to highlight the Federal Open Market Committee's target federal funds rate changes that caused a significant yield curve shift. This original spreadsheet assignment includes instructions on how to create user-defined functions to calculate bond prices, duration, the required number of bonds to immunize a portfolio, the future value of a series of reinvested coupon payments, and the "street" price of a bond. Students can learn how to assign and process data with "For, Next" statements, "If, Then, Else" statements, "Application.WorksheetFunction" statements, and the "Excel.Range" variable type.

The user-defined functions in this paper have been created in a flexible manner that allows students to enter any type of bond, any future liability, any assumed changes in the Treasury yield curve, and any assumed reinvestment rates for coupon payments. The instructor has the option to provide students with an Excel Add-In that already contains the user-defined functions. This way, the instructor can either choose to use the entire assignment or just focus on a few concepts with the Excel Add-In. Further, the spreadsheet is equipped with an automatic grading system that assigns half of the points per question to using cell-referenced equations and functions and the other half to obtaining the correct numerical answer.

Another strength of this assignment is that it overcomes the unrealistic assumptions of typical textbook examples illustrating bond immunization. Most textbooks assume a flat yield curve for the bond immunization period, which leads to perfect immunization. This assignment is unique in that it uses the actual Treasury yield curve data from January 2014 to January 2019 to model historical and estimated outcomes to bond immunization. Students explore the varying patterns of historical Treasury yield curves and the role of the FOMC during this period.

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## Appendix 1: Assignment File Names and Key Learning Objectives

The student, instructor, and add-in files are available by request from the author. The file names are:

1. Student Version Target Date Immunization.xlsm
2. Instructor Version Target Date Immunization.xlsm
3. User Defined Functions Excel Add In.xlam

Key Learning Objectives:

(1) Discuss the effects of the Federal Open Market Committee's changes in the federal funds rate on the Treasury yield curve from January 2014 to January 2019.

(2) Calculate Macaulay duration to determine the funding strategy that will achieve bond immunization.

(3) Interpolate Treasury yield curve rates using the *Spline* function.
*Spline* video link: https://youtu.be/vQnZOoctubM

(4) Create a user-defined function to calculate the bond price.
*BondPrice* video link: https://youtu.be/iKL9C_sr_Nk

(5) Create a user-defined function to calculate Macaulay duration in years.
*MacDurationAdj* video link: https://youtu.be/7S37HJ4MEeM

(6) Create a user-defined function that calculates the number of bonds that must be purchased to immunize a future liability.
*NumberBonds* video link: https://youtu.be/cbDNr-8wFlY

(7) Create a user-defined function to calculate the future value of the semi-annual coupon payments which are reinvested every 6 months at the current 6-month Treasury bill rate.
*FVCouponPmts* video link: https://youtu.be/cBt3T9_Pv4Y

(8) Create a user-defined function to calculate the transaction or "street" price of the bond on the date of Macaulay duration using the daily compounding method. This method accounts for accrued interest between bond payments.
*StreetPrice* video link: https://youtu.be/kNso3oHGQ-g

(9) Calculate the final value of the bond portfolio plus reinvested coupon payments on the date of Macaulay duration and determine if the portfolio is immunized.

(10) Describe how the current interest rate environment affects the ability to achieve bond immunization over historical periods of yield curve shifts.

## Appendix 2: VBA Script for *StreetPrice* Function

```
Function StreetPrice(YearsToMaturity, CouponRate, ParValue, YTMbeforeDuration, YTMafterDuration,
CompoundingPeriods, Duration, DaysInYear)
AdjCouponRate = CouponRate / CompoundingPeriods
NumPayments = YearsToMaturity * CompoundingPeriods
CoupPmt = ParValue * AdjCouponRate
Duration_UnAdj = Duration * CompoundingPeriods
nBeforeDur = Application.WorksheetFunction.RoundDown(Duration_UnAdj, 0)
nAfterDur = Application.WorksheetFunction.RoundUp(Duration_UnAdj, 0)
AdjnBeforeDur = nBeforeDur / 2

'Obtain Bond Price Before Duration and Bond Price After Duration.
PriceBeforeDuration = -Application.WorksheetFunction.PV((YTMbeforeDuration / CompoundingPeriods),
(NumPayments - nBeforeDur), CoupPmt, ParValue)
PriceAfterDuration = -Application.WorksheetFunction.PV((YTMafterDuration / CompoundingPeriods),
(NumPayments - nAfterDur), CoupPmt, ParValue) + CoupPmt

'Obtain Daily Return.
DailyReturn = Application.WorksheetFunction.Round(Application.WorksheetFunction.Rate((DaysInYear /
CompoundingPeriods), 0, -PriceBeforeDuration, PriceAfterDuration), 10)

'Obtain Bond Price at Duration.
```

PriceAtDuration = Application.WorksheetFunction.Round(-
Application.WorksheetFunction.FV(DailyReturn, DaysInYear * (Duration - AdjnBeforeDur), 0,
PriceBeforeDuration), 2)
**StreetPrice =** PriceAtDuration

*'Check Computations.*
Debug.Print "nBeforeDur " & nBeforeDur
Debug.Print "nAfterDur " & nAfterDur
Debug.Print "PriceAfterDuration " & PriceAfterDuration
Debug.Print "PriceBeforeDuration " & PriceBeforeDuration
Debug.Print "DailyReturn " & DailyReturn
Debug.Print "PriceAtDuration " & PriceAtDuration
Debug.Print "StreetPrice " & StreetPrice
**End Function**

# *Modeling on a Budget: Automating a Financial Modeling Course Without Subscription-Based Data Sources*

***Tim Mooney*[1]**

## ABSTRACT

The cost of popular finance databases puts them out of reach of many smaller institutions. This article shows how data freely available online can be integrated efficiently into a financial modeling course. We show how to import finance data from various sources automatically including financial statements, stock prices and returns, bonds, and options. We also provide example spreadsheets of financial modeling exercises fed by this data. This study can help improve student learning of difficult finance concepts and build spreadsheet skills. It can also help instructors create in-class exercises, assignments, and exam questions more efficiently.

## Introduction

A course in financial modeling is an important component of an undergraduate finance curriculum. Covering technical finance topics including pro forma financial forecasting, portfolio optimization, Monte Carlo simulation, and many others, financial modeling prepares students for some of the more challenging subject matter they may encounter in a finance career. Just as importantly, financial modeling requires students to learn how to use software and perhaps some programming skills. Although more advanced data analysis packages such as Stata, SPSS, or R are well-equipped to handle financial modeling tasks, modeling in a spreadsheet program such as Microsoft Excel or Google Sheets likely provides much better career preparation (Marriott 1992). This is because such spreadsheet programs are so widely used in industry. Furthermore, a student building a financial model from scratch in a spreadsheet will likely understand it much better than if it were done using a command-line "black box" style of data analysis in a more sophisticated program (Holden and Womack 2000).

A key input into a financial modeling course is data, and many academic finance data sources are expensive. The purpose of this study is to illustrate how finance data that is freely available online can be integrated into a financial modeling course efficiently. Many smaller universities simply do not have the scale to justify industry standard data sources like Bloomberg or academic databases like CRSP and COMPUSTAT. Lower-cost subscription options are available, including Standard and Poor's NetAdvantage and Morningstar Direct, but these are not as widely used. Financial statements and stock prices are also published online free of charge in several locations, but getting this data into a spreadsheet can be tedious.

In this paper, we discuss financial modeling data sources that do not require a subscription, and we provide methodology to feed this data into a spreadsheet program using only spreadsheet functions, very basic knowledge of extensible markup language (XML), and occasionally Excel add-ins. We also provide completed example spreadsheets showing how this methodology can be integrated into financial modeling exercises, which are available at the companion website for this article.[2] Integrating non-subscription data sources into widely used software applications such as Excel and Google Sheets can both enhance students' understanding of financial modeling concepts and better prepare them for their careers by improving software

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[2] https://sites.google.com/view/modelingonabudget/.

competency. To our knowledge, this is the first study to examine non-subscription finance data sources and detail their integration into a financial modeling course.

Our aim is not to advocate against any existing data sources. To be sure, a Bloomberg terminal would provide a highly relevant platform for a student to learn more about finance (Lei and Li 2012). We also do not seek to sway instructors from data sources that work well for them. Rather, we intend to contribute to the literature on financial modeling instruction by helping to fill any potential data gaps that may exist at an institution. We also seek to save both instructors and students time and effort by showing ways of automating some data importation tasks that might otherwise be tedious. Our experience has been that students can focus more on understanding finance concepts and building spreadsheet skills when the most menial data importation steps are automated.

Our study contributes to existing literature by expanding on Flanegin et al. (2009), who compare free and low-cost stock data sources to traditional subscription-based databases. To our knowledge, ours is the first study to present a broad scope of free finance and economic data sources spanning financial statements, stock prices, bonds, options, and macroeconomic data. Furthermore, we seek to build on studies such as Wann (2015) and Wann and Lamb (2016) by combining illustrative spreadsheet examples with automated real-world data. This study may be of interest to instructors in areas beyond financial modeling as well, as automated external data connections can reduce the time needed to develop in-class exercises, assignments, and exam questions based on finance and economic data. Finally, we hope to foster thought on how teaching finance and economics may be impacted or enhanced by the choice of data source, and how students can benefit from learning how to set up external data connections in spreadsheets.

## Literature Review

The importance of financial modeling with spreadsheets has been articulated at least as early as Klein (1980). Since then, the benefits of spreadsheet modeling have been well-documented. Ghani and D'Mello (1993) look at how student perceptions of challenge, skill, and other variables combine to influence their performance and satisfaction with spreadsheet-based financial modeling assignments. Holden and Womack (2000) argue the use of spreadsheet modeling brings several benefits, including enhanced understanding of finance concepts, better career preparation, and a more meaningful connection of theory to application. The authors also highlight an important distinction between the use of a spreadsheet template (ready-built) and spreadsheet modeling, which involves the student building the spreadsheet architecture to solve a problem. While recognizing the value of both, Holden and Womack contend that more active spreadsheet modeling is better for facilitating student learning, and Bauer Jr. (2006) presents a similar argument in the context of simple Visual Basic for Applications (VBA) programming with spreadsheets. To that end, students may learn better from the examples we present below by building them together with the instructor. Cagle et al. (2010) report that spreadsheet assignments improved student learning in an introductory finance course. MacDougall and Follows (2006) show that students report better skill development and feel finance instruction is more effective when they build spreadsheets that model course content. Mangiero et al. (2010) argue that Excel can help improve student learning of finance concepts. Balik (2009) argues that teaching students to build financial models prepares them for careers in business.

Numerous studies have provided insightful approaches to integrating spreadsheet work into business and finance curricula. McCloskey and Bussom (2013) provide a good review of many of these, but a few others are relevant to our work here. Roychoudhury (2018), LaBorde (2017), and Girard and Ferreira (2005) present techniques for building the efficient portfolio frontier in a spreadsheet with a focus on using real-world data, although their data is downloaded manually. Wann (2015) and Wann and Lamb (2016) present Excel-based assignments on Black-Scholes option valuation and bond duration with an emphasis on improving students' understanding of these concepts and also building spreadsheet skills. Andrews and Coates (2013) illustrate a spreadsheet-based simulation exercise in an economics class. Arellano et al. (2012) present a retirement financial model built in Excel to teach basic time value of money concepts. Boudreaux et al. (2016) present a bootstrap spreadsheet simulation of the distribution of future stock prices and returns. Green (2014) describes a spreadsheet-based macroeconomic policy simulation exercise.

Studies on alternative finance data sources are scarce. Kane and Masters (2009) argue in favor of open source data and software programs for financial analysis and provide a few rudimentary data source examples. Yan (2017) presents a programming-based methodology for retrieving data from the Internet using the R programming language. Flanegin et al. (2009) evaluate the accuracy of subscription databases such as CRSP to data from Internet sources such as MSN Money and Yahoo! Finance.

## Finance Data Sources

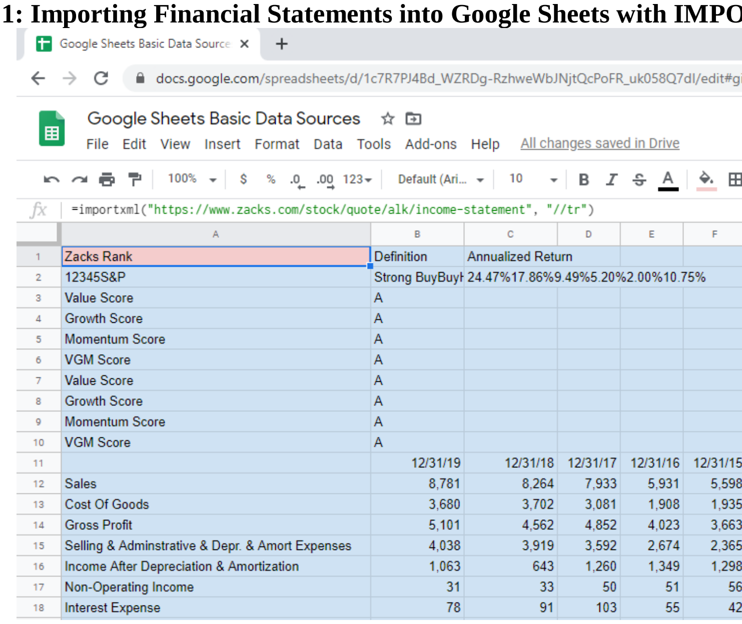
As stated above, the high cost of finance databases typically used by larger universities may put them out of reach for institutions that are smaller or more teaching-focused. In this section, we outline alternatives to subscription-based finance databases and provide basic illustrations of how to import this data into a spreadsheet. The companion website for this article contains an example Google Sheets spreadsheet entitled "Google Sheets Basic Data Sources" as well as an Excel spreadsheet "Excel Basic Data Sources.xlsm" to show these illustrations in both software applications. Our goal is to get financial data into a spreadsheet with a minimum of manual steps such as clicking and typing. In addition, we also seek to minimize unnecessary coding and more technical spreadsheet manipulation in order to keep these illustrations accessible to as broad an audience as possible. The section following this one gives further details how these data sources can be integrated into a financial modeling course.

