Confuser Cost

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Abstract

The terms "royalty", "marginal user cost", and "scarcity rent" are often used interchangeably in resource economics, resulting in considerable confusion. We suggest distinct and meaningful definitions for the terms "royalty", "marginal user cost", and "scarcity rent" and discuss the relationships among them. Using the example of extraction fees for leasees, we show how failing to understand the distinct meaning of these terms may lead to policy errors. By constructing a model containing both capital and resources as state variables, we verify that user cost in capital theory is a different concept than marginal user cost in resource economics and suggest a taxonomy that may help to avoid confusion and misinterpretation.

Key Words: renewable resources, marginal user cost, royalty, scarcity rent, shadow price, Hotelling rent, user cost of capital
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1. Introduction

Marginal user cost (MUC), the forgone value of using a resource now, is a central concept in resource economics. In order to allocate resources efficiently over time, the opportunity cost of having a smaller resource stock in the future must be taken into account. Despite its importance, there are a number of ambiguities and inconsistencies in the usage of the term, however.

In resource economics, the words "royalty", "marginal user cost", "scarcity rent", and "shadow price" are commonly used interchangeably. For example, Hartwick and Olewiler (1997, p.271) write:

> *"Rent in this case is referred to by various authors as user cost, royalty, dynamic rent, or Hotelling rent. Five names for the same thing!"*

A similar treatment can be found in Neher (1990, p.289):

> *"It* [royalty] *is being generated by recognition of the ultimate scarcity of the resource and so can be thought of as a scarcity value enjoyed by the resource owner. Sometimes it is referred to as user cost …."*

Pearce and Turner (1989, p.273) summarize the confusion thusly:

> *"In the literature R is known as the royalty …, the resource rent (or rental) …, the depletion premium, and the marginal user cost. The different terms are unfortunate since they add to the potential for confusion. The reader simply has to watch out for the context in which they are used."*

Additional confusion arises in optimal control settings, where marginal user cost is alternately interpreted as the co-state variable in both the present and current value Hamiltonians. Moreover, the evolution of user cost in resource economics and capital theory

has led to different meanings, even though they both are descendants of Keynes's *General Theory*.

In what follows, we provide definitions of royalty, marginal user cost, and scarcity rent that are distinct, are consistent with their historical meanings, and that support a useful interpretation of an extended Hotelling condition for renewable as well as non-renewable resources. We illustrate how a failure to associate these terms with distinct meanings can and has led to misleading policy recommendations. In the last section, we discuss how user cost has come to have a different meaning in capital theory, thereby contributing further to confusion regarding resource economics.[2]

2. Definitions and Relationships

Our objective in this part is to provide a taxonomy that will both distinguish the terms and illuminate their relationships.

2.1. Royalty

Royalty is defined as the difference between price and extraction cost. For example, Pearce and Turner (1989, p.272) explain: *"The price in the ground* [*p-c(X)*] *is better referred to as the royalty (a term that derives from sovereigns' rights to property in the ground)."*

2.2. Marginal user cost

"Marginal user cost", first introduced by Keynes (1936), is defined as *"... the loss in value when a capital asset is reduced by one marginal unit*" (Clark 2005, p.106). Even though primarily concerned with capital theory, Keynes (1936) also understood the importance of the concept for resource economics:

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[2] In Morey's "Confuser Surplus," the confusion arises because of the multiplicity of meanings (i.e., using one term for more than one thing). In the present case, the confusion arises more from a multiplicity of definitions (using terms with different definitions interchangeably).

"... if a ton of copper is used up to-day it cannot be used to-morrow, and the value which the copper would have for the purposes of to-morrow must clearly be reckoned as a part of the marginal cost" (p. 73).

Similarly, Toman (1986, p.343) describes marginal user cost as *"... the absolute size of the incremental reduction in the present value of maximum future profit caused by an incremental increase in the current extraction rate."*

These definition accord, at least roughly, with the common intuition of the requirement that royalty equals marginal user cost as the condition for optimal extraction of a resource (e.g. Howe, 1979; Pearce and Markandya, 1989). Royalty is the marginal benefit of extraction and marginal user cost as just defined is the marginal opportunity cost of using resource. Now, the question is to what extent is this intuition supported by rigorous treatments.

