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Teaching Marginal Revenue Product of Labor and Capital Using Elite Athlete Salaries and Pollution Control Examples

The motivation for this paper is student interest in real-world examples of marginal revenue product (MRP)—particularly examples that relate directly to their career interests. This paper presents examples of the MRP of labor and capital that Principles of Microeconomics students find compelling. The labor example related to elite athlete salaries illustrates how the performance or idea generation component of one's career—e.g., writing software code or devising money laundering detection strategies—features non-rival consumption that enables potentially unbounded marginal revenue product. The physical capital example of polluting firms investing in filters to avoid environmental fines illustrates how decision-makers in all fields must first measure what physical capital creates and then translate that measure into dollars. We provide an instructional guide for adopting these examples—and for generating additional context-rich examples—within a flipped classroom framework.

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1. Introduction

The marginal revenue product (MRP) of inputs is a key microeconomic concept that students encounter throughout their careers, beginning with their graduation job search. Since it is also typically the penultimate or final concept covered in introductory economics courses, its presentation imparts take-home points drawn from the entire course. Real-world examples of MRP are critical for revealing the full richness of the concept. As Bayer et al. (2020), Depro (2022), and others describe, students prefer examples that align more closely to the real world and to the specific types of work they plan to engage in upon graduation. Indeed, one day years ago, a principles of microeconomics student of one of this paper's co-authors remarked:

> The textbook examples about adding workers to a farm or a restaurant or a construction site and seeing how the firm's revenue increased compared to how its cost increased are clear enough in terms of deciding how many workers to hire. But, my major interest is in computing security. I am curious how this theory of optimally hiring inputs works in helping the firm decide how many computing security majors to hire or how many layers of software threat protection to invest in.

Another student said she was majoring in chemistry and was interested in how the textbook theory could help firms decide how much input to steer into making its current products versus how much input to direct into research and development efforts to create new products.

These excellent questions set into motion contemplation of the featured personal examples (one labor and one physical capital) presented here and of strategies for encouraging students to develop their models *in the contexts* of their career, topic, or market (CTM) of current interest. As Dalton and Shaffer (2010) and Bangs (2012) emphasize, coaching students in addressing context-rich problems exercises critical thinking skills in place of memorization and raises student satisfaction. In creating personalized MRP examples toward the end of introductory economics courses, students also glimpse how upper-level economics courses develop techniques that further enrich introductory course concepts. Exercising these glimpses of the gist of what economic theory has to offer as rules of thumb is insightful.[1] There is value in students seeing how instructors take that step in their work and in practicing the art of perceiving and/or explaining the gist of complex phenomena.[2] Skill with gist communication is a valuable general education learning outcome nurtured in part by the framework suggested here; students particularly enjoy the situation of the framework around each of their personal and professional interests.[3]

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[1] See Baumol and Quandt (1964) and Drexler, Fischer, and Schoar (2014) on the value of rules of thumb. The basic idea is that more sophisticated models than rules of thumb may be more accurate but they are also more costly. So, the optimal degree of sophistication is where the marginal benefit of the degree of sophistication just equals its marginal cost.

[2] See Reyna (2021) and Reyna and Brainerd (2023) for a discussion of the impact of gist communication in a wide range of policy contexts.

[3] Recent anonymous student feedback on course evaluations includes the following statements: "He also makes new material easier to understand as he goes through multiple real-life examples every class" (Fall 2022); "Had many real world applications for the concepts we were learning" (Fall 2022); "He also made classes so much more interesting by adding examples rooted in his past in the context of the economics topics we were learning. Homework assignments were also very interesting because they allowed us to answer economics questions in reference to our major" (Spring 2021); "Made the class mostly enjoyable as well as applied it to our own career path as students, which made the class much more engaging" (Spring 2021).

The approach we propose is consistent with Hoyt and McGoldrick's (2019) discussion of the economics profession's long-time interest in connecting what is covered in the classroom to reality to increase student engagement and demonstrate relevance. They emphasize the importance of cultivating relevant, engaging, and inclusive opportunities for students to practice the economic theory presented in textbooks. Moreover, we show how to situate personalized MRP example creation using the flipped classroom tool and the student-crafted method tool from Picault's (2019) economic instructor toolbox.