### *Financial Statements*

Financial statements are a vital source of data in economics and finance. While COMPUSTAT is a familiar database to most academic researchers and Bloomberg is common among practitioners, our focus is on data sources that do not require a subscription. Options abound for getting public company financial statements into a spreadsheet. We use financial statement information from Zacks Investment Research (*http://www.zacks.com*) and MarketWatch (*http://www.marketwatch.com*), although this methodology could certainly be applied to financial statement data from elsewhere on the Internet. To load financial statements into Google Sheets, we use the function IMPORTXML, which can import data in tabular and other forms. The IMPORTXML function takes two arguments, "url" and "xpath_query". The first, "url", is the web URL from which the data originates. The second argument, "xpath_query", uses XML language to specify what data from the URL will be imported. As an illustrative example, consider Alaska Air Group (ticker:ALK), whose income statement is available from Zacks website (*https://www.zacks.com/stock/quote/ALK/income-statement)*. To import the income statement table from the website, the xpath_query is "//tr". The spreadsheet "Google Sheets Basic Data Sources" on the companion website for this article has a tab "First Example" that shows how Alaska Air Group's income statement can be imported into Google Sheets using the following formula:

=importxml("https://www.zacks.com/stock/quote/ALK/income-statement", "//tr")

**Figure 1: Importing Financial Statements into Google Sheets with IMPORTXML**




| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Zacks Rank | Definition | Annualized Return | | | |
| 2 | 12345S&P | Strong BuyBuyh | 24.47%17.86%9.49%5.20%2.00%10.75% | | | |
| 3 | Value Score | A | | | | |
| 4 | Growth Score | A | | | | |
| 5 | Momentum Score | A | | | | |
| 6 | VGM Score | A | | | | |
| 7 | Value Score | A | | | | |
| 8 | Growth Score | A | | | | |
| 9 | Momentum Score | A | | | | |
| 10 | VGM Score | A | | | | |
| 11 | | 12/31/19 | 12/31/18 | 12/31/17 | 12/31/16 | 12/31/15 |
| 12 | Sales | 8,781 | 8,264 | 7,933 | 5,931 | 5,598 |
| 13 | Cost Of Goods | 3,680 | 3,702 | 3,081 | 1,908 | 1,935 |
| 14 | Gross Profit | 5,101 | 4,562 | 4,852 | 4,023 | 3,663 |
| 15 | Selling & Adminstrative & Depr. & Amort Expenses | 4,038 | 3,919 | 3,592 | 2,674 | 2,365 |
| 16 | Income After Depreciation & Amortization | 1,063 | 643 | 1,260 | 1,349 | 1,298 |
| 17 | Non-Operating Income | 31 | 33 | 50 | 51 | 56 |
| 18 | Interest Expense | 78 | 91 | 103 | 55 | 42 |

Figure 1 shows the output of this formula—note that the formula must use straight quotation marks and not smart quotes to work properly. One only needs to change the ticker symbol in the URL to import another company's financial statements. As shown in Figure 1, the output of the formula into the spreadsheet has some extra content at the top that may or may not be desirable. This formatting could be cleaned up by exploring different specifications for xpath_query. Viewing the page source information in a web browser would provide a way to see what specific xpath_query specification would provide the most desirable output. A wealth of information on using XML language is available online. But here, the intent is to maintain simplicity in our methodology. There are certainly other ways to import data into a spreadsheet. In Google Sheets, the same work can also be done using the IMPORTHTML function. Automating the importation of financial statements in Excel is not as simple as Google Sheets, as we are not aware of an analogous XML function in Excel. However, the spreadsheet "Excel Basic Data Sources.xlsm" on the companion website contains a VBA macro that imports financial statements automatically from MarketWatch. By entering a ticker and clicking the Get Financials button, the income statement, balance sheet, and cash flow statement are loaded automatically. Although outside the scope of this article, there are numerous resources to get started writing VBA macros in Excel, with a simple Google or YouTube search being a helpful starting point.

### *Prices and Returns: Stocks, Mutual Funds, ETFs, Indices*

CRSP is the stalwart database for academic stock return research, with historical price, return, and volume information going back to 1926, as well as dividends and other listing and delisting data. Historical price and volume data are also available from a variety of free sources online, including Yahoo! Finance, the New York Stock Exchange and NASDAQ websites, and many others. However, automatic downloading of historical data to a spreadsheet is often difficult or impossible. Google Sheets has a function GOOGLEFINANCE which can easily pull historical stock price information, but unfortunately it does not provide prices adjusted for dividends or splits, so computing total returns accurately is not feasible. Yahoo! Finance data has adjusted closing prices, well-suited for computing returns. Until 2017, the Yahoo! Finance interface included an application programming interface (API) that allowed for automated importation of stock data into a spreadsheet. Unfortunately, that API was discontinued. Currently, data can be downloaded from Yahoo! Finance manually to a spreadsheet in comma-separated value format, which works, but it requires several instances of clicks and typing by the user.

Alpha Vantage (*https://www.alphavantage.co/*) provides a wealth of financial market data for stocks, currencies, cryptocurrencies, and other assets. They offer access to historical data with creation of a free account, and although there is a limit on the frequency of data requests per minute, this limit is typically not intrusive. The Alpha Vantage Excel add-in is relatively easy to install and allows for simple importation of stock prices at several frequencies: monthly, weekly, daily, and even intra-day data are available. Historical data only goes back 20 years, but we find this to be a long enough time series for most financial modeling applications. In our view, Alpha Vantage is the best overall non-subscription stock data source. The Excel spreadsheet "Excel Basic Data Sources.xlsm" on the companion website for this article shows how the Alpha Vantage Excel add-in is used to import historical stock price data into Excel easily, under the tab "Stock Prices." It is not necessary to install the add-in in order to view an example of the stock price data retrieved, although the add-in is required to download new stock price data. The syntax of the add-in's function AVGetEquityTimeSeries is straightforward, and help documentation is readily available online. The main arguments of the function are firm ticker and data frequency. This methodology also works for ETFs, major index levels and returns, and mutual fund net asset values and returns. Google Sheets also supports an Alpha Vantage add-in with the same functionality. The spreadsheet "Google Sheets Basic Data Sources" on the companion website also provides an example in the tab "Stock Prices."

### *Bond Data*

Because bonds trade less frequently and generally receive less investor attention than stocks, data sources for individual bonds are more limited. The New York Stock Exchange publishes a spreadsheet of all bond issues that trade on the exchange with descriptive information such as issuer, maturity, and coupon rate (*https://www.nyse.com/publicdocs/nyse/NYSE_Bond_Master_List.csv*). The Financial Industry Regulatory Authority (FINRA) website (*http://finra-markets.morningstar.com/BondCenter/Default.jsp*) has a bond search feature, although automating the importation of data from the FINRA website does not appear straightforward. Business Insider (*https://markets.businessinsider.com/bonds/finder*) also provides a bond search feature that shows a bond's issuer, coupon rate, maturity, yield, current bid and ask prices, and credit rating. These search results can be imported using IMPORTXML. The tab "Bonds" in the "Google Sheets Basic Data Sources" spreadsheet on the companion website shows an example of how to import bond search results with the following formula:

=importxml("https://markets.businessinsider.com/bonds/finder","//tr")

This same data can also be imported into Excel with a VBA macro. The spreadsheet "Excel Basic Data Sources.xlsm" on the companion website provides an illustrative example of this in the tab "Bonds." The section further below discusses how to import bond data based on customized searches of the Business Insider database. A wealth of more general fixed-income time series data is available from the Federal Reserve Bank of St. Louis' Federal Reserve Economic Data (FRED) Database, including yields and spreads for various categories of corporate and Treasury bonds. FRED also has numerous other relevant economic and finance datasets. Importing FRED data into Excel is fairly straightforward with FRED's Excel add-in, available for free from the FRED website (*https://fred.stlouisfed.org/fred-addin/*). It is also convenient to import FRED data into Google Sheets without using an add-in. The tab "FRED Data" in the "Google Sheets Basic Data Sources" spreadsheet on the companion website provides an example using the IMPORTDATA function, along with several example data series from FRED that are relevant to financial modeling.

### *Options Data*

Like bond data, historical stock options data is not readily available. OptionMetrics is the main provider of historical stock option data and requires a paid subscription. Current information about stock options such as strike price, expiration, bid and ask prices, and volume can be obtained without a subscription from various sources, including Yahoo! Finance. We again utilize the IMPORTXML function in Google Sheets to import options data in one step. The "Google Sheets Basic Data Sources" spreadsheet on the companion website has a tab "Options" showing an example of options data imported for Amazon Inc., executed with the following formula:

=importxml("https://finance.yahoo.com/quote/AMZN/options","//tr")

Like the financial statement data above, only the ticker symbol needs to be changed to get a different company's options data, and the xpath_query is again "//tr". Below, we show how to evaluate put-call parity and use the Black-Scholes option pricing model with Yahoo! Finance options data. Similar to financial statement and bond data, automating the importation of options data into Excel is possible with a VBA macro, and the spreadsheet "Excel Basic Data Sources.xlsm" shows this functionality in Excel under the tab "Options."

There are certainly other data sources that could be integrated into a financial modeling course. Our aim here is not to provide an exhaustive list of data sources, which would be onerous and prone to obsolescence as the Internet evolves. Rather, we seek to provide a simple illustration of how free financial data can be integrated easily into the core components of most financial modeling curricula.

## Integrating Data Sources into a Financial Modeling Course

In the previous section, we identified the main data sources used in this article. Here, we detail how this data can be incorporated into exercises commonly found in a financial modeling course. Several of these examples are motivated by Benninga (2014), a popular financial modeling textbook. Although the examples provided are complete, we recognize the important distinction between building a financial model and using a ready-made template, highlighted by Holden and Womack (2000). Just how much of these spreadsheets instructors should provide to financial modeling students is an important consideration. Ultimately, it is up to the instructor to ascertain how students can best learn from these examples, whether seeing some parts completed or building parts from scratch themselves.

### *Pro-Forma Financial Forecasting and Valuation Model*

An enterprise valuation model based on forecast financial statements is a useful learning exercise for students studying financial modeling. We base our model on financial statement data from Zacks Investment Research, loaded automatically into Google Sheets with as little manual manipulation as possible. A completed example spreadsheet entitled "Pro Forma" is available on the companion website for this article and contains a pro forma valuation model for Alaska Air Group, Inc. Here, we briefly walk through the details of setting up the spreadsheet. The user enters the subject company ticker in the pink cell at the top of the "Pro Forma" tab. Based on the ticker entered, financial statements are imported from Zacks in the "Source Data" tab. The financial statements are imported with the most recent data on the left, which is not conducive to building a forecast. Consequently, we use the TRANSPOSE and SORT functions in the "Pro Forma" tab to rearrange the columns so that the most recent data is on the right. Once the data is set up this way, a pro forma forecast can be built out. The far right column provides example forecast assumptions to complete the pro forma. Below the pro forma, free cash flows are calculated, and weighted average cost of capital is estimated with the documented assumptions. In computing WACC, the firm's stock beta and market cap are obtained using the GOOGLEFINANCE function. Using a few more assumptions documented in the sheet, one can compute estimates of the firm's enterprise value and stock price per share based on the model.

With the ability to import financial statements automatically by entering only a ticker symbol, other useful applications abound, both for students and instructors. Given the consistency of financial statements imported using this methodology, it is relatively simple to set up a thorough ratio analysis model, comparing one firm to a peer group. In addition, a relative valuation model based on various multiples could also be a meaningful exercise for students. We have also found this automation to be a useful tool for developing examples for in-class discussions, assignments, or exams based on companies currently in the news.

### *Portfolio Modeling and Optimization*

The companion website has an Excel spreadsheet "Portfolio Optimization.xlsx" to illustrate how asset price data from Alpha Vantage can feed a model built on the classical portfolio theory of Markowitz (1952). Again, it is not necessary to install the Alpha Vantage Excel add-in to view the spreadsheet, although the add-in is required to retrieve any new data. In the "Optimization" tab, the user enters names and tickers for four asset classes. We use (i) U.S. large cap equity, measured by the SPDR S&P 500 ETF Trust (SPY); (ii) U.S. mid cap, measured by the SPDR S&P MidCap 400 ETF (MDY); (iii) U.S. small cap, measured by the Vanguard Small Cap Index Fund (NAESX); and (iv) Long-term Treasury bonds, measured by the Vanguard Long-Term Treasury Fund (VUSTX). Monthly adjusted closing prices for the four assets are imported in the tab "Source Data," which is linked to the ticker symbols the user enters. Returns and de-meaned returns are computed using the historical adjusted closing prices. Once these returns are computed, one can conduct all the portfolio analysis and optimization that is germane to a financial modeling course. The "Optimization" tab computes the mean and standard deviation of each asset class, along with the variance-covariance matrix, all using matrix operations. There is also a section to enter portfolio weights, and Excel's Solver add-in can be used for mean-variance optimization of an individual portfolio. For illustrative purposes, envelope portfolios are also computed, and a graph of the envelope is presented, as in Benninga (2014).

Automating the data feeding a portfolio optimization model allows instructors and students to adapt the model to different asset classes quickly, which can help illustrate how risk and return are managed in a portfolio. This automation also allows instructors to focus more on the practical limitations of mean-variance optimization due to the model's sensitivity to the estimated mean, variance, and covariance parameters. Possible extensions of this example abound, such as a Black and Litterman (1992) optimization model that incorporates views about asset class returns.

### *Monte Carlo Simulation with Assumptions from Real-World Data*

The Excel spreadsheet "Monte Carlo Simulation.xlsx" on the companion website shows how external data not requiring a subscription can inform various Monte Carlo simulation exercises. The tab "Retirement Simulation" illustrates a retirement portfolio simulation. The tab includes two data series imported using the FRED Excel add-in: a recession indicator time series based on quarterly GDP, and the quarterly level of the Wilshire 5000 total market index. It is not necessary to install the FRED add-in in order to use the spreadsheet. The idea behind the spreadsheet is to simulate a retirement portfolio with regular periodic contributions and simulated portfolio returns. The returns follow distributional assumptions that vary according to randomly occurring recessions. The historical mean and standard deviation of the Wilshire 5000 monthly return are shown after dividing the sample according to whether the recession indicator equals one during the year. Clearly, the mean stock return is lower in years where the recession indicator equals one: -2.53% per quarter during recession years compared to 3.84% during non-recession years. The tab also contains the frequency of recession quarters in the historical data, about 16.6%. Given other assumptions about an initial deposit, quarterly deposits, and annual deposit growth, each quarter a recession is randomly simulated, and then portfolio returns are simulated with mean and standard deviation that vary according to whether or not there is a recession. For brevity, the spreadsheet only runs 200 simulations of 10 years of portfolio outcomes, although either of these parameters could easily be increased. The ending portfolio values of the 10th, 25th, median, and 75th percentiles are also presented.

The spreadsheet contains other examples incorporating data sources discussed in this article. The tab "Stock Price Simulation" simulates stock returns using distributional assumptions designed to mimic the observed non-normality of stock returns. Given historical stock prices from Alpha Vantage, the mean return and standard deviation are calculated, and returns are simulated from an asymmetric distribution based on the skewness and kurtosis of the data. Below-median simulated returns follow a t-distribution to mimic the fatter negative tail and kurtosis of the return distribution. The tab "Binomial Option Values" simulates European-style binomial option ending payoffs, with stock price movement probabilities simulated based on historical stock prices from Alpha Vantage. The tab "Bond Defaults" shows how high-yield bond spreads from FRED and historical default probabilities can be used to simulate bond defaults and return outcomes. Additional details about these simulation illustrations are provided in the spreadsheet.

### *Bond Duration and Immunization*

The Google Sheet "Bond Duration and Immunization" shows how bond data imported automatically from Business Insider can be used to analyze bond duration and feed an immunization model. The left side of the main sheet pulls data for Ford Motor Company bonds. In the URL, the company is specified as "borrower=10746". Other company borrower numbers can be found by opening the URL in a browser and looking through the page source code. The "Search Fields" tab describes the search fields on the Business Insider bond search site and also provides example search queries that show how the URL changes as search fields are updated.

For each bond, the sheet computes the Macaulay (1938) duration and modified duration using the DURATION and MDURATION functions. The right side of the spreadsheet provides a space to create a portfolio of the imported bonds, where the user enters the par amount of each holding. Portfolio market value and duration measures are shown at the far right. In addition, information about a hypothetical liability stream provides a way to create a portfolio that is immunized to small changes in interest rates. This bond data automation can feed several other possible extensions, including analysis of non-parallel yield curve shifts, term structure modeling, and computing default-adjusted expected returns.

### *Option Valuation and Analysis*

The Google Sheet "Options" provides an example of how real-time data can inform option valuation analysis. The tab "Put-Call Parity" evaluates the parity condition for an option chain of Apple Inc. calls and puts. User-inputted data for the sheet are the stock ticker and assumed risk-free rate. Based on the ticker and expiration date, the sheet pulls options data from Yahoo! Finance using IMPORTXML, and the current stock price data is obtained with the GOOGLEFINANCE function.

The spreadsheet evaluates put-call parity by comparing two positions. The first is a fiduciary call, where an investor buys a call option and also invests the present value of the exercise price in a risk-free investment, thus ensuring sufficient funds to exercise the option. The second position is a protected put, where the investor buys both the stock and a put option. Given that the payoffs of these two investments are equivalent in the absence of transaction costs and other market imperfections, the value of these two positions should be theoretically equal. It is important to note that this parity theory applies to European-style options, where exercise is permitted only on the expiration date. In contrast, U.S. exchange-listed stock options are American-style and can be exercised any time until the option expires. Nevertheless, this illustration can be of interest to students, and the application of real-time options data to put-call parity may help students better understand both the concept of parity and the limitations of the theory.