Formally, it is natural to identify the marginal user cost with the co-state variable of the Hamiltonian derived from a benefit maximization problem. In particular, Clark (2005) solves the resource allocation problem:

$$\max_{x_t} V_t = \int_{t=0}^{\infty} e^{-rt}[p - c(X_t)]R_t dt \qquad \ldots (1)$$

$$s.t.\ \dot{X}_t = f(X_t) - R_t$$

by maximizing the present value Hamiltonian,

$$H = e^{-rt}[p - c(X_t)]R_t + \alpha_t[f(X_t) - R_t] \qquad \ldots (2)$$

where p is resource price, c is unit extraction cost, R is resource extraction, X is resource stock, f is natural growth function, r is discount rate, and α is the co-state variable.[3] The corresponding first-order condition for the problem is:

$$e^{-rt}[p - c(X_t)] = \lambda_t \qquad \ldots (3)^{4}$$

Clark also notes that the co-state variable, α, from the above is the marginal user cost, i.e. the "*the loss in value when a capital asset is reduced by one marginal unit"* (p.106). Equation 3 has considerable appeal. It is simple and serves to unify renewable and non-renewable resource economics. The "extended Hotelling" equation stays the same (even though the equation for the co-state variable includes more terms for the case of a renewable resource)[5]. However, from equation (3), the optimal condition requires marginal user cost equal *discounted* royalty. Thus, identifying the co-state variable of present value Hamiltonian as the marginal user cost does not provide the intuitive optimal condition suggested above.

This confusion can be avoided by using the current value Hamiltonian and defining marginal user cost as the corresponding co-state variable. In fact, this is the correct way, as the *loss in value* must be evaluated at the time resource is used, not at the beginning period. Considering a simple renewable resource optimization problem, a social planner chooses the resource extraction path to maximize the present value of net benefit over time, i.e.:

$$\max_{x_t} V_t = \int_{t=0}^{\infty} e^{-rt} \left[\int_0^{R_t} p(z)dz - c(X_t)R_t \right] dt \qquad \ldots (4)$$

$$s.t.\ \dot{X}_t = f(X_t) - R_t$$

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[3] Some notations of variable are different from those used in Clark (2005).

[4] This optimal condition is same as equations 4.19, and 4.32 in Clark (2005).

[5] Non-renewable resource extraction can be modeled as a special case wherein $f(X) = 0$.

The corresponding current-value Hamiltonian can be written as:

$$\tilde{H} = \int_0^{R_t} p(z)dz - c(X_t)R_t + \lambda_t[f(X_t) - R_t] \qquad \ldots (5)$$

where λ_t is the co-state variable for the resource stock (or the current shadow price of the resource). Mathematically, λ_t can be interpreted as the marginal value of the state variable at time t *in terms of value at t* (Kamien and Schwartz 1991, p.165), or $\frac{\partial V_t^*}{\partial X_t}$.[6] The corresponding optimal condition can be written as:

$$\rho_t \equiv p(R_t) - c(X_t) = \lambda_t \qquad \ldots (6)$$

Thus, according to the definition, it is more appropriate to identifying the co-state variable of current value Hamiltonian as marginal user cost. This results in the intuitive optimal condition. Note that, as the present value and current value co-state variables are equal at time t_0, the use of present value co-state variable will be valid when discussing the change in resource stock that occurs at time t_0.

2.3. Scarcity rent

Scarcity rent or Hotelling rent refer to the difference between price and extraction cost when resource is extracted such that the net benefit is maximized over time (Nordhaus and Kokkelenberg 1999, p. 215).

2.4. Summary

In summary, the terms “royalty”, “scarcity rent”, and “marginal user cost” have their own distinctive definitions. To allocate resource optimally, resource must be used such that its marginal benefit equals marginal opportunity cost, i.e. royalty equals marginal user cost.

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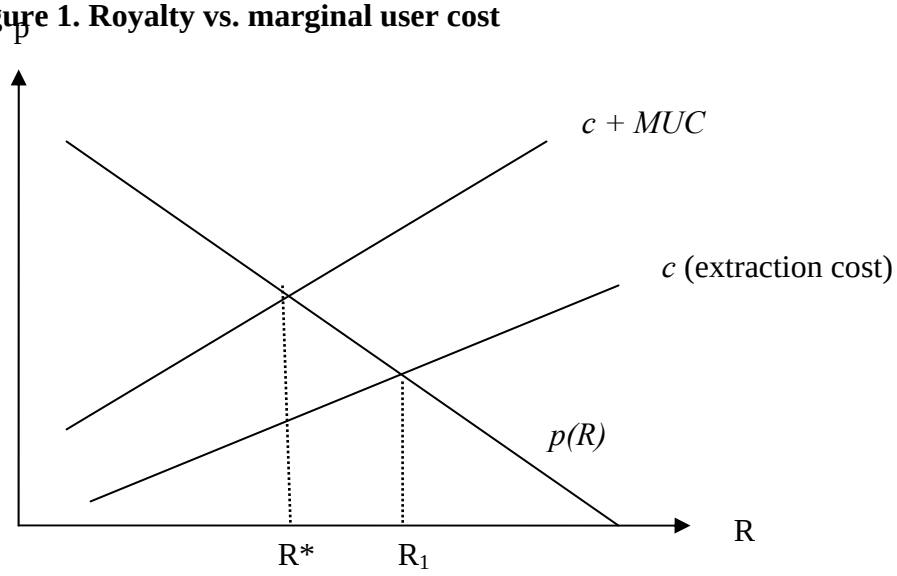
[6] The symbol (*) is used to designate values of variables along the optimal trajectory.