The first instructor example describes how to formulate a simple measure of MRP for labor that accurately predicts elite athlete salaries. The measure takes the average attendance boost provided by an elite player's presence as the marginal physical product (MPP); the marginal revenue product per elite player is then the MPP multiplied by the average ticket price. The example is based upon the second author's appearance on live local sports talk radio during contract negotiations, ultimately leading an elite athlete to leave for another team. The attendance-based MRP measure of $4.92 million is close to the athlete's contract demand of $5 million; the example leads students to think quite carefully about their own MRP as a concept that goes far beyond declaring a major in college. In particular, students realize that a key driver of high salaries is non-rival consumption feasible for a marginal physical product that is performance or idea-based. Professional athlete performances and novel ideas share the valuable property that, in many contexts, one person's consumption does not diminish consumption opportunities for others. Hence, if the performance or novel idea can be streamed to an infinite number of consumers, the performer's or innovator's marginal revenue product may be practically unbounded. The elite professional athlete example sheds light on the power of cultivating non-rival consumption opportunities and sustainable salaries in all our majors and our interests.

The second example illustrates how polluting firms think about how much abatement technology to employ. Abatement technology could comprise an array of filters; in that case, the MPP of a filter may be the degree to which it reduces the likelihood of an environmental accident. We must multiply the MPP by the 'price of the output' to estimate the MRP. In this pollution filter context, that price may be a financial penalty the firm must pay if an environmental accident occurs. The MRP is, therefore, the MPP (the reduction in the probability of an accident) multiplied by the financial penalty should an accident occur. Both of these examples are admittedly ambitious examples for an introductory economics course. However, they are rule-of-thumb models that communicate the gist of how economists think at one level above the typical principles of economics textbooks and, therefore, one step toward how upper-level economics courses and, ultimately, professional analysts use introductory economic concepts to organize salient facts into more sophisticated decision-making tools.

To summarize, our paper makes two contributions. First, we present a flipped classroom approach to the teaching of marginal revenue product in introductory economics courses, organized around two examples of MRP in action. Second, we show that rule-of-thumb approaches such as these taken in introductory economics courses can be satisfactorily accurate from an empirical point of view and useful for communicating the gist of the economic theory. Sections 2 and 3 present the two instructor examples of MRP. Section 4 suggests ideas for lesson plans and homework assignments and discusses some challenges that may arise and how those can be managed. Conclusions are offered in Section 5, and a concise version of the lesson plan ideas in Section 4 is presented in the appendix.

2. Marginal Revenue Product in the Context of Elite Athlete Salary Determination

The generic optimal input/labor hiring example presented in most Principles of

Microeconomics textbooks typically mimics agricultural examples used in teaching perfect competition in output markets. The good reason for doing so is to set aside complexities of barriers to entry and product differentiation in both the output and input markets. In so doing, we can show—invoking economic writers at least as far back as Plato and Adam Smith—how the demand for any input is driven by underlying specialization and cooperation ('assembly line') effects that are only enhanced by differences in resource quality (such as human capital). These well-intended abstractions are weak because students do not see their employment aspirations in the generic resource optimization model. We need examples that are compelling to our students. The following elite athlete salary determination application of the MRP concept is such an example because ultimately, our students produce ideas and/or performances characterized by non-rival consumption. Copies of the creative work can be sold at low, if not zero, marginal cost. Our introductory economics students who are studying subjects as diverse as fashion design, computing security, software engineering, and finance are surprised at first to realize that this non-rival consumption property is a strong factor that relates their professional goals and market environment to those of elite professional athletes; however, after considering the following example, they see the connections.

Estimating human capital values and comparing those values to wages and salaries now comprises a significant economic literature. Within the sports economics literature, Scully (1974) is among the first to set forth a theoretical approach to measuring the value of contributions made by professional athletes (specifically baseball in his analysis). His marginal revenue product formulation continues to be assessed, utilized, and extended. In our first example, we show that a parsimonious, rule-of-thumb version of Professor Scully's (1974) multiple linear regression framework is surprisingly accurate in terms of predicting a sample of elite National Hockey League salaries in the modern era. In particular, we present multiple cases in which increases in attendance when the elite player joins the team—as a very simple measure of marginal physical product—multiplied by rough estimates of unweighted average ticket prices—can explain elite NHL player salary outcomes reasonably well.