The tab "Black-Scholes" estimates the price of put and call options for a specified stock using the model of Black and Scholes (1973). The user inputs the stock ticker, option expiration date, and assumed risk-free rate. The sheet pulls data from three sources to provide all required inputs into the Black-Scholes model: options data and the stock's dividend yield come from Yahoo! Finance, and volatility is measured from five years of price history data using the GOOGLEFINANCE function. Although stock prices from

GOOGLEFINANCE do not include dividends, weekly returns without dividends are a convenient proxy for overall stock volatility and are easy to implement. Additional infrastructure could also be built into the sheet to use dividend-adjusted prices from Alpha Vantage. Once all the ingredients of the Black-Scholes formula are imported, the top-left portion of the sheet computes the value of a put and call option for a user-specified exercise price. Below that, Black-Scholes put and call prices are calculated for the entire option chain. Again, the Black-Scholes formula used is for European-style options, not American options. A Black-Scholes model built for American options is likely beyond the scope of an undergraduate financial modeling course. Still, comparing the Black-Scholes European option values to their market values can be a worthwhile exercise for financial modeling students. One possible extension would be to find the implied volatility for a given option iteratively and compare it to the volatility calculated using historical data.

## Conclusion

Searching for finance data and getting it into a spreadsheet manually can be a valuable learning exercise for students. It can also be a significant barrier to focusing on the more difficult concepts covered in a financial modeling course. This paper shows how a financial modeling course can be built and automated around data sources that do not require a subscription. We show how to import financial statements, historical prices and returns for stocks, indexes, mutual funds and ETFs, and data for bonds and options with a minimum of typing and mouse clicks. In some cases, the automation is easier to implement with free data sources than paid databases. We also provide and discuss examples of how these data sources can feed financial models typically covered in a modeling course. Building and using these spreadsheets in class can help students better understand financial modeling and also develop spreadsheet skills that are desired by employers.

This study can help smaller or more teaching-focused institutions without access to expensive finance databases deliver financial modeling courses more effectively. In addition, the examples in this study have a wide range of useful applications for instructors. For example, they could help instructors quickly and easily update course content, using current real-world finance data for in-class exercises, assignment and exam questions, or group projects. As the Internet continues to evolve, some of the examples, illustrations, and data sources we present are sure to become outdated. Hopefully, these illustrations will continue to be useful even if some no longer function perfectly; indeed, a rudimentary understanding of XML described here could allow one to import most any financial data presented in tabular format on a website.

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# *Building an Excel Model of Efficient Frontier to Analyze a College Foundation's Portfolio*

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## ABSTRACT

Markowitz's Modern Portfolio Theory (MPT) has laid a foundation for modern financial economics. Teaching the principles of MPT is a necessary part for financial education. In this paper, we discuss how to guide students to build an Excel model of efficient frontier and apply the model to analyze portfolios in the real world. In an advanced finance course at SUNY Oneonta, Portfolio Management, students use Excel to construct a model that produces the efficient frontier for the assets held by SUNY Oneonta Foundation. They use the model to analyze the Foundation's portfolio, assess its performance, and propose their investment suggestions.

## Introduction

Modern Portfolio Theory (MPT), pioneered by Markowitz (1952), is a milestone of financial economics. As a result, risk diversification and portfolio optimization are an important part of finance textbooks at various levels. In the classroom, instructors explain to their students what the efficient frontier is, how it is constructed, and how it is applied to portfolio management. With the advancement of information technology, many types of application software have been developed and are now used not only in the industry but also in teaching MPT.[2]

Students who have taken finance and investment courses usually take in the ideas that systematic risk is compensated with a risk premium and that unsystematic risk can be reduced by diversification of investment. They also learn that the portfolios on the efficient frontier dominate the portfolios below or to the right of the efficient frontier because they understand that a portfolio on the efficient frontier maximizes its expected return given a fixed level of risk or minimizes its risk given a fixed level of expected return. In teaching, however, the explanation is theoretical, the examples are hypothetical, and students lack hands-on experiences to apply the theory in the real world. Specifically, their understanding of the theory is superficial; they can use software to build an efficient frontier, but they have little understanding about how the software is working out the efficient frontier. Once they have built an efficient frontier with the software, many students are not able to further apply the efficient frontier for the purposes of their own analysis. Moreover, students often have no chance to apply the model to the analysis of a real-money portfolio. In this case, students who obtain the knowledge and skills from books and classrooms stay book smart; they need hands-on experiences in real-money investments to internalize what they have learned.

To bridge from classroom learning to practice in a real-world setting, we cooperate with the management office of The State University College at Oneonta Foundation Corporation (hereafter, the College Foundation or the Foundation) in an advanced finance course, Portfolio Management. While students are studying MPT, they are allowed access to the College Foundation's information and have an opportunity to discuss the Foundation's operation with its managing officers. Under the guidance of the instructor, students explore the What-If Analysis tools of the Excel, such as Data Table, Solver, Visual Basic for Applications, and Charts,

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[2] Haugen (2001) describes a detailed procedure to find the efficient set using a hypothetical population of three securities. Bodie et al. (2014) present a spreadsheet model to construct the efficient frontier and capital allocation line in relation to seven international funds. Also using Excel, Holden (2015) develops a portfolio optimization model that further maximizes an investor's utility.

and integrate them into a framework that can process raw data and output efficient frontiers under different constraints for the assets held by the College Foundation. Furthermore, students use this tool to analyze the Foundation's portfolio, assess its performance, and contribute their suggestions to the Foundation's investment decisions. After wrapping up what they have done in this project and presenting their report before the Foundation's board, students gain a more integrated understanding of MPT and reap hands-on experiences in the real world.

Not only do students learn from their involvement in the Foundation's investment decisions, the Foundation management also benefits from students' suggestions. Students search for assets in a broader range of candidates and from various perspectives, and the Foundation management often finds some investment of the students' suggestions valuable and useful. By undertaking these suggestions, the Foundation improves its performance.

This paper summarizes our exploratory practice in which we combine teaching MPT with the portfolio management of our university foundation. Some business schools have student-managed funds where students can engage in investment activities. But almost all universities have a foundation that can provide students with an access to real-money portfolio management. This paper shares our experiences cooperating with the College Foundation to enrich the teaching of MPT. We organize the paper as follows. First, we present the theoretical foundation of the efficient frontier. Second, we briefly introduce the College Foundation. Next, we describe the data and methodology used to build the efficient frontier in the Excel framework, which are the main part of the student practice. Before concluding the paper in the end, we discuss some applications of the model in the students' suggestions to the Foundation management.[3]

## Theoretical Foundation of the Efficient Frontier

Given a population of assets, the central question in MPT is how we find the best way to combine the assets into a portfolio. In terms of the expected return and standard deviation, we would like to invest in a portfolio that has the lowest standard deviation given a level of expected return. Suppose that there are *n* assets in the portfolio. Then, the portfolio's expected return and standard deviation are determined with the following formulae,

$$E(r_P) = \sum_{j=1}^{n} w_j E(r_j) \quad (1)$$

$$\sigma(r_p) = \left[\sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j cov(r_i, r_j)\right]^{\left(\frac{1}{2}\right)} \quad (2)$$

where, $w_i$ is the weight of the asset *i* in the portfolio.

Now the question boils down to a constrained optimization problem, i.e., finding the weights of *n* assets in the portfolio that minimize the portfolio's standard deviation for a given level of expected return. In terms of mathematics, this optimization problem can be expressed as minimizing

$$\sigma(r_p)^2 = \left[\sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j cov(r_i, r_j)\right] \quad (3)$$

subject to a target expected return $E(r_p^*)$, i.e.,

$$E(r_p^*) = \sum_{j=1}^{n} w_j E(r_j) \quad (4)$$

and the sum of the portfolio weights that should be equal to one, i.e.,

$$\sum_{j=1}^{n} w_j = 1 \quad (5)$$

Equation (3), in which $\sigma(r_p)^2$ is to be minimized, is called the objective function, and Equations (4) and (5) state the constraints.

[3] The data, templates, and solutions for this exercise are available upon request.

Using Lagrangian multipliers, we can have an analytical solution for the weights. In fact, the computational software usually uses the trial-and-error convergence algorithm to seek a numerical solution. MPT refers to the collection of all portfolios with the weights that minimize the portfolios' variance for different levels of expected returns as the minimum variance set. The minimum variance set is divided by the global minimum variance portfolio, which is a portfolio that has the lowest standard deviation among all portfolios in the minimum variance set. In the minimum variance set, the portfolios with higher expected returns than the global minimum variance portfolio dominate the portfolios with lower expected returns than the global minimum variance portfolio. Of course, only those portfolios above the global minimum variance portfolio are the targets of portfolio managers, and MPT calls the set of these portfolios the efficient frontier. In other words, the efficient frontier is the collection of those portfolios that produce the highest expected returns for different levels of standard deviations.

The efficient frontier can be obtained under different conditions. Theoretically, an investor can sell short any assets in his portfolio. In the real world, however, mutual fund managers are not allowed to do short sales, and they are required to keep the holdings of specific risky assets below 10 percent of their total holdings. Then, the efficient frontiers under different constraints would be different from each other. Usually, the efficient frontier with short sales envelops the efficient frontier without short sales.

MPT points out that an investor would invest in a portfolio with the highest Sharpe ratio on the efficient frontier. This portfolio with the highest Sharpe ratio is referred to as the optimal risky portfolio. In the space of $E(r_P)$ and $\sigma(r_p)$, the line connecting the risk-free asset and the optimal risky portfolio represents the combinations of these two assets that have the same Sharpe ratio as that of the optimal risky portfolio. In fact, this line, denoted by the capital allocation line, originates from the risk-free asset and is tangent with the efficient frontier at the optimal risky portfolio. A rational investor would choose a portfolio on the capital allocation line to maximize his utility.

We follow this principle to build an Excel model that produces the efficient frontier as well as the capital allocation line for the population of the assets managed by the College Foundation. Then we use this model to analyze the holdings of the Foundation and propose our suggestions to improve the portfolio performance.

## SUNY Oneonta Foundation

Before moving on to the student exercise, we briefly introduce SUNY Oneonta Foundation. The State University College at Oneonta Foundation Corporation was established in 1982. The Foundation is organized in accordance with section 501 (c) (3) of the Internal Revenue Service code and is, therefore, exempt from New York State and local sales taxes and Federal and state income taxes. Its mission is to raise, receive, and administer private funds for scientific, educational, and charitable purposes for the State University College at Oneonta.

As a university fund, the SUNY Oneonta Foundation pursues prudent investment policies, a long-term investment horizon, and a consistent diversified asset allocation plan. Generally, the Foundation can hold only mutual funds, and the holdings via mutual funds in fixed income securities are limited below 25%, in equity securities below 65%, and in other asset securities below 10% of the total market value of the portfolio managed by the Foundation. Furthermore, the investment in an individual common stock shall not exceed 7% of the equity investment at market value. The Foundation conducts periodic reviews of the mutual fund portfolio to achieve investment diversification.

At the end of 2015, the Foundation held 16 equity mutual funds, three fixed income mutual funds, and three mutual funds specializing in other types of securities. The weights of these funds in the portfolio of the Foundation are reported in Table 1.

## Data and Methodology

In this section, we discuss the data and methodology while we show the steps in the student exercise that lead students to build the Excel model of efficient frontier. For simplicity, we use the following notations hereafter: $E(r)$ to stand for the expected return, $Var(r)$ for the variance, and $\sigma(r)$ for the standard deviation. The Excel templates are available upon the request.

**Table 1: The Weights of Mutual Funds Held by SUNY Oneonta Foundation**

| Mutual Fund Name | Ticker | Type | Weights (%) |
|---|---|---|---|
| AMG Yacktman Service | YACKX | Equity | 7.30 |
| Dodge & Cox Stock | DODGX | Equity | 3.68 |
| Hennessy Focus Investor | HFCSX | Equity | 6.87 |
| Homestead Small Company Stock | HSCSX | Equity | 3.45 |
| JHancock Disciplined Value I | JVLIX | Equity | 7.79 |
| MFS International Value I | MINIX | Equity | 9.05 |
| PRIMECAP Odyssey Stock | POSKX | Equity | 3.10 |
| Sterling Capital Stratton SmCp Val Instl | STSCX | Equity | 2.25 |
| Thornburg International Value A | TGVAX | Equity | 8.55 |
| Tweedy, Browne Global Value | TBGVX | Equity | 10.17 |
| Vanguard Emerging Mkts Stock Idx Adm | VEMAX | Equity | 3.64 |
| Vanguard Health Care Adm | VGHAX | Equity | 3.37 |
| Voya Corporate Leaders Trust B | LEXCX | Equity | 9.03 |
| Pimco Total Return Bond Fund | PTTDX | Fixed Income | 6.22 |
| Vanguard Total Bond Market Fund | BND | Fixed Income | 6.33 |
| SIT US Government Bond fund | SNGVX | Fixed Income | 6.36 |
| CGM Realty | CGMRX | Other | 0.62 |
| Fidelity® Real Estate Income | FRIFX | Other | 0.94 |
| Nuveen Real Estate Securities I | FARCX | Other | 1.28 |

### *Step 1. Collecting and Organizing the Inputs for the Model*

The data source for the student project is the Yahoo! Finance website, which provides historical market information of all the mutual funds and ETFs as well as publicly traded common stocks. We choose Yahoo! Finance to collect data such as price, dividend, and share split, since we want students to practice how to use Excel to process the raw data into the commonly used return per period and further to calculate the arithmetic average return, geometric average return, and annualized return. The free availability of these data at Yahoo! Finance is another advantage since students can still do financial analysis even if their schools do not subscribe to financial databases like WRDS or Bloomberg. However, the date coding on the monthly data at Yahoo! Finance may be confusing, as it uses the first trading date of a month to label the data of that month (Donaldson and Ingram 2014). For example, when a dataset downloaded from Yahoo! Finance uses April 1, 2016 to indicate the fourth month of 2016, the "Open" refers to the open price on April 1 and the "Close" represents the close price on April 29, the last trading date of this month.

We use monthly returns over a five-year period—from January 2010 to December 2015 in our case—as the inputs to build the efficient frontier for 19 mutual funds held by the Foundation. Monthly returns are computed using the adjusted close price to include the impact of both stock splits and dividends. In addition, we use SPDR S&P 500 ETF Trust (SPY) to proxy for the market portfolio because the ETF price has included the impact of dividends. We choose 3-month Treasury bill to proxy for the risk-free asset and it monthly interest rate on the secondary market is downloaded from the Federal Reserve website.[4]

### *Step 2. Estimating Statistics for 19 Mutual Funds in the Foundation's Portfolio*

After getting the monthly returns, we estimate the basic statistics for 19 mutual funds held by the College Foundation as follows.

[4] *http://www.federalreserve.gov/releases/h15/data.htm*. In the Federal Reserve website, the monthly interest rate of 3-month T-bills is annualized using a 360-day year or bank interest. We convert this rate into a monthly rate.

First, students use two methods to estimate $E(r)$, $Var(r)$, and $\sigma(r)$ for each asset and the covariances between the mutual funds and SPY. One method is to follow statistical formulae and calculate these statistics step by step in the Excel. The other is to use the Excel functions to get results directly. For example, students first apply the formula $Var(r_{it}) = \frac{1}{N-1}\sum_{t=1}^{N}(r_{it} - \overline{r_{it}})^2$ to calculate the average return and the variance from time series data of monthly returns. After they obtain the results, they use the Excel function "VAR.S" to confirm their calculation. In this way, students would understand statistic concepts and apply tools in various software programs.

Second, for each mutual fund in the Foundation's portfolio, we estimate the beta, $\beta = \frac{cov(r_i,\ r_m)}{\sigma(r_m)^2}$, with SPY proxying for the market portfolio. We also demonstrate that the beta for a particular asset can be obtained by regressing the returns on the market portfolio against the returns on that asset.