Scarcity rent or Hotelling rent is the value of both royalty and marginal user cost when they are equal (at the optimum).

3. The Shadow Price of Extraction

The confusion in the use of these terms is not just a semantic issue. Failing to distinguish these terms is problematic for policy analysis. For public pricing, the shadow price of public goods must be charged. Since royalty is observable and thought to be interchangeable with marginal user cost and "shadow price," economists sometimes suggest charging concessionaires of public leasing contracts (e.g. forestry) an extraction fee equal to royalty (Repetto 1988, Gillis 1988). As explained above, however, royalty is only equal to MUC, and in turn scarcity rent, if the resource is being optimally extracted. In particular, if the resource is overused, the observed royalty will be less than the shadow price.

Figure 1. Royalty vs. marginal user cost



For example, if the resource is open-accessed, it will be harvested until the price is equal to the extraction cost (R_1 in figure 1). Charging observed royalty, which equals to zero, would not improve efficiency. The first-best policy is to charge either the marginal user cost

or the royalty where each is evaluated at the optimum. Note that in the optimal solution, the necessary condition depicted in figure 1, i.e., $p_t=c_t+MUC_t$, holds for all time periods. (In the standard autonomous case and starting with an initial stock of the resource greater than its steady state value, the inverse demand function is stationary and the total marginal cost, $c + MUC$, increases over time, implying a monotonic increase in shadow price up to its steady state value.)

4. "Marginal user cost" vs. "User cost of capital"

Another source of confusion arises from the inconsistent use of the term "user cost" in resource economics and capital theory. It is natural to believe that "user cost" and "marginal user cost" refer to the same user cost but that only one of them is a marginal concept. We show, however, in this section, that both of them are marginal concepts but that the two implicit meanings of user-cost are different.

In capital theory, the term "user cost of capital", commonly attributed to Jorgenson (1963), usually refers to the implicit rental price of capital services (harkening back to Walras's, 1874, price of capital services). For example, Diewert (2005) explains the user cost of capital as the *"net cost of using the new asset for period t,"* and calls it the "*end of period vintage rental price*" of capital.[7]

In order to explicitly establish that user cost has different meanings in resource economics and capital theory, we add natural resources as an additional input in Jorgenson's (1963) capital accumulation model. Capital, labor, and resource inputs are chosen in order to maximize net worth, which is the present value of net benefits over time. Inasmuch as using

[7] Diewert's "*stock value of the asset"* defined in the same paper as the "*discounted future service flows that the asset is expected to yield in the future period*" is closely related to "user cost" as used in resource economics (see also Diewert, 2005).

both meanings to interpret the first-order conditions for the integrated model would exacerbate confusion, we suggest using the Keynesian marginal user cost for the resource and implicit rental price for the cost of capital.

Let *P* be the price of output; *Q(K,L,R)* be the output which is produced by using capital *(K)*, labor *(L)*, and resource *(R)*; *I* be the investment; *w* be the price of labor; *q* be the price of investment (purchase price of capital); and δ be the capital depreciation rate. The optimization problem can be written as:

$$\max_{I_t, L_t, x_t} W_t = \int_{t=0}^{\infty} e^{-rt}\left[PQ(K_t, L_t, R_t) - wL_t - qI_t - c(X_t)R_t\right]dt \qquad \ldots (6)$$

$$s.t. \quad \dot{K}_t = I_t - \delta K_t$$
$$\dot{X}_t = f(X_t) - R_t$$

The corresponding current value Hamiltonian is:

$$H = PQ(K_t, L_t, R_t) - wL_t - qI_t - c(X_t)R_t + \mu_t(I_t - \delta K_t) + \lambda_t(f(X_t) - R_t) \qquad \ldots (7)$$