As described in the Introduction and the concise lesson plan presented in the appendix, the class meeting within the flipped classroom framework should feature student and instructor examples that are related to each person's CTM. The motivation for this elite athlete salary example is the second author's (Prof. A) appearance on KMOX radio in St. Louis, Missouri in 1998 when Brett Hull was seeking $5 million per year on a new contract. Prof. A. is an avid hockey fan and hockey is relatively popular on our campus. (Students read the following version of the interview before class, and then Prof. A re-enacts the interview live in class.) St. Louis Blues management didn't react favorably to this contract demand and the KMOX radio Sports Open Line program was alive with public comments on both sides of the topic, ranging from "Brett Hull is the best player St. Louis has ever had and is worth every bit of $5 million" to "How could any pro athlete be worth $5 million, when St. Louis area policemen, school teachers, and nurses make so much less than that?" Prof. A phoned in and told the radio host he could describe how economists estimate values like these. They put Prof. A live on the radio after the commercial ended! Prof. A said to them that first of all, we needed to agree on what an individual pro athlete in a team sport produces. Prof. A and the two radio hosts agreed that while elite NHL forwards like Brett Hull score goals and that goals win a lot of games, ultimately, what elite players like Brett Hull do is put paying fans in seats. So, Prof. A asked the radio hosts how much they thought home game attendance had increased since Brett Hull came to town. Various numbers were bandied about—no one had ready access to complex data—and they finally agreed that it had probably increased by around 4,000 per night. (In retrospect, the guess of 4,000 was pretty

accurate in that radio show discussion.[4])

The conversation then turned to the marginal revenue component of the marginal revenue product, and Prof. A argued that a good first approximation of that would merely be the average ticket price—ideally the weighted average ticket price—but that using the unweighted average could suffice as a simple approximation. That called forth all kinds of comments about how complex the ticket pricing had become (even in the 1990s)—that there were more of some kinds of seats than others, and several other complications like student night price discounts and military service member discounts. Prof. A said, "Would it be reasonable to take a stab at it with something like $30 for the average price?" The hosts went back and forth on that but agreed that that was probably reasonable—that, if anything, $30 might be a little low. Prof. A told them the last step is to multiply the above figure by 41, as there are 41 home games. Prof. A said, "Okay, listen, I don't have a calculator here with me because I heard you guys talking about this when I walked in the door to my apartment and didn't set up to do any calculations." One of the hosts found a calculator and punched in $30 x 4,000 tickets x 41 games = $4.92M, and on live KMOX radio exclaimed: "$4.92 million—that's the $5 million Brett Hull is asking for! How did you do that?!"

Does this attendance-based measure of MRP hold up in additional cases of elite NHL players?[5] Consider the case of Tampa Bay Lightning star Steven Stamkos near the point of finishing his second contract with the team and signing a long-term extension. In the summer of 2016, Stamkos was set to become an unrestricted free agent. Throughout the five years on Stamkos' first extension after his rookie contract, he was the Lightning's leading goal scorer in every season but one. Consequently, when he became an unrestricted free agent, Stamkos had a lot of leverage, especially given the recent success of the Lightning. Average attendance rose steadily from 17,268 in 2010-2011 to full capacity attendance of 19,092 in 2015-2016.[6] The average ticket price also increased to approximately $106.53 in 2015-2016.[7] Our parsimonious MRP calculation gives $106.53 x 1,824 tickets x 41 games = $7.97M. During the 2016 offseason, Stamkos signed an eight-year extension of $68 million (or $8.5 million per year).