Finally, we calculate the funds' Treynor ratio, $Treynor\ Ratio = \frac{E(r)-r_{rf}}{\beta(r)}$, and Sharpe ratio, $Sharpe\ Ratio = \frac{E(r)-r_{rf}}{\sigma(r)}$, for further risk analysis and performance assessments.

### *Step 3. Estimating Statistics for the Foundation's Portfolio*

Using the weights in Table 1 and the monthly returns computed from the raw data in Step 1, we estimate $E(r)$, $Var(r)$ and $\sigma(r)$, and Treynor ratio and Sharpe ratio for the Foundation's portfolio.

First, there are two ways for estimating the portfolio's $E(r)$. One way is first to calculate the return on the portfolio in each month, which is the weighted average return across all funds in the portfolio with the weights of the funds as the weighting factors in the average, and then to estimate the portfolio's $E(r)$ as if we do with an individual asset after getting its historical returns. In the other way, we take a weighted average of the expected returns on the funds in the portfolio, which have already been obtained in Step 2, with the weights of the funds in the portfolio as the weighting factors in the average. This average is nothing but the estimation of the portfolio's $E(r)$. Either way produces the same results. In these calculations, the Excel functions "SUMPRODUCT", which returns the sum of the products of the array of the fund returns and the corresponding fund weights, is very useful.

Second, there are two methods for estimating $Var(r)$ and $\sigma(r)$ of the portfolio's return. After getting the time series of monthly return on the Foundation's portfolio, we estimate its $Var(r)$ and $\sigma(r)$ as if we do with a single asset. A portfolio's $Var(r)$ and $\sigma(r)$ can also be estimated through its covariance matrix. We devote Step 4 to describing how to estimate the covariance matrix and then use it to estimate the portfolio's $Var(r)$ and $\sigma(r)$ because it is an important part of finding the efficient frontier.

Third, looking upon the Foundation's portfolio as a single asset, we continue to estimate its covariance with the market portfolio and its beta. Furthermore, we calculate its Treynor ratio and Sharpe ratio.

### *Step 4. Estimating the Covariance Matrix of the Foundation's Portfolio*

After students know how to use the time series data to estimate the covariance step by step, we now use the Excel function "COVARIANCE.S" to estimate the covariance matrix, which will be used as a template to calculate a portfolio's standard deviation in the efficient frontier model.

First, in the first column of the matrix, we manually fill the augments of the "COVARIANCE.S" function with the monthly returns on the fund in the first column and the monthly returns on the fund in the diagonal column, with the returns in the diagonal column locked by clicking the key "F4" on the keyboard. Then, highlighting the first column and scrolling it over to the rightest column creates the covariance matrix. To make sure that scrolling has done the right things, we randomly choose a cell to confirm that the function in the cell is correct.

Second, after adding the weights of the funds to the corresponding funds on the top and to the left of the covariance matrix, we multiply each element in the covariance matrix by the weight on the top and then by the weight on the left and then add the products up across all the cells in the matrix. The sum is the portfolio's the variance and the square root of the sum is the portfolio's standard deviation. After students grasp the computation step by step, we further show students how to carry out this computation with the Excel function "SUMPRODUCT" or "MMULT" with "TRANSPOSE" embedded, which simplifies the Excel coding to two or one step(s). Using the weights in Table 1, the template of covariance matrix produces the same $Var(r)$

and $\sigma(r)$ as the Step 3 does. When it is incorporated in the Excel tool of Solver, the weights would change to minimize the portfolio's $\sigma(r)$, given a level of $E(r)$.

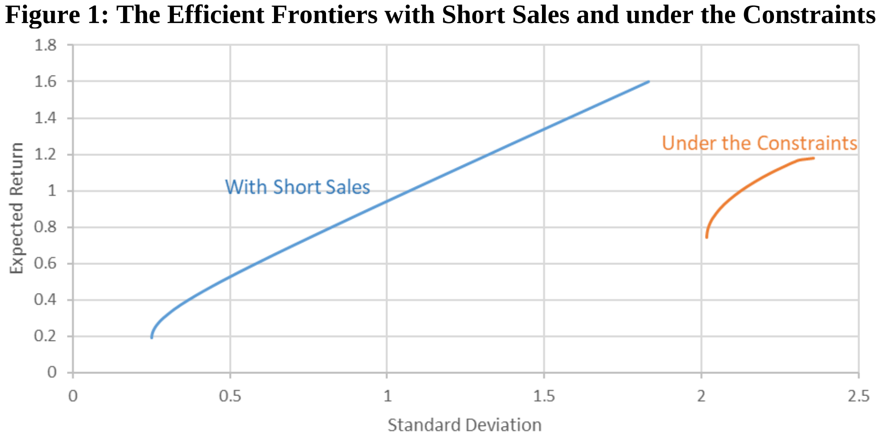
### *Step 5. Solving for the Efficient Frontiers Using the Excel's Solver*

We use the Excel add-in program, Solver, to build the efficient frontier. We first solve for the efficient frontier permitting short sales. Although short sales are not allowed in the Foundation, considering the possibility of short sales is a starting point for students to understand MPT. Then, we move on from the theoretical model to the applied model in the real world by imposing various constraints.

First, to solve for the efficient frontier with short sales, we start with the global minimum variance portfolio, which is the portfolio that has the smallest standard deviation among all possible portfolios. In the Excel window Solver Parameters, we set the parameters to find this portfolio. The objective is set to minimize the portfolio's $\sigma(r)$ generated by the covariance matrix. The changing variable cells are the portfolio weights in the covariance matrix, which are subject to the constraint that the sum of the weights is one. By changing the weights, Solver solves for a portfolio that meets the requirements of the setting. The solution produced by Solver under this setting is the global minimum variance portfolio with $E(r)$ equal to 0.19% and $\sigma(r)$ equal to 0.25%. Then, we construct portfolios with minimum standard deviations at different levels of expected returns. To do so, we add to the constraint block in Solver Parameters one more constraint, i.e., the portfolio's $E(r)$ is set at a given level. Again, Solver solves for a portfolio, by changing the weights in the covariance matrix, that has the minimum standard deviation among all portfolios with the same given expected return. As the level of $E(r)$ in the constraint changes from the global minimum variance portfolio's $E(r)$ to higher levels, Solver produces a series of portfolios that constitute the efficient frontier. In our case, we make the expected return in the constraint start at 0.19%, the global minimum variance portfolio's $E(r)$, increase by one basis point every time, and go a bit beyond 1.5%. Here, the 1.5%, the expected return of the fund of VGHAX, is the highest expected return among all mutual funds in the portfolio. Putting the pairs of $E(r)$ and $\sigma(r)$ of these portfolios in a graph, we show the efficient frontier with short sales for the College Foundation in Figure 1.

Second, by adding the constraints required by the Foundation to the constraint block in Solver Parameters, we continue to solve for the efficient frontier under the constraints that the Foundation can use to analyze its portfolio. As shown in its investment statements, the College Foundation limits its ultimate holdings in equity assets less than 65%, in fixed income assets less than 25%, and in other types of assets less than 10%. With these additional constraints in place and following the same procedure described above, we construct the constrained efficient frontier, which is presented, along with the efficient frontier with short sales, in Figure 1. Not surprisingly, the set of the constrained efficient frontier is inside the set of the efficient frontier with short sales.

**Figure 1: The Efficient Frontiers with Short Sales and under the Constraints**




### *Step 6. Solving for the Optimal Capital Allocation Line*

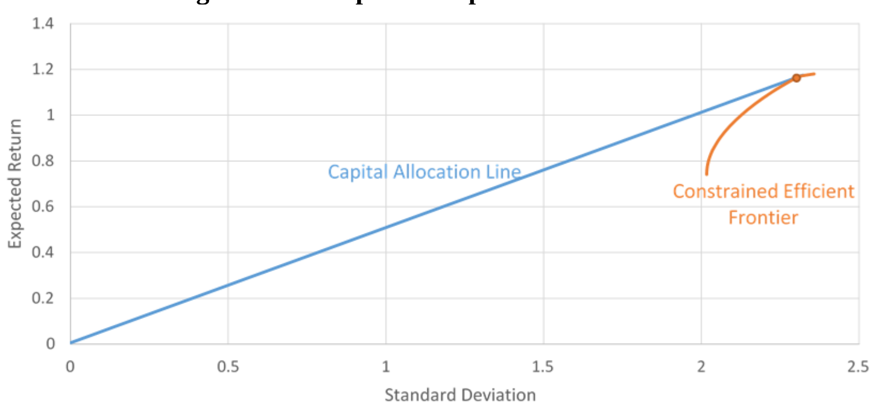
When the risk-free asset is introduced, an investor would choose a portfolio on the optimal capital allocation line. In the $E(r)$ and $\sigma(r)$ space, the optimal capital allocation line starts from the risk-free asset and is tangent with the efficient frontier at the optimal risky portfolio, representing the collection of portfolios constructed with the risk-free asset and the optimal risky portfolio. Since the optimal risky portfolio has the highest Sharpe ratio on the efficient frontier, the portfolios on the optimal capital allocation line also have the highest Sharpe ratio. We continue to use Solver to determine the optimal capital allocation line in relation to the Foundation's constrained efficient frontier.

First, in Excel, the Sharpe ratio formula, $Sharpe\ Ratio = \frac{E(r_P)-r_{rf}}{\sigma(r_p)}$, is created in a cell, where $E(r_P)$ and $\sigma(r_p)$ are the expected return and the standard deviation, respectively, of the portfolio that is subject to change, by altering the portfolio assets' weights, to maximize its Sharpe ratio, and $r_{rf}$ is the average interest rate of T-bills over the sample period.

Second, in Solver Parameters, setting the objective function to maximize the Sharpe ratio and applying the Foundation's constraints (the equity share less than 65%, the fixed income share less than 25%, and the share of other types of assets less than 10%, plus the total is equal to one), we obtain the optimal risky portfolio on the constrained efficient frontier as well as the highest Sharpe ratio, which is 0.5 in our case. Then, with the highest Sharpe ratio, the capital allocation line is represented by the equation, $E(r_P) = r_{rf} + Sharpe\ Ratio\ \times\ \sigma(r_p)$.

Third, in Excel, we calculate the $E(r_P)$ and $\sigma(r_p)$ as $\sigma(r_p)$ changes from zero to the standard deviation of the optimal risky portfolio, which is 2.32% in our case. Plotting the pairs of these results on the $E(r)$ and $\sigma(r)$ space produces the capital allocation line shown in Figure 2. The capital allocation line represents the collection of portfolios that invest in the risk-free asset and the optimal risk portfolio and that produce the highest Sharpe ratio. In the graph, the point at which the optimal capital allocation line is tangent with the efficient frontier represents the optimal risky portfolio. At this point, the optimal risky portfolio has expected return of 1.18%, standard deviation of 2.32%, and Sharpe ratio of 0.5.

**Figure 2: The Optimal Capital Allocation Line**



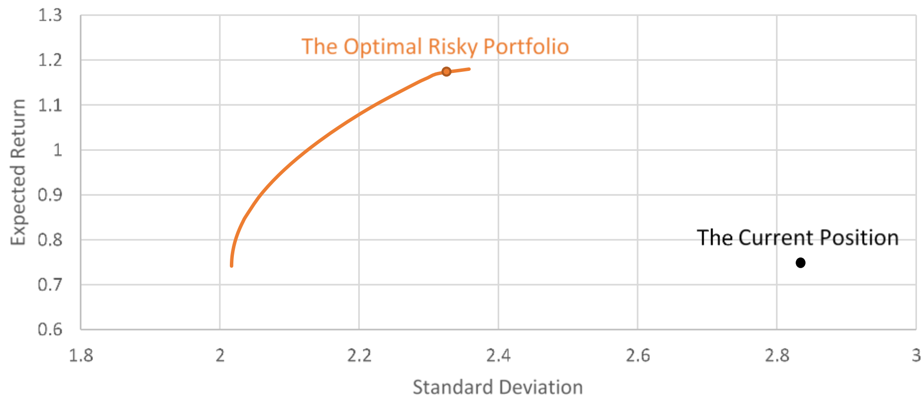

### *Step 7. Wrapping up the Model*

With Macro codes, we can connect the steps all the way into a template which would output the efficient frontier and the capital allocation line when the monthly return data of a population of assets are input. We begin with the College Foundation's portfolio and end up with a model that can be applied to portfolio management. In fact, this step is not required for students, though ones skilled in Excel Macro programming are encouraged to do so. Some excellent students can develop a model that completes the process from downing data from Yahoo! Finance to outputting the efficient frontier and the capital allocation line.

## Application of the Efficient Frontier Model

After completing the efficient frontier model, we use the model to carry out some analyses to improve the performance of the Foundation's portfolio. One application that we do in class is comparing the current position of the portfolio with the efficient frontier under the Foundation's constraints. This comparison is presented in Figure 3.

**Figure 3: The Efficient Frontier and the Portfolio's Current Position**




In the $E(r)$ and $\sigma(r)$ space, it is straightforward how far away the current position of the portfolio is from the efficient frontier. The current position has expected return of 0.76%, standard deviation of 2.83%, and Sharpe ratio of 0.27, while the optimal risky portfolio has expected return of 1.18%, standard deviation of 2.32%, and Sharpe ratio of 0.5. Obviously, considering the relative positions between the current portfolio and the optimal risky portfolio, it is reasonable to move the portfolio to the optimal risky portfolio. Not only would the Foundation be able to increase its expected return, but also be able to reduce its risk, thereby improving its Sharpe ratio in two ways.

A simple comparison of the weights between the optimal risky portfolio and the current portfolio in Table 2 provides buy and sell suggestions. When the weight of a mutual fund in column (3) is greater than the weight in column (2), then increase the holdings of that mutual fund to the optimal level, and vice versa.

**Table 2: Buy and Sell Suggestions**

| Ticker (1) | Weights of Current Position (2) | Weights of Optimal Risky Portfolio (3) | Buy and Sell Suggestions (4) |
|---|---|---|---|
| YACKX | 7.30% | 0.00% | Sell |
| DODGX | 3.68% | 0.00% | Sell |
| HFCSX | 6.87% | 0.00% | Sell |
| HSCSX | 3.45% | 0.00% | Sell |
| JVLIX | 7.79% | 0.00% | Sell |
| MINIX | 9.05% | 0.00% | Sell |
| POSKX | 3.10% | 0.00% | Sell |
| STSCX | 2.25% | 0.00% | Sell |
| TGVAX | 8.55% | 0.00% | Sell |
| TBGVX | 10.17% | 0.00% | Sell |
| VEMAX | 3.64% | 0.00% | Sell |
| VGHAX | 3.37% | 65.00% | Buy |
| LEXCX | 9.03% | 0.00% | Sell |
| PTTDX | 6.22% | 0.00% | Sell |
| BND | 6.33% | 25.00% | Buy |
| SNGVX | 6.36% | 0.00% | Sell |
| CGMRX | 0.62% | 0.00% | Sell |
| FIRFX | 0.94% | 0.00% | Sell |
| FARCX | 1.28% | 10.00% | Buy |

At this point, a question arises. MPT tells us that diversification reduces the risk. Why does the optimal risky portfolio have a much higher concentration, with all money invested on only three mutual funds? Usually, we encourage students to think about the question and try to give their own answers using what they have learned in finance. Some students explain that the concentration results from the constraints. Some students say that it is unnecessary to over-diversify a portfolio because the benefit of diversification is diminishing. Some students point out that unnecessary diversification might lead to increased transaction fees, and they suggest that the Foundation's management optimize the portfolio to reduce trading costs.

We also direct students to conduct the following applications on a group basis: a) see what would happen to the efficient frontier if the constraints are relaxed (e.g., we examine if the efficient frontier improves the risk-return trade-off when the constraint of only no-short-sales is applied); b) examine the performance of the portfolio if we include some market index funds in the portfolio; c) check the model's stability by using different sample periods, like a three-year period, and different estimations of the expected returns, like the expected returns estimated by CAPM.