where μ_t and λ_t are the current shadow prices of capital stock and resource stock respectively. Suppressing time subscripts, the first-order necessary conditions are:

$$\frac{\partial H}{\partial L} = PQ_L - w = 0 \qquad \ldots (8)$$

$$\frac{\partial H}{\partial I} = -q + \mu = 0 \qquad \ldots (9)$$

$$\frac{\partial H}{\partial K} = PQ_K - \delta\mu = r\mu - \dot{\mu} \qquad \ldots (10)$$

$$\frac{\partial H}{\partial R} = PQ_R - c(X) - \lambda = 0 \qquad \ldots (11)$$

$$\frac{\partial H}{\partial X} = -c'(X)R + \lambda f'(X) = r\lambda - \dot{\lambda} \qquad \ldots (12)$$

Equation (8) states that labor should be used until its value of marginal product equals the wage rate. Equations (11) and (12) have the same interpretation as equation (3) and (4) that the resource must be used until its marginal benefit is equal to the sum of extraction and marginal user costs.

Equations (9) and (10) specify the optimal investment rate and capital accumulation. Equation (9) requires that the marginal benefit of investment (the shadow price of capital) equals the marginal cost of investment. The shadow price of capital gives the change in the maximized value when the capital stock is changed by one unit. In problems such as (7), the shadow price or co-state variable is usually interpreted as the marginal benefit of adding a unit of capital. If we think instead of subtracting a unit of capital (e.g. by *using* and depreciating it), we can understand the Keynesian MUC terminology.

Jorgenson (1963) rearranges equations (9) and (10) as:

$$PQ_K = q(\delta + r - \frac{\dot{q}}{q}) \qquad \ldots (13)$$

The right-hand side of equation (13) is the "implicit rental of one unit of capital service per period of time" and is called "user cost of capital" (Jorgenson 1963, p.249). Equation (13) states the condition for optimal level of capital. Capital must be accumulated such that its marginal value is equal to its implicit rental price. Comparing equations (9) and (13), it is obvious that Jorgenson's "user cost of capital" has different meaning than Keynes' "marginal user cost." Ironically, "marginal user cost" as referred to in resource economics is consistent with the Keynesian definition, even though Keynes was defining the term primarily for its use in capital theory. But since Jorgenson's (1963) canonical article on capital theory, the term "user cost" has come to mean the implicit rental price of capital services (e.g. Diewert, 2005; Diewert and Schreyer, forthcoming).

5. Conclusions

The terms “royalty”, “marginal user cost”, and “scarcity rent” are often used interchangeably in resource economics, resulting in considerable confusion. We suggest distinct and meaningful definitions for the terms “royalty”, “marginal user cost”, and “scarcity rent” and discuss the relationships among them.

Marginal user cost in resource economics descends from Keynes and can be defined as the change in maximized value of the resource that results from a marginal change in the level of resource stock. Unfortunately, Clark’s (2005) well-known formalization of this concept defines marginal user cost as the co-state variable for the present-value Hamiltonian, thus failing to support the oft-used condition (Howe 1979, Pearce and Markandya 1989) that efficient extraction requires equating royalty, the difference between price and extraction cost, and marginal user cost.

We show that reproducing Clark's analysis using the current value Hamiltonian results in the condition that royalty equals marginal user cost, where marginal user cost is the co-state variable and equal to the change in the optimized "present value" of the resource at the time that the marginal unit is extracted. The condition must hold for all time periods. Scarcity rent is then the value of both royalty and marginal user cost when the efficiency condition is satisfied. Thus, the terms “royalty”, “scarcity rent”, and “marginal user cost” have their own distinctive definitions and must be used carefully in their own contexts. The confusion is more than semantic issue. We show via the Gillis-Repetto example how failing to understand the distinct meaning of the terms may lead to policy errors.

Lastly, user cost in capital theory and marginal user cost in resource economics are different concepts, resulting in additional confusion. Even though Keynes defined marginal

user cost primarily in the context of capital use, his definition survived in resource economics but not in capital theory. Following Jorgenson's (1963) canonical article on capital accumulation, "user cost" of capital has come to mean the implicit rental price of capital services (e.g. Diewert, 2005; Diewert and Schreyer, forthcoming). To clarify, we expand Jorgenson's model to include resource use and provide an interpretation of necessary conditions that distinguishes between the marginal user cost of resource extraction and the implicit rental price of capital.

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