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[4] Looking at the 2017-18 Blues Media Guide data at St. Louis Blues (2017, 260), http://www.sports-labs.com/fr/pdf/2016-17_StLouis.pdf, this seems reasonable. At first approximation, one would just compare the average attendance in 1988-1989 with that of 1987-1988; this difference is only 14505 – 13240 = 1265, well below the hypothesis of 4000. But there is an argument to be made for taking a longer view of a star player's impact, and that would favor comparing average attendance based on the ten years before Brett Hull's arrival with the average based on the ten years including Brett Hull. Attendance in the ten full seasons that begin after Hull's arrival in St. Louis in March 1988 is as follows: 14505 (1988-89 season), 15138, 15813, 17158, 17518, 16338, 17561, 19489, 18806, and 16807, for an average of 16913. Attendance in the ten full seasons prior to and including Hull's arrival are as follows: 10633 (1977-78 season), 10130, 12259, 14603, 14433, 12612, 12987, 13397, 12230, and 13240, for an average of 12652. The change is therefore 16913 – 12652 = 4261, which is quite close to the radio hosts' sense that it must be around 4000.

[5] One way to delineate 'elite' or 'star' players from non-stars is according to which players' names frequently appear on the backs of fan jerseys at the stadium. There is also data at https://www.nhl.com/news/toronto-maple-leafs-forward-auston-matthews-has-top-selling-jersey-in-nhl/c-298136872, for example, on sales of player-named jerseys per time period that provide a good sense for which players are the 'stars'. The rule-of-thumb method is less reliable for estimating the MRP of non-star players, for it is more difficult to attribute changes in attendance to the presence of non-star players. We believe the rule of thumb nevertheless has value, since salaries of star/elite players (and other most highly paid figures in the economy, such as CEOs) draw steady public and economic policy interest.

[6] Computed from http://www.hockeydb.com/nhl-attendance/att_graph.php?tmi=8385.

[7] http://blog.ticketiq.com/2016/10/2013-14-nhl-average-ticket-prices-team/.

This example suggests that Stamkos's representatives were able to negotiate an extra $4 million ($0.5 million for eight years) above his value to the hockey market of Tampa Bay. Our estimated MRP is very close (93.7%) to his actual salary.

Another elite hockey player of interest is Shea Weber, a defenseman for most of his career with the Nashville Predators. Average attendance increased by 1,158.[8] The estimated average ticket price during Weber's tenure was $108.18.[9] Hence, our MRP estimate is 1,158 tickets x $108.18 x 41 games = $5.1M. Halfway through his ten years in Nashville—in the summer of 2011—Weber signed a contract extension that raised his annual salary from $4.5 million to $7.5 million. Hence, our average MRP figure proves fairly accurate at 85.6% of his average annual salary of $6 million over that time period.

Let us now consider a final case—the tandem of Sidney Crosby and Evgeni Malkin of the Pittsburgh Penguins. Before their arrival, attendance at Pittsburgh games was quite low. In fact, the Pittsburgh Penguins were close to declaring bankruptcy and moving out of Pittsburgh.[10] However, this changed after drafting two very special players. With the additions of Crosby and Malkin, the Penguins earned spots in the NHL playoffs for 16 straight years. The team also won three Stanley Cups, and Malkin and Crosby have each won multiple NHL awards and achieved international accolades. The data suggests that average attendance (MPP) is greater by 2,193 fans when Crosby and Malkin are in the lineup.[11] As far as ticket prices are concerned, the best source we have suggests that Pittsburgh's average ticket price in the 2013-2014 season just prior to Crosby signing a restructured 12-year contract that pays $8.7 million per year and Malkin signing an eight-year contract that pays $9.5 million per year was $203.93.[12] Our MRP estimate is 2,193 x 41 games x $203.93 = $18.34M. Dividing this figure by two, we obtain $9.17M per player. Comparing with their average annual salaries, we find that Malkin's MRP estimate is 96.5% of his average annual salary ($9.17M/9.5) and that Crosby's MRP estimate is 105.4% ($9.17M/8.7).

Of course, star players produce more than simply increased attendance revenues, and other variables attract fans to games other than the acquisition of an exciting new player(s) and their production. However, in our sample of case studies, we find that changes in attendance alone can be reasonably accurate indicators of the star's value, at least to a first approximation. We hasten to add that while our rule-of-thumb approach is simpler than more sophisticated econometric approaches featured in the literature, the exchange Prof. A had in the public forum of KMOX radio in St. Louis demonstrates how a simple approach enables accessibility to non-specialists who are interested to learn the gist of what economic theory has to offer. Public accessibility to solution concepts suggested by economic theory is important in contexts such as these where private enterprises (pro sports franchises) routinely call upon public financing (and therefore public support) for new stadiums and complementary infrastructure. In addition, this simple approach is accessible to principles of economics students learning the intuition or gist of the MRP concept.