Students are encouraged to develop their own applications of the model in their analysis. Working in groups, students think creatively, discuss enthusiastically, and cooperate closely. In this way, they become active learners. At the end of the course, students present their results before the board of the Foundation.

## Summary

This paper describes an exercise that we perform when teaching Portfolio Management at SUNY Oneonta. In cooperation with SUNY Oneonta Foundation, students build an Excel model of efficient frontier to analyze the Foundation's portfolio. The exercise is designed to develop three competencies that are indispensable in a financial professional's career: comprehension of financial theory, proficiency in data analysis, and accumulation of experiences in the real world. The combination of these three factors in one project makes our exercise unique and valuable. Both students and the College Foundation benefit from the cooperation in this project.

By doing the project, students internalize their understanding of MPT, practice their skills to collect and process financial data, and reap hands-on experience in a real portfolio management environment. Some students said that their experiences in the course help in their internships and job interviews. After graduation, some students gave their feedback that they are more confident to start their careers.

Students search for mutual funds in a broader range of candidates and from different perspectives. The management of the Foundation often finds some mutual funds chosen by students valuable. They appreciate students' comments and suggestions and are ready to accept some investment proposals from our students. By undertaking these suggestions, the Foundation improves its performance.

The exercise in our class is easily transferable to instructors of "Portfolio Management" or "Investment Management" since many colleges and universities have endowment foundations. Managements of college and university foundations are often willing to work together with faculty because not only do they benefit from students' new and different investment perspectives, they would like to contribute to student growth. College and university foundations exist solely to support students, research, and learning.

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# *The Simple Analytics of an eGig Firm: Uber as a Microeconomics Course Exercise*

***Will C. Heath, James Underwood, and Joby John***[1]

## ABSTRACT

This paper provides a microeconomic framework for what we call the eGig firm in the transportation market. The pedagogical value lies in seeing the interrelatedness of principles that students may see as compartmentalized into "consumer theory," "production and costs," "welfare economics," and so on. First, we develop a basic model of an eGig taxi firm, then address specific aspects of eGig transportation, including surge pricing and "machine learning." We also examine social welfare implications of the eGig paradigm. The model is not complex, yet it gives students a unifying framework for topics covered in the undergraduate microeconomics course.

## Introduction

The typical microeconomics course covers consumer behavior, production, costs, firm behavior under various market structures, public goods, game theory, and welfare economics. The inter-relatedness of all these topics can be difficult for students to see; furthermore, the abstract nature of economic reasoning leaves some students wondering what it has to do with the real world. The purpose of this article is to bring together many of the topics covered in the typical undergraduate microeconomics course within the context of an important and timely application. This application context is what we call the "eGig Taxi firm."

Perhaps the most prominent such firm is the Uber taxi company. The Uber phenomenon, or what Harris and Krueger (2016) dub the "gig" economy, has been written about in popular publications and scholarly journals alike. Sometimes described as "Uberization," this phenomenon refers to changing the market structure for a service by introducing a different way of consuming or providing the service through the use of mobile technology.

Absent in the literature to date is a simple microeconomic model of this phenomenon, an analytical framework within which the various issues can be contextualized and brought together in a coherent overall theoretical configuration. This paper offers such a model, and demonstrates its value as a sort of "capstone" exercise for the undergraduate microeconomics course.

First, we develop a basic model of an eGig taxi firm within the standard theoretical framework of the firm. While this model draws much from real-world firms such as Uber and Lyft, it is not intended as a full or precise representation of either. Our model is of a hypothetical eGig taxi firm that incorporates some of the distinct characteristics students will have experienced with Uber and Lyft. We then employ the model to address specific aspects of eGig transportation, including surge pricing and "machine learning." We also examine social welfare implications of the eGig paradigm. The model is not complex, yet it gives students a unifying framework that brings together many topics covered in the undergraduate microeconomics course. We identify the microeconomic principles covered in each section of the model, which we break down into the product market, the input market, and the production market. We then provide exercises that actively engage students as they explore these principles in the context of the eGig firm.

The value of using the Uber phenomenon as an instructional exercise has been recognized in the literature. For example, Bashir et al. (2016) present a case study based on Uber specifically, with attention to the larger questions of market disruption, technology's role in that disruption, as well as general implications for worker and consumer welfare. Our exercise differs from Bashir et al. (2016) in that it develops a more general model

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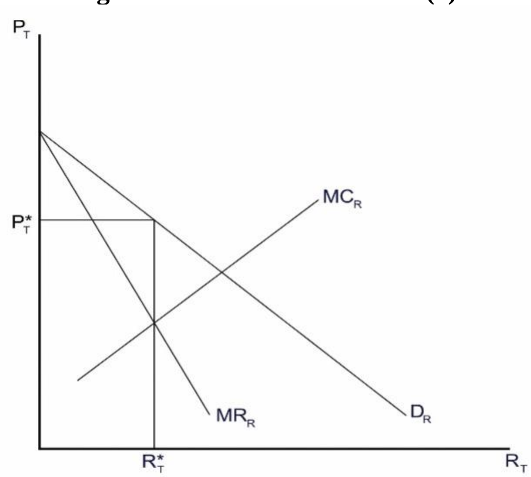
of an eGig taxi firm, not specifically Uber or Lyft, and couches the analysis in the language of microeconomic theory of the firm. In common with Bashir et al. (2016), we hope our exercise will encourage students to think about the larger questions of how and why markets evolve, the factors that lead to market disruption, as well as the implications for resource suppliers and consumers.

## The Product Market

### *Topics: Demand, Price, Marginal Revenue and Profit Maximization*

Most taxi companies, including Uber and Lyft, exercise a considerable degree of market power (Gabel 2016). The salient analytical property of firms with market power is a downward-sloping demand curve, with marginal revenue below demand at all levels of output. The demand curve for rides ($D_R$) is shown in Figure 1, along with the marginal revenue of a ride ($MR_R$) and marginal cost of a ride ($MC_R$).

**Figure 1: The Product Market (1)**




The firm will produce rides ($R_T$), measured as "ride time," to the point at which the marginal revenue of a ride ($MR_R$) equals its marginal cost ($MC_R$). The firm will charge a price for ride time ($P_T$) as determined by demand. Students will recognize these as the usual profit-maximizing solutions for a firm with market power.

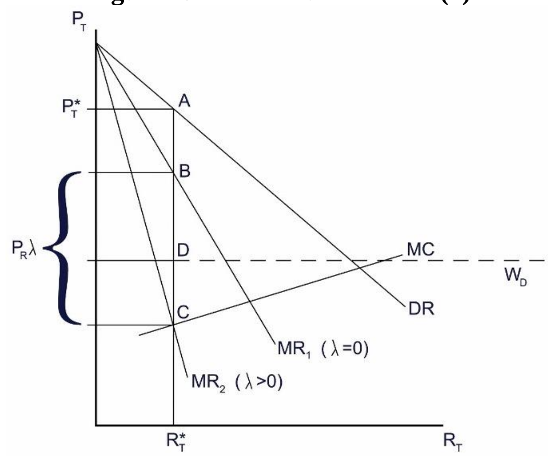
The eGig taxi firm operates as a traditional taxi company in some respects, but differs from the traditional taxi company in important ways: the eGig firm does not furnish automobiles, insurance, fuel, and other variable inputs that would otherwise be internally managed and allocated by a manager/entrepreneur and would comprise internal costs for the traditional taxi company. In other words, much of the cost of producing rides is externalized to drivers, thus not considered part of the firm's internal costs. Figure 1 does not imply that the eGig firm necessarily produces fewer rides at a higher price than a traditional firm would do. The marginal costs for the two types of firms are not necessarily comparable – a point not discussed further here.

Traditional taxi firms require drivers to rent cabs and an associated medallion/license from the owner. These rental rates are set by the taxi company, and drivers keep the fare (which is set by local regulations) plus tips, minus what the cab/medallion costs. Drivers for the eGig firm retain a *portion* of revenue, specified as a percentage of the fare. The firm sets the prices of rides and the percentage drivers are allowed to keep. Total and marginal revenues for the *firm* are thus defined in terms of that portion of the fare going to the firm, $(1-\lambda)P_T$, where $\lambda$ is the percentage of fare retained by the driver, $P_T$ is the total fare, and R is ride time, a measure of quantity purchased by the client/passenger. Hence, total revenue (TR) = $P(1-\lambda)R$. Therefore, marginal revenue (MR) = $\frac{\partial TR}{\partial R} = P + \left(\frac{\partial P}{\partial R}\right) R - P\lambda + \left(\frac{\partial \lambda}{\partial R}\right)$ R. For simplicity, assume $\frac{\partial \lambda}{\partial R} = 0$. In this case, MR = $P + \left(\frac{\partial P}{\partial R}\right) R - P\lambda$. If $\lambda = 0$, then MR becomes $P + \left(\frac{\partial P}{\partial R}\right) R$.

These equations present students an interesting twist on the usual mathematics of the firm with market power. The assumption that $\frac{\partial \lambda}{\partial R} = 0$ facilitates a simple graphical depiction of driver compensation without altering the substance of the model. Marginal revenue when there is sharing of revenue with driver-partners

($\lambda > 0$) is depicted as $MR_2$ in Figure 2 below. If there were no sharing of revenue with driver-partners ($\lambda = 0$), marginal revenue would be represented by $MR_1$. The difference between $MR_1$ and $MR_2$ is $P\lambda$, the revenue per ride going to the driver-partner. This value is shown in Figure 2 as the line segment, BC. Alternatively, $P\lambda$ is equal to segment [$BR_T^* - CR_T^*$], which is equivalent to $DR_T^*$. Compensation to driver-partners on a per ride basis, $W_D$ (= $P\lambda$), is thus depicted as a horizontal line passing through point D. An increase (decrease) in $\lambda$ would raise (lower) the $W_D$ line.

**Figure 2: The Product Market (2)**




Equilibrium of the complete model obtains in part through adjustments in $\lambda$. Before we can more fully describe the nature of this equilibrium, we must consider the input market, specifically the market for drive time.

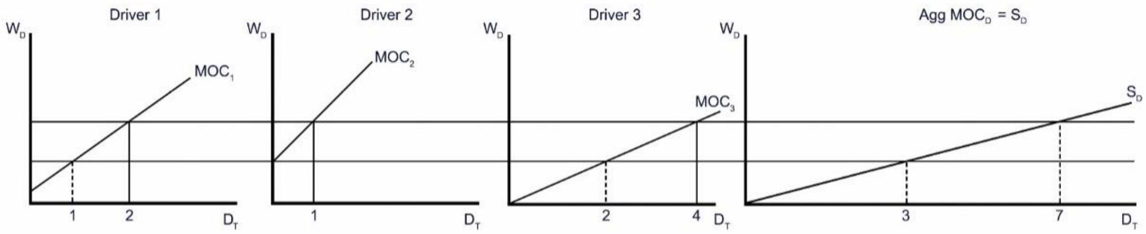
## The Input Market

***Topics: Opportunity Costs, Input Supply Curve, Supply Elasticity, Producer Surplus, Production Function***

Inputs internal to the eGig firm include both fixed and variable factors, such as labor, technology, and physical capital. Internal variable costs are represented graphically, as usual, in terms of the marginal cost curve. However, "driver-partners" and resources they provide (cars, fuel, maintenance, etc.) are external to the eGig firm. Therein lies another interesting variation on the usual analysis of the firm. The externalization of costs incurred in the production of transportation is much more extensive for the eGig firm than for the traditional taxi firm.

Each driver is unique, and each faces his or her own "marginal opportunity cost" for driving ($MOC_D$). These opportunity costs could include alternative wages foregone or the value of leisure time. The aggregate $MOC_D$ function is the horizontal sum of all drivers' $MOC_D$ functions, and may be interpreted as the (short run) supply of driver time curve ($S_D$) for eGig drivers, as depicted in Figure 3, which illustrates the supply function in terms of three drivers. Equilibrium in the market for drivers is achieved at the point where $S_D$ is equal to $W_D$.

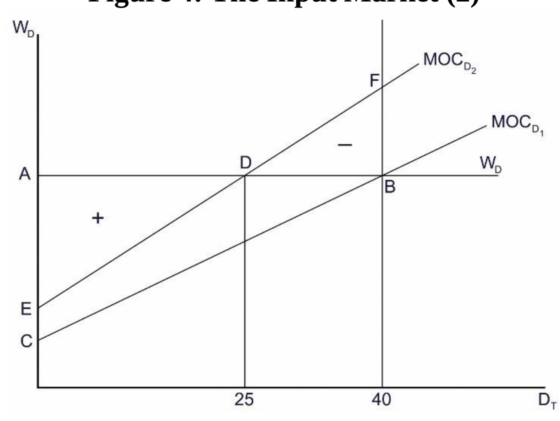
**Figure 3: The Input Market (1)**



Students will find an exploration of the welfare implications of the eGig firm interesting and instructive. For various reasons, individual motivations and attitudes toward work and leisure are shifting to a decreased desire for full-time work or increased desire for part time employment, on the part of young and even some older workers (Fox 2016). Freelancers as a percentage of the work force rose from 10.1 percent in February 2005 to 15.8 percent in late 2015 (Katz and Krueger 2016). Also reflecting this workplace trend, the Government Accountability Office (2015) reported that alternative work arrangements increased from 35.3 percent to 40.4 percent of employment from 2006 to 2010. Others have reported that online gig employment is growing very rapidly (Farrell and Grieg 2016a, 2016b). Travis Kalanick, CEO of Uber, said in an interview with *The Economist* (2015) that workers today "choose when, where and how long we work…."

The eGig labor market offers workers (driver-partners in the case of Uber) considerable flexibility in choosing when, and how much, to work. The upshot is that suppliers of labor are able to generate more surplus value for themselves than would be the case if hours and times were more rigidly fixed. Driver's surplus is the difference between $W_D$, the payment per unit of drive time, and the marginal opportunity cost of producing that unit. Figure 4 below depicts the hypothetical situation in which drivers are offered a fixed, 40-hour per week schedule. We do not wish to imply that the traditional taxi model requires a fixed, 40-hour work week. The point is to explore the advantages of driver time flexibility. The driver who prefers to work exactly 40 hours (Driver I) realizes surplus value equal to the area ABC. Driver II would choose to work only 25 hours, and would capture surplus value shown by area ADE. If that individual were contractually committed to a 40-hour week, surplus would be reduced by area DFB. The welfare implications of the labor market are obvious: a labor market generates more surplus value for workers if it offers flexible employment arrangements than if it does not offer such flexibility. This conclusion is true in general and holds also for traditional taxi companies that offer flexible working hours. While this conclusion may seem almost axiomatic, the analysis brings into clear focus a very important aspect of the eGig phenomenon, which is to offer greater flexibility in working arrangements than is the case in many traditional firms. A simple mind experiment is instructive on this point. Suppose the task is to maximize the amount of salt in a glass jar which has already been partially filled with rather large salt rocks, to the point that no more large rocks can be added. The only way to fill the jar further is to introduce smaller rocks to fill in the spaces between the larger rocks. Analogously, the eGig firm brings smaller "rocks" to the labor market. Otherwise unused "rocks" of labor time are added to the existing supply of 40-hour-per-week labor "rocks." In this manner, additional surplus value is created, for both consumers and producers. The eGig firm exists precisely because it makes this gain realizable at the individual level.

**Figure 4: The Input Market (2)**




To this point we have discussed the welfare benefits to producers, but the appeal among consumers is equally important. Price may not be the primary reason consumers use eGig services. Salnikov et al. (2015) find that Uber is not always cheaper than a traditional taxi service for a given ride. The Salnikov et al. (2015) results imply that consumers also value other aspects of the service, such as frictionless payments or nicer cars.