Students find this professional athlete context for learning MRP relatively more interesting than standard, abstract textbook examples—even though almost no students will become elite athletes commanding millions of dollars per year in salary. As we suggested at the beginning of the example, students identify that what elite athletes produce is surprisingly not too different from the ideas/performances that they will go on to produce: the outputs are non-rival in consumption. One person's consumption of an elite athlete's performance via in-person attendance, and particularly via digital streaming, does not draw down opportunities for other

[8] Computed from http://www.hockeydb.com/nhl-attendance/att_graph.php?tmi=7024.
[9] https://www.forbes.com/pictures/fjlg45mhf/24-nashville-predators-avg-price-108-18/#244d6df65b04.
[10] https://www.nytimes.com/1999/03/14/sports/hockey-lemieux-is-trying-to-save-the-bankrupt-penguins.html.
[11] http://www.hockeydb.com/nhl-attendance/att_graph.php?tmi=7475.
[12] https://www.forbes.com/pictures/fjlg45mhf/10-pittsburgh-penguins-avg-price-203-93/#5138192b29c8.

consumers. Indeed, digital/streaming consumption is rapidly overtaking in-person attendance consumption in professional sports as well as in several careers of students' interest.[13] As Rosen (1981) describes, this technology yields the economies of scale effect at the root of many of our students' productivity. Any of our students who produce intellectual property has the opportunity to create that property once and, in principle, sell an infinite number of (digital) copies at zero marginal cost using the same 'attendance multiplier' described in this elite athlete example. For example, the 'attendance multiplier' accounts for the significant market power earned by popular social media influencers and by popular musicians across all genres. In addition, the same significant impact via the 'attendance multiplier' can arise from research and development efforts. For instance, an undergraduate student who goes on to graduate/medical school to generate research on the particular healthcare needs of underserved populations such as transgender clients will generate an MRP that derives from improved client health outcomes anchored to the student's non-rival research results. Those improved client health outcomes translate into dollars of MRP attributable to the research results when healthcare expenditures fall as client health strengthens, or when client productivity in dollars rises with strengthened health outcomes. Students' heightened levels of interest in the examples in this section naturally lead them to be interested in analogous labor examples and in learning more sophisticated approaches to measuring MRP that are outlined in subsequent economics courses.

3. Marginal Revenue Product in the Context of Pollution Control Technology Selection

Our second example of MRP for introductory economics courses is a physical capital example that complements the preceding labor example, as both labor and physical capital are typically covered in the same 'input selection' chapter of introductory economics textbooks. This physical capital example involves a polluting firm choosing an optimal degree of filtration to install at its plant. Students must first consider what adding a filter to an array of filters produces. That is to say, what is the marginal physical product (MPP) of each of possibly several filters added to a pollution control system? As suggested in the Introduction, one way of conceptualizing the MPP of capital such as a pollution filter is to consider that the filter reduces the likelihood of a pollution event for which the firm could be held legally liable.[14] Filters are valuable because they reduce the probability of a sufficiently large leak in the local environment (the MPP). The dollar value of this can be obtained by multiplying the MPP for each filter by the financial loss if such a leak occurs. This yields the MRP for filters and is also the firm's maximum willingness to pay or demand for pollution filters. Consider now in Table 1 the firm's thinking

[13] A recent example is the streaming revenue that new Major League Soccer star Lionel Messi's presence is generating and that, per his contract, he is gleaning from Apple TV broadcasts of games. See https://www.sportsbusinessjournal.com/Journal/Issues/2023/07/24/Upfront/apple-and-messi.aspx.

[14] This example is a simplified version of the precaution or care-taking law and economics framework presented in Charles Kolstad's (2011, 384) upper-level undergraduate textbook and Kolstad, Ulen, and Johnson (1990, 890). A risk-neutral agent wants to choose units of care x to minimize the sum of the cost of taking such care, $C(x)$, and the dollar expected damage, D, from an environmental accident. Expected damage is the product of the probability p of an accident, which can be reduced at a decreasing rate by taking care x, and the dollar estimate D of damage should an accident occur. So we would have the agent minimizing expected social cost $S(x) = C(x) + p(x)D$. The first order condition, per Kolstad, Ulen, and Johnson (1990, 890, eq. (2)), is $dC/dx + (dp/dx)D = 0$, and that leads the agent to invest in care x such that the marginal cost of care (dC/dx) just equals the expected marginal damages avoided ($-(dp/dx)D$). This choice of x is illustrated with x* in Figure 1 by Kolstad, Ulen, and Johnson (1990) and Fig 18.6 by Kolstad (2011). Marginal cost is positive and non-decreasing; expected marginal damage avoided is positive but non-increasing. Our principles of microeconomics version of the problem features the following simplifications: (1) the care the firm can take is merely choosing several filters x to install in an array; (2) filters can be acquired at a constant marginal cost of $1000; (3) there are discrete numerical data points substituted for the continuous $-dp/dx$ term; and (4) it is assumed that the regulatory instrument is a fine F that is assumed to be identical to the damage D should an accident occur.

about the prospect of installing multiple filters to the pollution control array. First, we have the total product (TP) as the probability of no leak occurring, given the number of filters. From this data, we can compute the MPP as the marginal increase in the probability of no leaks by each additional filter. We see that each additional filter is useful but decreasingly less impactful. For instance, the MPP of the first filter is a 20% increase in the likelihood of avoiding a sufficiently large leak of pollution that the firm is fined. The next (second) filter is useful but only achieves an additional 15% increase in the probability of a good outcome. Suppose the 'price of the output' is a fine of $20,000 the firm faces if such a leak occurs. Then, the MRP is the statistical or expected value of a filter, and it is useful to assume the firm is 'risk-neutral' in that it only cares about expected values. Finally, suppose the price of each filter is $1,000.

Table 1. Comparing Probability-based MRP and Price of a filter

Filters	TP	MPP	P=fine	MRP	Filter Price
0	0.4	-	$20,000	-	$1,000
1	0.6	0.20	$20,000	$4,000	$1,000
2	0.75	0.15	$20,000	$3,000	$1,000
3	0.85	0.10	$20,000	$2,000	$1,000
4	0.90	0.05	$20,000	$1,000	$1,000
5	0.91	0.01	$20,000	$200	$1,000
6	0.915	0.005	$20,000	$100	$1,000

Again, the first filter's physical contribution is that it will make the firm's production process 20% safer; that is, it raises the likelihood of avoiding a $20,000 fine by 20%. In economic perspective, such a filter is worth $4,000 (from $20,000 x 0.20). How many filters should the firm consider installing in a pollution control array? The optimal choice is four filters, where the filter price (or marginal resource cost) is equal to the marginal benefit or MRP of filters. It is useful to point out why it is not optimal to choose either three filters or five filters. Doing so enables the class to revisit the concepts of consumer surplus and social welfare as the course draws to a conclusion. It is also advantageous to sketch the downward-sloping demand (MRP) for filters at this point and see that it crosses the constant marginal cost line of $1,000 at four filters.

4. MRP Lesson Plan Ideas

The two examples suggested above are ambitious next steps beyond the standard examples in principles of microeconomics texts. A flipped-classroom framework is quite useful for this material, where in the first step, students are encouraged to arrive at class (1) having read the textbook MRP chapter so that they are familiar with the MRP concept and the standard examples; (2) having skimmed the professor's online notes for the chapter which comprises the content presented in this paper; and (3) having contemplated one or more examples of how the MRP might be computed for an input purchasing decision in the context of the career, topic, or market (CTM) of their most significant interest at the moment.

With this background, the class may begin with the instructor asking students to explain the MRP concept, how it is computed in straightforward examples, and for an input

selection context from their CTM. Brief mentions of these personal student examples provide a gateway for the instructor to present one or two personal examples of their own in some detail. These realistic examples—such as the two presented in this paper—will no doubt be more complicated than the standard textbook examples. However, experience suggests that students will be inspired to wade through the complications because doing so takes them closer to how microeconomic theory can inform their personal and professional decision-making well beyond the introductory course. As the class period concludes, the instructor can circle back to a few of the examples students briefly shared at the top of the class and invite students to develop a fuller, computational version of their career-specific example in a manner analogous to the instructor's two examples presented in class. The fuller example could be collected/graded the following week or could be part of an in-class examination.