As stated above, taxi providers operate in an imperfectly competitive market. But Uber and other eGig firms have unambiguously increased competition (Zervas et al. 2015). As competition increases, consumers have new options and incumbents may be forced to respond. In the traditional taxi world, dissatisfied consumers had few options. They could incur extra costs to avoid taxis—in terms of convenience if switching to the bus or subway or in terms of money if switching to car services or using one's own car instead of taking cabs. Alternatively, they could complain about the poor service to the taxi regulator. Either way, taxi cabs had little incentive to improve service.

In the new world of taxi competition, consumers can switch providers at low cost. As a result, traditional taxis may face a new incentive to compete. Competing on price in the short run is difficult—prices are typically regulated and change infrequently. They might also compete on quality—making sure their cars are clean and features like credit card readers operable, running the air conditioner in the summer, not talking on cell phones, and so on.

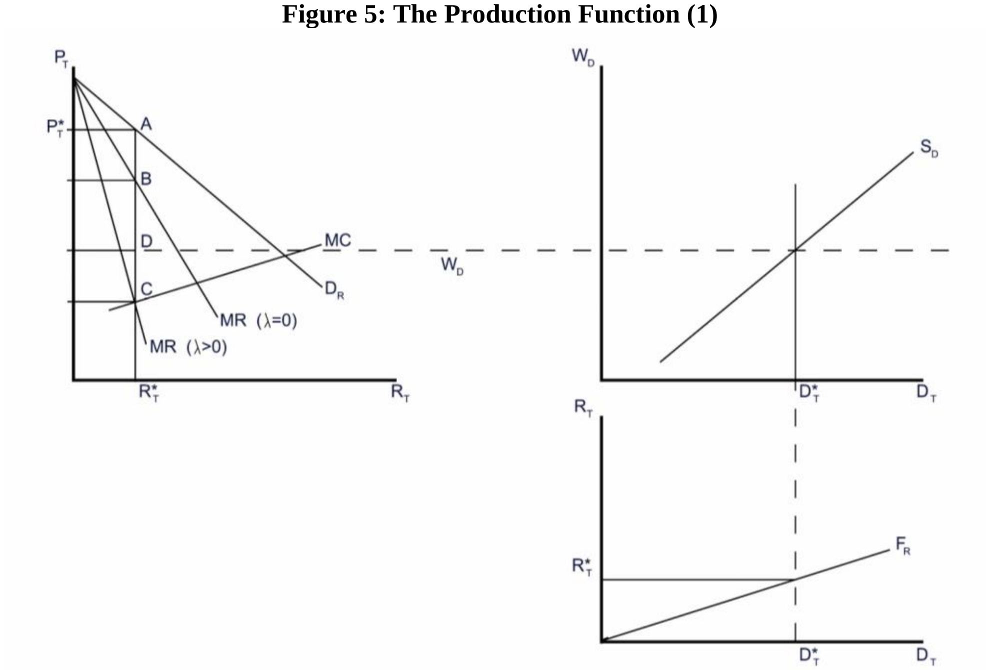
Of course, the incentive to improve quality is blunted by the problems of signaling and lack of repeated interactions. In particular, how is a driver cruising for fares able to demonstrate to potential riders that he offers a high-quality ride? One way to generate that signal might be through newer cars, so perhaps we might expect to see the average age of taxi fleets drop over time.

## The Production Function

### *Topics: Production Function, Changing Technology, Marginal Revenue Product*

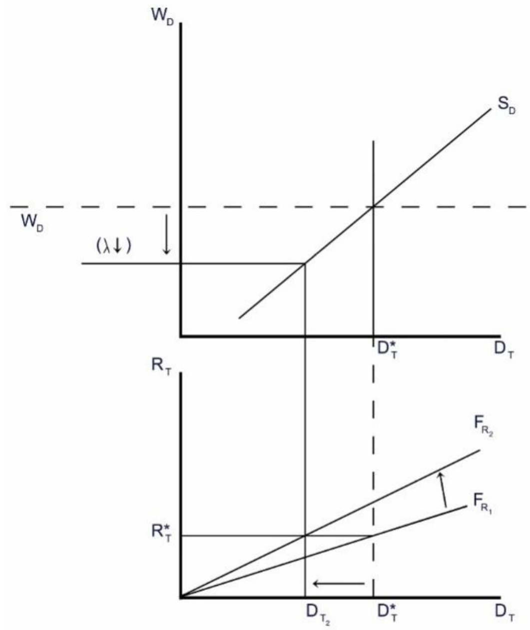
Drivers produce ride time according to a production function ($F_R$) that combines human and physical capital (knowledge, time, automobiles, fuel, etc.) to produce rides. Here we focus on driver time as the input and ride time as the output; $F_R$ describes the conversion of the former into the latter, as shown in Figure 5.

**Figure 5: The Production Function (1)**




Driver time is not identical to ride time. Driver time is the total time a driver devotes to being on the job, available for hire. Ride time is the time spent actually transporting passengers – time for which charges apply. The function ($F_R$) is therefore not depicted as equidistant from the vertical and horizontal axes, but with a slope less than 45 degrees from the horizontal axis. In general, any factor that decreases driver wait time between rides would steepen the slope of $F_R$, and vice-versa. For instance, better dispatch technology or GPS navigation would reduce distances, therefore wait times, between drop-off locations and pickup locations. After the improvement in technology, the same quantity of ride time could be produced with less driver time, all else equal. Graphically, this enhanced efficiency is depicted in Figure 6 as a steeper $F_R$ curve. On the other hand, an increase in traffic congestion, for instance, would decrease the amount of ride time relative to driver time. Speed limits, the number and timing of traffic signals, and potentially other factors would also affect the slope of $F_R$.

**Figure 6: The Production Function (2)**

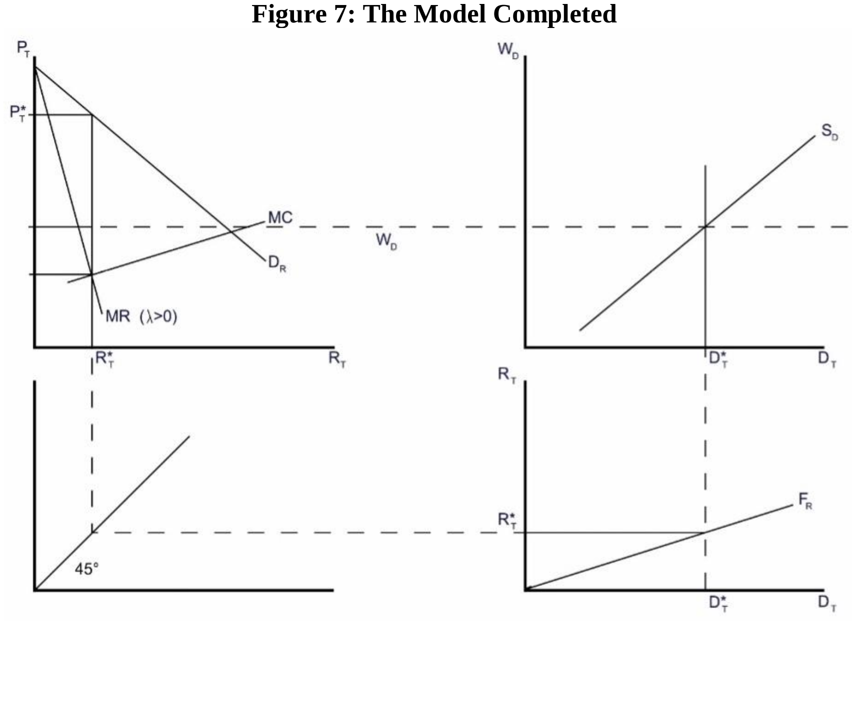



## The Model Completed

To summarize, the eGig taxi firm chooses the quantity of ride time where marginal revenue equals internal marginal cost, and sets price according to demand. It adjusts driver compensation (i.e., determines the value of λ) depending on the driver time supply function, and the driver time needed to produce various quantities of ride time, given the nature of the ride production function. Figure 7 brings all of these elements together.

The product market is shown on the upper left; the input market on the upper right; and the lower right shows the production function. The model is in full equilibrium when marginal cost equals marginal revenue – defined such that $\lambda > 0$ – in the product market, with price set at $P^*_T$ and ride time $R^*_T$. The share of revenue going to the driver is $W_D$, and the equilibrium level of driver time is $D^*_T$. Given the production function as shown in the lower right graph, the optimal level of ride time, $R^*_T$ is produced by the driver time $D^*_T$.

**Figure 7: The Model Completed**



## Applications

### Surge Pricing

The demand for rides is not constant. As with most services, the market brings periods of peak demand and periods of lesser demand. Surge pricing, also known as dynamic pricing, is the firm's response to peak demand. (It might not be the only response, as we shall discuss.)

The increase in demand motivates increases in price and ride time, as the eGig firm seeks new profit maximizing solutions. In order to meet demand, the firm must offer higher driver compensation to incentivize a greater quantity of driver time. $W_D$ increases due to the increase in $P_R$, and may be further adjusted through changes in the value of $\lambda$. The degree to which $W_D$ must rise depends upon the responsiveness of driver supply to increases in compensation. The greater the responsiveness of $S_D$, the less $W_D$ must rise to attract a given increase in driver time, and vice-versa.

### UberPool

Uber has come under some criticism for surge pricing, although many of their drivers maintain that without it, they would not continue to drive for Uber (Shahani 2016). The company has responded to peak demand in a couple of ways other than surge pricing. One way is through what they call "UberPool," which works as follows. Passengers drop a pickup pin (i.e., electronically specify their position and request a ride), and Uber asks them to enter a destination and select how many seats they require. Uber then shows two pricing options: one for a shared UberPool ride, the other for a private car. Uber thus segments the passenger market into two groups, private travelers and "pool" passengers, and charges each a separate price. Dynamic pricing is in effect, but Uber also offers customers a less expensive option than the full private-car fare. In effect, the firm is practicing second-degree price discrimination. The firm earns higher profits through this method of price discrimination (or it would not price discriminate). Customers paying lower fares are better off, and those paying higher fares worse off, than in the absence of price discrimination.

Uber promotes its pool plan among drivers by pointing out that it reduces wait time between fares. On a normal trip, the driver takes the passenger to the destination, and ends the ride at that location. The next fare doesn't start until another request comes through and the new passenger has been picked up. With the pool plan the driver picks up multiple riders and collects fare continuously from the first pickup through the final drop-off, eliminating the unpaid period spent waiting for another request and traveling to another pickup location. However, the driver retains a percentage of a lower fare than the fare for "private car" transportation. Pooling improves driver efficiency, as less driver time is required at each quantity of ride time produced. The overall impact of pooling on total driver compensation would depend upon the net result of the reduction in wait time (positive for drivers) and reduced fares (negative).

### Machine Learning

A second Uber strategy for dealing with peak demand involves "machine learning," whereby the firm gathers and analyzes large bodies of data in an effort to make predictions about the level of demand. Uber maintains that if it can predict peak demand, it can get that information out to drivers, have supply available where needed to meet demand, and thereby reduce or even avoid surge pricing altogether (Shahani 2016). Critics of Uber note that surge pricing continues, and dismiss the notion that machine learning will eliminate the need for higher peak-time fares (Griswold 2016).

More effective means of informing drivers of peak demand, hence the availability of higher compensation, would effectively increase the elasticity of drive time supply. The greater the number of drivers who are aware of the opportunity to take advantage of higher compensation, the more supply will expand in response. Greater elasticity of supply lessens the raise in compensation necessary to produce a higher level of ride time.

In summary, it appears that neither UberPool nor "machine learning" has significantly affected surge pricing. Both would suppress the increase in driver compensation that would otherwise accompany surge pricing. However, both measures bring the potential for higher profits for the eGig firm.

## Suggestions for Instructional Use

For instructional purposes, we offer here a sample of questions for classroom discussion. This is obviously not an exhaustive set; instructors will find that the eGig model offers ample material for additional questions and discussions. The following questions are suggested for classroom discussion or written assignments.

1. Discuss the role of technology in business model innovation. Discuss how eGig firms such as Uber and Lyft are leveraging mobile technology in their business to stay ahead of its competitors.
2. Our eGig taxi firm is assumed to exercise market power. What factors and barriers to entry establish the competitive nature of the taxi market?
3. High fixed costs for starting a business can be an impediment to competition. Compared to the traditional taxi firm, how does the eGig firm bring down startup costs?
4. Identify the eGig taxi firm's internal costs. Are variable costs relatively greater or lower than for the traditional taxi firm? How do fixed costs compare?
5. Describe equilibrium in the market for drivers.
6. Consider Figure 4. Suppose $W_D$ were increased enough to encourage the driver represented by $MOC_{D2}$ to work 40 hours per week. Draw that new $W_D$ on Figure 4. Identify that driver's total surplus.
7. Identify factors that would change an individual driver's supply function.
8. What are the determinants of driver supply elasticity?
9. Why is the aggregate driver supply function more elastic than the individual driver's supply function?
10. How would driver elasticity in the aggregate be affected by placing lower limits (e.g., 30 hours per week) on the time individual drivers can work? How would such limits affect aggregate driver supply?
11. What are the pros and cons of the firm's frequently changing $\lambda$, the percentage of the fee retained by driver-partners? Would frequently varying $\lambda$ create transaction costs, such as information costs associated with communicating changing fare sharing arrangements to drivers, or negative effects on driver supply due to increasing uncertainty over expected compensation? Might adjusting the value of $\lambda$ lead to greater efficiency? How would a "sticky" $\lambda$ inhibit the firm's ability to achieve optimum fees and ride time?
12. Identify environmental factors, i.e., those beyond the control of the driver, that would shift the $F_R$ curve.
13. Identify factors controlled by the driver that would shift the $F_R$ curve.
14. Are circumstances possible in which the slope of the $F_R$ curve is greater than 45 degrees?
15. Figure 5 depicts a linear $F_R$ function. Is linearity a reasonable assumption? Why might the function be nonlinear?
16. Define the marginal revenue product for drive time. How does it change with changes in the value of $\lambda$?

## Conclusions

This paper provides a microeconomic framework for what we call the eGig firm in the transportation market. In the real world, the Uber firm's ride-share taxi market is perhaps the quintessential example. The eGig model brings together many topics covered in the typical undergraduate microeconomics course. The pedagogical value lies in seeing the interrelatedness of principles that students may see as compartmentalized into "consumer theory," "production and costs," "welfare economics," and so on. Moreover, the eGig model brings elements of "Uberization," a very timely and relevant phenomenon, into the classroom, albeit in a simplified formulation.

The world stands on the verge of momentous changes in societal and economic behavior, as firms such as Uber and Lyft disrupt established models. Students can discuss implications for integrating various disciplines, including marketing, sociology, law, management and public policy, among others. Such integration of disciplines is sometimes lacking in business education; the eGig model presents an opportunity to rectify that situation, beyond the boundaries of technical microeconomics.

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# *Deal or No Deal? Teaching the Concepts of Risk and Decision Making Through an Experience Learning Activity*

***Peter Brous and Bo Han[1]***

## ABSTRACT

This paper introduces an innovative method to teach about risk and decision making through an engaging, interactive, and impactful experience learning activity. We simulate consequential decision making given uncertain outcomes by playing the TV game *Deal or No Deal*. The reflection and discussion allows students to observe how some decisions are behaviorally biased and can result in irrational decision making. Observing their personal behavior and reflecting on the root causes leads students to a deeper understanding of how humans make decisions given uncertain outcomes. Student engagement in the activity and positive student feedback suggests this method is effective.