Sample assignment question: Consider the input purchase decision in the context of your current career interest or of a topic or market of particular interest. Please write a proposal to a colleague in which you feel there is a need for a specific input and make a case for how many units of that input should be purchased. Please include some reasonable numbers in your example, including your best guess as to the price of the input. Please include a graph that illustrates the efficient choice of input rate. (For simplicity, assume the price per unit is constant.)

General answer: For this question, we want to apply the MRP theory described in the previous problem and in class to an input selection problem of your own. Select an input of need in your CTM—maybe it is laptop computers for your employees. Think about the MPP for those laptops. It may be that each laptop enables a certain number of additional documents (e.g., proposals for clients, bills, legal documents) to be prepared per time period. The first laptop probably produces more additional documents than the second, third, and so on. So, MPP is likely positive but likely falls after one or a couple of units. Suppose the average price for which you can sell a completed document from the laptop is $400. We multiply each of the declining MPP values by $400, and our MRP is positive but declining, as is the demand for other things. Suppose you can purchase as many laptops as you want for a competitive (that is, constant) price of $600. We then want to purchase all laptops that have MRP greater than or equal to the laptop price of $600. Each student example could have four or five rows of data for units of input, MPP, 'price of the output', MRP, and input price, as in Table 1. Each student's assignment could also include sketching a graph that features a downward-sloping MRP function and a horizontal or upward-sloping input price or input supply function, with labels indicating how much input is optimal to hire.

Several possible variations and/or extensions suggest themselves. First, instead of—or in addition to—working individually on a personal, career-oriented example, students may work in pairs, developing either a single example or working together on each other's example. Second, if students would like to consider additional examples before proceeding with their own, instructors could provide those before or after the class meeting. Some examples are: (1) How would a firm decide whether to employ single-factor, double-factor, or triple-factor authorization software by which employees would access the firm's computers from home offices? (2) How would a city administration decide upon the number of bulletproof vests for police officers to purchase? and (3) How would a city administration decide upon the average amount of road salt to order for winter roads? Each of these questions spans several college majors and is addressed with the same concepts employed in our elite athlete valuation and pollution control valuation examples.

We conclude this section by discussing some of the challenges in implementing the flipped classroom framework, including the two featured examples. The main limitation with the flipped classroom approach and with implementing our examples within that framework is the preparation of the materials for students to utilize before class. Preparation can be labor-

intensive. However, the COVID pandemic was an 'action-forcing event' for many of us to create a lot of digital material that may now be deployed to overcome that barrier in setting up flipped classroom frameworks.

Second, there is a variance in student preparation before class. Of course, this is always a challenge, with or without a flipped classroom approach. But, with the flipped classroom approach, students doing their part before class is of heightened importance. Experience suggests that once students gain the rhythm of the approach, the instructor has an easier time gaining a sense of a good starting point for the in-class work. Students report that it is not a lack of interest but rather over-commitment with too many courses or with a job, or with extracurricular activities, that sometimes results in their appearing in class without having done their part to prepare. On average, the flipped classroom approach does work. Ramping up to the approach in the earliest days of the semester is key so that as many students as possible are on pace.

Third, some students have a difficult time settling on a career/topic/market to feature in their personalized investigations of concepts like marginal revenue product. In those cases, the advice for students is to spend 30 minutes on the settling process and then either consult with the instructor for help in narrowing the topic or to pick the one that sounds most exciting, independent of whether it could be a career and independent of whether tastes might change as soon as next week. Emphasize to students that we are practicing the analysis *process* rather than committing to a long-term study of a *topic*, such that effective practice of solution processes in context-rich environments can occur with any topic.