*"I hear and I forget. I see and I remember. I do and I understand."*

Confucius (551 BC-479 BC)

## Introduction

Upon graduation, students will be faced with consequential personal and business decisions with unknown outcomes and, therefore, it is crucial that their education encompasses a strong understanding of the concepts of risk and decision making. These concepts, however, are abstract and difficult for students to fully appreciate. The standard teaching approach is to describe quantitative measures of risk, discuss various theories, and provide examples of tendencies in decision making that are relevant to prevailing theories. The literature suggests the learning of complex concepts can be enhanced through hands-on learning experience. To achieve this objective, we have created an experience learning activity by placing students in a situation where they have to make consequential decisions with uncertain outcomes, and we use their decisions to illustrate that humans have the capacity for both rational and irrational decision making. We believe this active learning experience increases their awareness of how individuals make decisions and that this understanding will help their own decision making in the future. The purpose of this paper is to introduce this innovative method in hopes that we can encourage other instructors to adopt this engaging approach.

The in-class experience learning activity that we created is based on students playing the TV game *Deal or No Deal* to win extra credit points towards their course grade. In the popular TV game show, a contestant faces 26 briefcases containing a cash value from $0.01 to $1,000,000. After selecting their personal case to keep, which remains closed until the last round of the game, the contestant selects a specified number of cases in each round to reveal the contents inside these cases. Each opened case reveals new information about the values remaining in the unopened cases, including the contestant's personal case. At the end of each round, a "banker" offers a cash amount to buy the contestant's case and the contestant then faces two choices: "deal" – accept the cash offer and exit the game, or "no deal" – reject the offer and continue the game. If the contestant rejects the banker's offer over the first nine rounds, then in the final round they will open their personal case and receive the amount contained therein. For a detailed game flow chart, please refer to Appendix A.

There are several reasons the *Deal or No Deal* game is an appropriate activity for our purpose. First, the

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game rules are very straightforward to follow, even for those who have limited exposure to the game show. Second, the game requires no prior knowledge of subject matters outside of class. This ensures that students from all backgrounds can play the game on a level playing field. Lastly and most importantly, the game's reward mechanism mimics situations where random events and individual decisions jointly determine an individual's payoff. This replicates situations business practitioners face, be it portfolio investment, capital budgeting, loan review, start-up financing, etc. In summary, the simplicity of the game doesn't compromise the essential lessons it can deliver when applied to more complex real-world situations.

To motivate students to attach value to their decisions, we tie their performance in the game directly to their course grades. Based on our observations, this incentive mechanism effectively keeps students highly engaged. After the game play experience, we ask students to reflect on their decision making and to consider two questions: how did their feelings and emotions impact their decision making, and how did the decisions of other players impact their decision making. Our discussion then focuses on how the game outcomes relate to the prominent theories regarding risk and decision making. In particular, we use students' decisions while playing the game to discuss expected utility theory (EUT) and explore the key concepts of concave utility functions, risk aversion, certainty equivalence, and the existence of risk premiums. Additionally, we investigate how students' decisions relate to behavioral economics through discussions of herd behavior, regret bias, anchoring effects, and prospect theory. We believe that a critical part of the enhanced learning experience occurs because the decisions used to examine these theories are derived from students' personal choices when facing consequential uncertain outcomes. A key benefit of this experience learning activity is that students are able to identify that their own personal decisions are at times rational but that there are also situations where their decisions are impacted by certain behavioral tendencies. Furthermore, students are able to recognize how other people's feelings and emotions impacted their decision-making process.

Based on the level of engagement displayed by students during the game and in the post-game discussion, we believe students' learning experiences are greatly enhanced. The level of excitement while playing the *Deal or No Deal* game suggests students were taking the game seriously and enjoying it. Students were nervous, excited, and highly involved in the activity, expressing enthusiasm when good news was revealed and disappointment when bad news was revealed. Observing students engaging in the game is both enlightening and rewarding. In addition, we consistently received positive student feedback for this in-class learning activity.[2] For example, "Deal or No Deal was an excellent way to teach about risk," "great exercise to see people experience risk," "learned a lot from the experience," "very interactive way to get students to implement what we've learned in class," "learned about human behavior and had fun," "the stakes were high enough that everyone was very involved."[3] The level of student engagement and the positive feedback implies this is an effective learning activity.

## Related Literature

Educators have long realized the need to change the focus from teaching to learning, and experiential learning (active learning, or learning by doing) has played a significant role in this transformation. Experience learning involves active participation in a planned event, an analysis of and reflection on the experience, and the application of principles learned to relatable life situations. Built on the tradition of Locke (1693), Dewey (1938), and others, the approach claims that personal experience provides a rich resource for learning that helps students understand and retain knowledge in unforgettable ways. In fact, over 90 years ago, Dewey (1926, p. 38) recognized the benefits of applying active learning strategies in the classroom by asking, "Why is it, in spite of the fact that teaching by pouring in, learning by passive absorption, are universally condemned, that they are still so entrenched in practice?" Experience learning theory defines learning as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb 1984, p. 41). The experiential learning model suggests that for learning to transpire, both the experience and the reflection on that experience are essential.

[2] We acknowledge that providing students with the potential to earn extra credit from successful game play might be part of the reason that students provide positive feedback, but we do not think this is a major reason for the positive feedback.

[3] After the in-class activity, we sent a survey to a total of 335 students, in which we asked the question "Do you have any comments or suggestions on how to make this exercise a better learning activity?" In response, a total of 60 students commented on their experience from this activity; 59 of them provided positive feedback and only 1 student expressed that although this activity may be interesting in an undergraduate class, it is not appropriate at the graduate level.

Active learning is defined by Bonwell and Eison (1991, p. 2) as "anything that involves students in doing things and thinking about the things they are doing." Similarly, Hawtrey (2007, p. 145) states, "Students remember only a fraction of what they hear but a majority of what they actively do."

Most experts agree that when students take an active role in the learning process their learning is optimized (Davis 1993). Experiential learning has resulted in positive outcomes (Bonwell and Eison 1991; Weimer 1991; Sousa 1995; Picciano 2002; Sarason and Banbury 2004; Benek-Rivera and Mathews 2004; Watkins 2005). Andres (2017) provides empirical evidence that active teaching is positively correlated with course grade and learning motivation. Furthermore, his analysis suggests that increasing active teaching reduces the negative relation between course difficulty and learning motivation. In summary, the findings suggest that student learning outcomes are impacted by pedagogy (active teaching), learning motivation, and learning content complexity.

Student-managed investment funds, business or trading simulations, and game play are common experiential learning activities utilized by business faculty. The experiential benefits of student-managed investment funds have been addressed by Lawrence (1990 and 1994) and more recently by Jones and Swaleheen (2014) and Goff and Cox (2016). Business or trading simulations are other examples of common in-class experiential learning. These simulations allow students to make business or trading decisions, observe the outcome of their decisions, and then reflect on the learning from their decisions and outcomes. Evans and Jones (2016), Karadas and Hoffer (2017), and Mukherji et al. (2018) discuss the benefits of business simulations, and Green (2014) and Bruehler et al. (2017) explain the benefits of general management simulations. The common theme is that the experience of students making decisions, observing the outcomes, and reflecting on those outcomes are all crucial to enhance the learning experience.

The game *Deal or No Deal* is an ideal game to provide students with a real-world experience of decision making given uncertain outcomes. According to Post et al. (2008, p. 39), "the game show *Deal or No Deal* has such desirable features that it almost appears to be designed to be an economic experiment rather than a TV show." The most desirable feature is the simple, well-defined, known probability distribution. Additionally, since the game involves multiple rounds, it affords the opportunity to observe decision making with uncertain outcomes based on previous outcomes, namely to observe path-dependent decision making. The use of this game show as an experience-based learning activity has been discussed by Chow et al. (2010) and by Chan (2013). Chow et al. (2010) focus on basic expected value calculations and assessing probabilities. Chan (2013) uses the game to introduce more advanced topics associated with decision making given uncertain outcomes by moving beyond a basic discussion of expected values and probabilities to discuss certain equivalence, expected utility, risk aversion/sequencing of outcomes, and anchoring. In Chan's learning experience, students all play as one team, making a group decision for each round, while we allow all students to play individually, making their own deal or no deal decisions, generating greater student involvement and providing a larger set of observations to analyze and discuss. Additionally, we provide an incentive for students based on the outcome of their decisions, resulting in students having a stake in the game and a more impactful learning experience. This game show has also been widely used to test various risk preference theories (see Andersen et al. 2006a and 2006b; De Roos and Sarafidis 2010; Mulino et al. 2009; Blavatskyy and Pogrebna 2006, 2007, and 2010; Baltussen et al. 2007; Bombardini and Trebbi 2007; Botti et al. 2008; Pogrebna 2008; Deck et al. 2008).

## The Experience Learning Activity – Deal or No Deal

We have implemented this activity in introductory finance classes at both the undergraduate and graduate level with positive results in both cases.[4] It is more appropriate to schedule this activity after the topic of risk and return has been introduced. By this time, students should be familiar with the concepts of expected return, variance, and standard deviation of stock returns. We typically schedule this activity in the last or second-to-last week of a 10-week quarter. The timing ensures that all the relevant risk and return concepts have been covered, and students reported that they especially appreciate this engaging exercise towards the end of the quarter when they were more comfortable with their cohorts and that they welcomed the break from

[4] This activity has been implemented in three courses. The first is an undergraduate Business Finance class, which is a required core class for all business school students. Students taking this class include both finance and non-finance majors who are typically college juniors. This activity was also implemented in the Corporate Financial Management course, a required class for business graduate students. Lastly, it was introduced in the required Financial Modeling class for Bridge MBA students (graduate students with a non-business undergraduate degree).

traditional classroom instruction later in the course.

To facilitate the smooth implementation of this activity, and to make efficient use of class time, it is suggested that students attain a basic familiarity with the *Deal or No Deal* TV game show. More specifically, we instruct students to watch a YouTube video of an episode of the TV show at home and refer them to the questions provided in Appendix B.

The entire activity consists of two components – the game play and the post-game reflection and discussion. To play the game, we use a copy of *Deal or No Deal - the Interactive DVD Game Show* by Imagination Entertainment Limited, which can be purchased from retailers such as Amazon.[5] Upon conclusion of the game, we provide time for students to reflect on their decisions before we proceed by using the game results as the key component to discuss different theories on individual decision making under risk, including the EUT and behavioral theories.

## *The Game Play*

We begin the class by explaining the purpose of the activity and the planned procedures. In order to avoid exerting undue influence on student behavior, we refrain from discussing the risk-related concepts and empirical findings prior to the game.

Before the game begins, we outline the differences between the game show on TV and our classroom activity. First, instead of playing for cash, students are playing for extra credit points for the course (our conversion ratio was $100,000 to 1 point).[6] Second, students are offered a buy-out price of 0.75 points towards their course grade ($75,000 cash value in the actual game) for not playing the game at all. Third, instead of playing the game individually like TV contestants, the class selects and opens cases together, however, the decision to accept or reject the "deal" is made individually. Fourth, before students decide to accept or reject the banker's offer in each round, we provide them with the key statistics of the distribution of remaining cash payments. Lastly, as an added feature, before the students hear the banker's offer, they are asked to record their reservation price for each round (the minimum price they would be willing to sell their case and exit the game).

It is recommended to play a few practice rounds of the game to eliminate any confusion regarding the ground rules. Students are then handed a participation form as shown in Appendix C to use during the activity. On the top-left portion of the participation form, the dollar values contained in the 26 cases are listed. Students should record, for each dollar value, the round in which it was eliminated. This will aid students in tracking the eliminated values (outcomes) throughout the game. The top right section of the form lists the number of cases to be opened in each corresponding round. The bottom part of the form provides space for each student to record the banker's offer, their reservation price, and their "deal" or "no deal" decision for each round.

As previously stated, when the game begins, students are first offered 0.75 points for not participating, which very few students take. Next, the class selects the "lucky" case to keep, which remains closed until the final round. During each round of the game, students are asked to select a predetermined number of cases to open according to the game rules. After the cases are opened for that round, the game is paused and we compute the summary statistics of the remaining amounts on an Excel spreadsheet (mean, median, min, max, and standard deviation), which are projected on the screen for everyone to observe. We then allow a few minutes for students to determine and record their reservation price (the minimal price required for them to take the deal in that round). We then resume the game and reveal the banker's offer. Students are given a few minutes to make their deal or no deal decision. For those who decide to take the deal, we ask them to take a picture of the form with their smart phone as a record for the post-game discussion and collect their participation forms. The game continues with the "no deal" group and the process of case opening, statistics calculation, reservation price determination, banker's offer revelation, and the "deal" or "no deal" decision is repeated until the final round. In the final round, if the banker's offer from the previous round is not accepted, then the amount in the selected case is revealed and the game is concluded.[7] To prepare for the

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[5] A search on Amazon.com on June 17, 2019 shows the DVD game is priced in the range of $6.50 to $18, depending on the seller.

[6] We have varied the amount of extra credit students can earn over time. Currently, graduate students can earn up to 10% of their final grade and undergraduate students can earn up to 10% on their final exam which equates to 3% of their course grade. Our observations do not suggest that the difference in grade incentive lead to less interest at the undergraduate level**.**

[7] In theory, if all students have accepted the banker's offer prior to the final (ninth) round, the game finishes in that round. In practice, we always have at least one student who stays until the final round.

post-game discussion, we recommend appointing a student to record relevant information on a white board during the game. For each round, the information recorded should include: amounts revealed, key statistics, the banker's offer, and the number of students accepting the offer (see Appendix D for an example).

While playing the game, the class atmosphere can become lively and intense. Depending on the case's content, revelations are often accompanied by cheers or groans by the crowd. We notice that students become more excited and anxious as the game progresses. These reactions validate the purpose of this activity – to study behaviors of individuals under risk when stakes are real.[8]

### *Post-Game Reflection and Discussion*

Upon conclusion of the game, we ask students to examine the picture they took of their participation form and reflect on their individual decisions to either take or not take the deal after each round. Specifically, we ask them to consider two questions: how they thought their feelings and emotions might have impacted their decisions and how the decisions of other players impacted their decision. We organize students in pairs to discuss their responses to these questions and to record their answers, which we refer to in the post discussion.[9] After their reflection time, we proceed to use the game-generated results to discuss various decision-making theories and concepts.

To lead the post-game discussion, we use the game play data recorded earlier on a whiteboard as the foundation. Upon examining the data, we first raise a simple question: "In each round, which is higher – the expected (mean) outcome or the banker's offer?" Students typically recognize that in most rounds, the banker's offer is below the mean of future outcomes. We then ask students, "Why then, would you knowingly accept an offer below your expected outcome?" Students often cite intuitive psychological factors in an attempt to justify their decisions. Built on this discussion, we introduce the EUT and its predictions. With a graphic illustration, we demonstrate that under EUT, if an investor has a concave utility function, it is perfectly rational to accept a payoff that is below the expected outcome. During this discussion of the EUT, we introduce the concept of risk aversion, which many students exhibited by accepting an offer below the expected outcome. We mention how the difference between the expected outcome and the banker's offer (gap) is a measure of both the risk premium (payout for taking the risk) and the price of insurance (how much you would pay to eliminate risk). Next, we ask students to reflect on the meaning of the reservation prices they recorded on their participation form. We discuss the connection between their reservation price and the concept of certainty equivalent payoff (the guaranteed amount an investor deems as equally desirable to a distribution of uncertain outcomes) and that it is rational, based on EUT, for their reservation price to be lower than the expected outcome.

We then ask students to study the gaps between the expected outcome and the banker's offer throughout the first nine rounds. They can normally identify the general pattern where the gap tends to decrease as the game progresses. We remind our students that throughout the game, as more case contents are revealed, the uncertainty regarding the unrevealed amount in their chosen case decreases. The key learning objective is that this observed behavior is rational and consistent with the EUT prediction, as they tend to accept a lower risk premium as the risk decreases.[10]

After discussing how their decisions often appear to be consistent with rational decision making given EUT, we then shift our focus to examine how certain aspects of their decision making appears to be irrational and is impacted by behavioral tendencies. For example, we ask students to read their answer to the reflection

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[8] Although students from all classes appeared to be highly engaged during the game, we noticed that undergraduate students exhibited stronger emotions during game play than graduate students. This is despite the fact that the game outcome has lower impact on an undergraduate student's grade than the grade of a graduate student. We observed that graduate students behaved more rationally and independently while undergraduate students showed a stronger tendency to impress their peers with aggressive game play.

[9] From our observation, graduate students typically offer more insightful comments than undergraduate students during the post-game reflection and discussion. As a group, they are more capable of expressing not only their own personal feelings and emotions but also connecting them to the concepts introduced in the post-game discussions.

[10] Part of this post-game discussion should be based on unique outcomes of the game and how these unique outcomes relate to various theories. For example, in the game results presented in Appendix D, the million dollar case was revealed in round 7**,** which reduced the level of uncertainty significantly (the standard deviation decreased from $421,878 at the end of round 6 to $236,264 at the end of round 7) and the difference between the expected outcome ($175,028) and the banker's offer ($175,000) was almost zero, representing a very small discount for risk.

question: How did their feelings and emotions impact their decision? Students often report that their intense emotions made decision making more difficult, particularly when larger sums were still available. This leads to the discussion of *regret bias* to explain their decision to not take the deal.[11] As long as there was "big money" available, they wanted to stay in the game. We then turn to the second reflection question regarding how the decisions of other players may have impacted their decision. Students' responses often lead to a discussion of the common observation that others staying in the game at the beginning made it more difficult to take the deal, however, once students started to take the deal it made it easier for them to take the deal. This behavior reflects the group effect of *herd behavior*.[12]

The typical game results also provide an opportunity to discuss Prospect Theory, a behavioral economic model describing how individuals make decisions given uncertain outcomes. In their seminal work, Tversky and Kahneman (1974) demonstrate that people make decisions based on the potential losses or gains relative to a reference point, which they refer to as the "anchoring effect."[13] We provide a basis to discuss the anchoring effect by offering students 0.75 points ($75,000) as a buy-out price before the game officially starts. We begin the discussion with the question: "Do you consider the 0.75 points that you could have taken for not playing when you evaluate the banker's offer in each round?" Consistent with empirical findings on the anchoring effect, several students acknowledge that they do compare the banker's offer in later rounds against the initial buy-out price and feel uncomfortable accepting an offer below this price. Another question relating to anchoring effect is to ask students if their "deal" or "no deal" decision was influenced by the banker's offers in previous rounds. Some students admit that they feel unease in accepting an offer below the offer in previous rounds, adding more support to the anchoring effect.

As an extension to their original work, Kahneman and Tversky (1979) develop a model where investors place more weight on perceived gains than perceived losses against their reference point. Thaler and Johnson (1990) provide further evidence that investors' risk-taking behavior is affected by prior gains and losses. Certain aspects of student behavior in the game are consistent with the predictions of their models. For example, after either a series of extremely positive outcomes (small dollar values revealed) or extremely negative outcomes (large dollar values revealed), students become less risk averse. As evidence of this reduced risk aversion, we have observed that some students refuse to take an offer that is at or even above the expected outcome after a series of positive or negative outcomes. We explain to students that such behavior can't be explained by the EUT but is perfectly consistent with the predictions of Prospect Theory – individuals increase risk seeking both after a prior gain ("house money effect") and a prior loss ("break-even effect").[14]

Lastly, the information conveyed during the game provides opportunities to discuss other interesting decision-making tendencies. First, if there is a disastrous round where many high-value cases are eliminated, we observe a large wave of students taking the banker's offer and exiting the game. We compare this behavior to the occurrence of the 2008 financial crisis, where many retail investors fled the stock market. We ask students whether this behavior is rational and urge them to consider the difference between intrinsic and revealed risk. Second, we observe another interesting phenomenon - that student's reservations prices are often extremely optimistic – they request a price to be bought out of the game that is above the expected payoff. We use this opportunity to engage in a short discussion of the difference between personal preference and market reality.

The deep learning from this experience occurs in the post-game reflection and discussion portion of the class. This discussion provides concrete examples to students where individuals often make rational decisions given uncertain outcomes, but that there are unique situations that decision makers face when behavioral tendencies come into play, which can result in irrational decisions. As the literature suggests, this is an experience learning activity in which students can actually observe themselves making both rational and irrational decisions. The ability to identify and recognize the type of situations that lead to irrational decision making increases their understanding of human decision making. Understanding how and when their

[11] For a detailed discussion of regret bias, see Bell (1982).

[12] For an empirical study of herd behavior and investment decisions, see Scharfstein and Stein (1990).

[13] For a complete review of the anchoring effect, see Furnham and Boo (2011).

[14] In their seminal study, Post et al.(2008) also find that the behavior of contestants in the *Deal or No Deal* TV show is consistent with predictions of the Prospect Theory because their decisions are not only based on the expected future payoff but are also influenced by past outcomes.

decisions were consistent or inconsistent with existing theories will impact students' abilities to make decisions given uncertain outcomes in the future.

## Conclusion

Individual behavior under risk is one of the most challenging and important topics to teach to business and economics students. With an innovative pedagogical method built around the *Deal or No Deal* game show, we place students in a situation where their decisions under risk directly affect their rewards (extra credit). This creates an opportunity for students to personally experience the psychological impact of decision making given uncertain outcomes. The subsequent student reflection and in-class discussion, built around the game results and their decisions, illuminates the process of decision making under uncertain outcomes using a method that is less abstract and impersonal, and more concrete and meaningful. We believe this active learning experience helps students grasp concepts that will have a lasting impact on their education and careers.

There are various ways to adapt and expand this exercise to different formats. First, the game can be played individually by students in a computer lab, while supervised by a teaching assistant. This variation not only saves valuable class time, but also provides a richer set of game outcomes for the instructor to discuss in class. Second, the game can be played twice during a course offering – once before the concepts of risk are covered and once afterward. This adaptation allows students to examine whether the knowledge learned in class actually affected their behavior. Third, after an instructor has implemented this game several times, they can compile the game data to use as teaching materials to illustrate different behavioral patterns for future students.

Beyond the educational benefits, this experience provides one of the most engaging student activities in our curriculum. This activity creates an exciting learning environment, provides students with the opportunity to reflect on their decisions, and allows for a comprehensive discussion of how decision making under uncertain outcomes is related to many important finance and behavioral economic theories. This active learning experience consistently receives strong positive student feedback and can easily be adopted by any instructor who desires to implement a similar exercise for their students.

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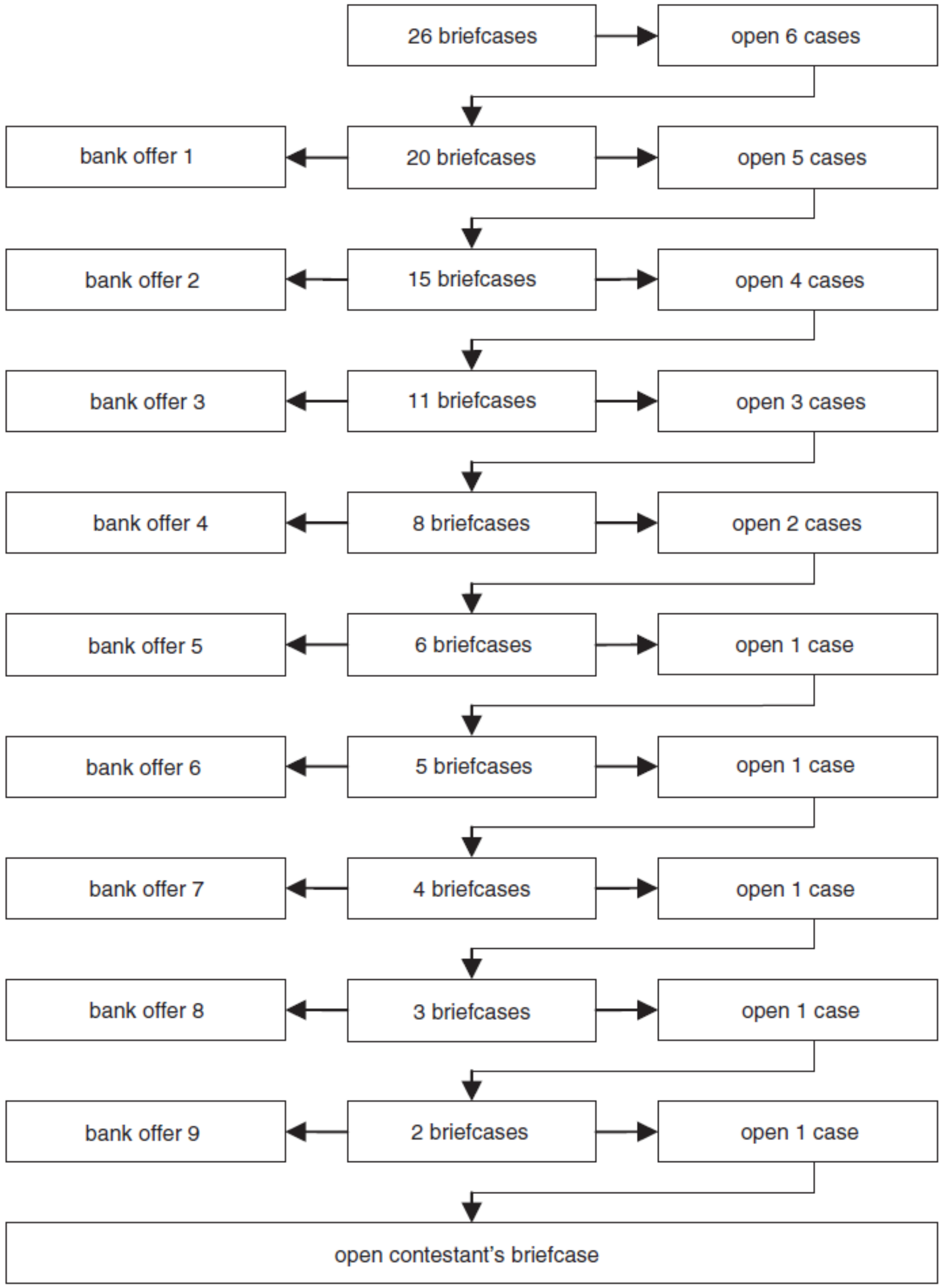
## Appendix A: Deal or No Deal Game Flow Chart




Source: Post et al. (2008).

## Appendix B: Questions on Game Format

Watch the YouTube video of the game show *Deal or No Deal* (https://youtu.be/EOJIqloD-ts) and be prepared to answer the following questions:

1. At the beginning of the game, how many cases can the contestant choose from?
2. Once the contestant chooses a case, when can they open their case?
3. What is the maximum amount contained in a case?
4. What is the minimum amount contained in a case?

5. Once the contestant chooses a case, can they open the case and see its content right away?
6. In the first round of the game, how many cases does the contestant need to open?
7. In the second round of the game, how many cases does the contestant need to open?
8. In the third round of the game, how many cases does the contestant need to open?
9. In the fourth round of the game, how many cases does the contestant need to open?
10. In the fifth round of the game, how many cases does the contestant need to open?
11. In the sixth to ninth round of the game, how many cases does the contestant need to open in each round?
12. What is the role of the banker in this game?
13. Can the contestant reject the banker's offer and then open their chosen case to get paid the amount contained in the case?
14. After a new round starts, can the contestant take the deal offered by the banker in the previous round?
15. Once the contestant takes the banker's offer, can they continue to play the game?

## Appendix C: Student Participation Forms

| *Price* | *Round opened* | *Price* | *Round opened* | *Game Rule* | | |
|---|---|---|---|---|---|---|
| $0.01 | | $1,000 | | | Open | |
| $1 | | $5,000 | | Round 1 | 6 | cases |
| $5 | | $10,000 | | Round 2 | 5 | cases |
| $10 | | $25,000 | | Round 3 | 4 | cases |
| $25 | | $50,000 | | Round 4 | 3 | cases |
| $50 | | $75,000 | | Round 5 | 2 | cases |
| $75 | | $100,000 | | Round 6 | 1 | case |
| $100 | | $200,000 | | Round 7 | 1 | case |
| $200 | | $300,000 | | Round 8 | 1 | case |
| $300 | | $400,000 | | Round 9 | 1 | case |
| $400 | | $500,000 | | Round 10 | 1 | case |
| $500 | | $750,000 | | | | |
| $750 | | $1,000,000 | | | | |

| | Round 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Final Round |
|---|---|---|---|---|---|---|---|---|---|---|
| Reservation Price | | | | | | | | | | |
| Banker's offer | | | | | | | | | | |
| Take Banker's offer (Y/N)? | | | | | | | | | | |

## Appendix D: Sample Information on the White Board

### *First Nine Rounds*

| Round | $ Revealed | Summary Statistics of the Remaining Values | | | Banker's Offer | Number of Takers |
|---|---|---|---|---|---|---|
| | | Median | Standard Error | Mean | | |
| 1 | $750,000; $750; $300; $10,000; $25; $50 | $3,000 | $251,910 | $132,864 | $20,000 | 0 |
| 2 | $1; $5,000; $5; $25,000; $1,000 | $50,000 | $280,089 | $175,086 | $48,000 | 0 |
| 3 | $200; $500; $400; $100,000 | $75,000 | $311,197 | $229,562 | $82,000 | 0 |
| 4 | $0.01; $75,000; $50,000 | $250,000 | $392,238 | $300,000 | $180,000 | 1 |
| 5 | $300,000; $400,000 | $100,050 | $402,052 | $283,364 | $168,000 | 1 |
| 6 | $75 | $200,000 | $421,878 | $340,022 | $253,000 | 8 |
| 7 | $1,000,000 | $100,050 | $236,264 | $175,028 | $175,000 | 1 |
| 8 | $10 | $200,000 | $251,615 | $233,367 | $232,000 | 4 |
| 9 | $100 | $350,000 | $212,132 | $350,000 | $350,000 | 5 |

### *Final Round*

| $ Revealed in the Last Case Eliminated | $ in the Chosen Case Received by Students in the Final Round | Number of Students in the Final Round |
|---|---|---|
| $500,000 | $200,000 | 16 |

## Appendix E: Suggested Classroom Teaching Plan

Our finance course begins after students have been introduced to the concepts of risk and return. They have had some practice in the calculation of expected return and standard deviation of return. They have been directed to watch a YouTube video of the *Deal or No Deal TV* game show at home before the class. The teaching plan is designed to cover the case in one 100-minute class session.

(5 minutes) Explains the purpose of this activity and the rules. Hand out student participation forms.

(5 minutes) Play a few practice rounds of the game to get students familiarized with the game rules and the requirements for this activity.

(40 minutes) The game is played. At the end of each round, the game is paused for the students to make a deal or no deal decision, after which the game is resumed until no student is in the game or the last round.

| | |
|---|---|
| (5 minutes) | Reflection and student group discussion: Examining your participation form record, how do your feelings and emotions impact your decisions? How did the behavior of your peers affect your decision? |
| (15 minutes) | Q: In each round, which is higher – the expected outcome or the banker's offer? |
| | Q: If you accepted a banker's offer that is lower than the expected outcome, what motivated you to make such a decision? |
| | Q: Throughout the rounds, does the gap between the expected outcome and the banker's offer get smaller or larger? |
| | - Collect a number of comments. |
| | - Discuss EUT. |
| (15 minutes) | Q: When you made a decision at the end of each round, did you compare the banker's offer with the offers from previous rounds? |
| | Q: In certain rounds, the banker's offer is equal to, or even above, the expected outcome, but some students chose not to take the deal. Is this consistent with the EUH we just introduced? |
| | - Collect a number of comments. |
| | - Discuss the concept of reference point and prospect theory. |
| (10 minutes) | Q: After a disastrous round (extremely large dollar value revealed), an unusually large number of students took the deal. What motivated them to do so? |
| | Q: Was your decision affected by the behavior of your peers? |
| | Q: How did you decide your reservation prices? |
| | - Collect a number of comments. |
| | - Discuss investor's emotional reaction to risk and herd behavior. |
| (5 minutes) | Summarize and conclude. |