5. Concluding Points

The purpose of this paper is to present a flipped classroom approach to the teaching of marginal revenue product in introductory economics courses, organized around two examples of MRP in action. The examples of elite athlete and pollution control valuation contribute to the sports and environmental economics literature, respectively, by showing that rule-of-thumb approaches such as these taken in introductory economics courses can be satisfactorily accurate from an empirical point of view and useful for communicating the gist of economic theory. The examples facilitate rich discussion of several other possible applications students design based on their interests. Students find it quite interesting that the MRP concept requires them to go far beyond identifying a college major to conceptualize what the market will pay them to do upon graduation. Doing so enables students to strategize from as soon as in high school and during the first year of college to develop a compelling marginal *physical* product—ideally, one that features clear product differentiation, significant barriers to entry (i.e., barriers to easy copying by competitors), and non-rival consumption. Creating a flipped classroom environment is instructor resource-intensive; however, the action-forcing event of the COVID pandemic nudged many instructors to create significant quantities of digital materials that now permit the creation of flipped classroom approaches at much lower cost than before. This, in turn, enables more customized learning opportunities since much of the basic material is available digitally for students to survey before class, and class meetings can focus on the intricacies of applying fundamental concepts to real-world contexts that arise in each student's anticipated career. The exchange of career-specific examples between the instructor and students sheds much light on the properties of concepts such as marginal revenue product.

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Appendix

Sample Lesson Plan: Concise Version of Section 4 Materials

1. Lesson Overview
    a. This lesson introduces the concepts of marginal physical product and marginal revenue product and shows how the marginal revenue product of an input and the input's cost are compared to determine optimal hiring. Two real-world examples of marginal revenue product determination and input selection are presented—one for labor and one for physical capital. Achievement of student learning outcomes may be assessed via take-home assignment or via written response on an in-class examination, wherein students derive their example of marginal revenue product and hiring decision in the context of their intended work upon graduation.
2. Economic Concepts
    a. Marginal physical product
    b. Marginal revenue product
    c. Optimal hiring rule
3. Compelling Question
    a. How do individuals and firms determine how much of a production input to utilize?
4. Intended Student Learning Outcomes
    a. Explain the gist of how economists use the concepts of marginal physical product and marginal revenue product to measure the values of inputs like labor and physical capital.
    b. Describe examples of deriving the marginal revenue product of an input in one's work of current interest.
    c. Analyze how the comparison of an input's marginal revenue product and cost determines the optimal hiring of the input.
5. Preparation: A Flipped Classroom Approach
    a. In the traditional chalk-and-talk approach, the instructor presents basic definitions and standard applications in the classroom; students then practice those applications in homework and discuss questions and extensions with the instructor and classmates outside of class. The flipped classroom approach turns these stages around: the instructor provides materials to students in advance of class—with the expectation that students will at least skim the materials and become familiar with the basic ideas for the next class—and class time is devoted to active applications of the concepts, discussion of questions, and formulation of extensions. For the MRP chapter, the advanced materials posted to the online course management system may comprise the textbook chapter and personal lecture notes with definitions of the concepts and calculations (and graphs) of

straightforward examples. Students should also come to class with an input selection example custom to their intended work upon graduation.

6. Class Day Instruction

    a. Begin by asking a few students to briefly describe their input selection examples. This facilitates student engagement, establishes a creative flow of energy for the class meeting, and an efficient review of the basic concepts.

    b. The instructor then presents one or two real-world examples encountered in their career, topic, or market of interest. Two specific instructor examples—one for labor and one for physical capital—are presented in Sections 2 and 3 of this paper.

        i. Explain the context for each input decision. For instance, in the first example presented in Section 2, the context was whether one's favorite sports team should renew a star player's contract for several million dollars per year.

        ii. Review how MPP and MRP are calculated and illustrate with the instructor's examples.

        iii. Draw a graph of the MRP and add the marginal resource cost, to illustrate how optimal hiring occurs where the input's MRP equals its marginal resource cost.

7. In-Class Practice

    a. Return to student examples, inviting them to describe their examples to classmates (perhaps at the board while sketching their own MRP and cost functions).

    b. In relatively large classes, students can break into small groups and TAs can circulate among the groups to help facilitate discussions.

8. Practice after Class

    a. Students may then pursue extensions of their examples or create new examples in an assignment following the class period; Section 4 of this paper includes a sample assignment.

9. Assessment

    a. Achievement of student learning outcomes may be assessed via take-home assignment or via written response on an in-class examination, wherein students derive their example of marginal revenue product and the hiring decision in the context of their intended work upon graduation.