RECOGNITION AND RECOUPMENT OF SCARCITY RENT
AS A MEANS OF FINANCING LOCAL GOVERNMENT

by

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Government entities operating outside the normal market nexus have severe, inherent problems in reflecting all costs in their financial accounts and thus have great difficulty in "getting the price right." The resulting undercosting begets underpricing and underpricing deprives the entity of revenue. Among the sources of undercosting is the failure to recognize any scarcity value on resources owned by the entity. We provide a rationale for including scarcity value in user charges, and a procedure for estimating its magnitude. Applying this to the case of water supply in Honolulu, scarcity value alone would justify a very significant increase in water user charges and could lead to a very noticeable increase in city revenues.
I. Introduction

The essential idea underlying this paper might be summarized this way: "Undercosting begets underpricing and underpricing begets revenue losses by government entities depending on user charges." Government entities operating outside the normal market nexus have severe, inherent problems in reflecting all costs in their costing process and thus have great difficulty in "getting the price right." The basic difficulty may be that government charges are set in a political context with many constraints.

A variety of pricing pitfalls are commonly associated with this institutional context:

1. Use of average rather than marginal cost in increasing cost situations.
2. Use of nominal dollar accounting cost data, resulting in gross undercosting of the depreciation or interest components of capital cost (a very important costing distortion in capital intensive government enterprises).
3. Failure to recognize or incorporate imputed costs or subsidies such as government provided land, capital or forgiven taxes.
4. Institutional rigidities such as limits on "profits."
5. Failure to recognize, cost out and subsequently include in the relevant price any scarcity value or rent when it is present.

Either separately or in concert these sorts of defects in the government pricing process lead to inefficiencies (excessive or wasteful use) and inequities (cross subsidies between different groups of users as well as between users and non users if tax subsidies are present).

This paper focuses on the last reason given above for the chronic undercosting and

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1 We do not mean to imply that conventional private sector prices are not frequently distorted by market failures. However, absent such market defects, occasional transfers of assets, such as by merger or sale, along with accounting revaluation of the assets involved, assures that accounting based measures of capital costs for private sector entities are usually more valid than in the public sector.
underpricing that occurs in most government entities that assess user or development charges.\textsuperscript{2} After providing a conceptual framework, we examine scarcity value on limited water sources controlled by a municipal water supply agency as a case study. The resulting estimate of scarcity value in this case study is significant both in qualitative and quantitative terms. The revenues of the local government involved could be augmented if the related charges were increased accordingly.

II. Scarcity Value Concept

A. Intuitive Description of Scarcity Value

The essence of scarcity value in general can be developed in the following framework. It lends itself well to practical problems of evaluating scarcity value in actual situations, including urban pricing situations in which we are interested here. Assume the explicit marginal cost profile over time represented in Figure 1 for some service or good provided by a local community, with the explicit marginal costs being correctly valued with regard to all out-of-pocket costs of supply in real terms. For the moment any implicit or imputed costs such as scarcity value are ignored. MC in this case is constant at \( C_1 \) until time \( T \), when low cost capacity or sources, such as water wells, are all being pumped at sustainable yield. After \( T \), explicit marginal costs increase to \( C_\text{r} \) as the result of the sequenced shift in technology or location when a higher cost "backstop" source of supply, e.g., desalination, comes into play. In the absence of any recognition of scarcity value the long run price path

\textsuperscript{2}Positive externalities or income distribution considerations may explain some part of the observed chronic underpricing by government entities as in education, health, and perhaps urban mass transit.
would follow the $C_1$ abd locus as demand, $D_1$ in this case, shifts right over time. This assumes adherence to the $P = MC$ pricing rule; e.g., the price would be fixed at $C_1$ up until time $T$ in this case, and $C_T$ thereafter.

The above approach to costing and pricing even when significant scarcity value is present is likely to occur only in government situations. The scarcity value inherent in the explicit marginal cost configuration represented in Figure 1 would usually be recognized and valued in a private sector market, with a commensurate increase in the market price; i.e., $P = MC + \phi$, where $\phi$ stands for scarcity value.\(^3\) The resulting difference in the long run price path is represented in Figure 2. The gradient going from time $t_0$ to time $T$ in the figure represents the rising "efficiency price" (explicit marginal cost plus a premium for scarcity value) as the system moves closer to the time when a more expensive source has to be resorted to.\(^4\) The difference between the efficiency price and the explicit marginal costs is the scarcity value premium $\phi$ which can be viewed essentially as the present value at time $t$ of the eventual cost increment confronting all users resulting from the current use of the marginal unit at time $t$.

In more concrete terms, as current use of scarce low cost water sources (wells) drives the urban water system closer to the time the much higher cost source has to be resorted to, a cost is being imposed on the users in the system. As the system moves closer to the time of having to switch to the higher cost source, the length of time until the switch goes

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\(^3\)We find it useful to distinguish between scarcity value and scarcity rents. Scarcity value refers to the magnitude of the scarcity value whether it is recognized and recouped or not. If explicitly recognized and captured, we refer to scarcity rents.

\(^4\)Under appropriate conditions, the market would settle on the efficiency price, as in the case of markets for in-situ petroleum or timber resources.
down, thus raising the present value of the cost difference that will eventually manifest itself. The use of the last unit of the low cost source will have an efficiency price similar to the cost, (as well as the efficiency price), of the first high cost unit to be used.

At any point in time the appropriate price is defined by the efficiency price locus, C\textsubscript{i}a'bd in Figure 2. In the case where the government has ignored the value of the raw, in-situ water, an amount equal to the relevant $\phi$ should be added in the form of a "tax" or user charge. Thus, the total price inclusive of the user charge would mimic the efficiency price of water at all points in time once the relevant imputed scarcity value is so recognized and incorporated into the price.\footnote{Once the efficiency price on the inframarginal units is considered, we have to cope with a semantic problem arising from the various types of rents on the infra-marginal units, i.e. both scarcity and Ricardian. Appendix A spells out this distinction in order to make the costing and pricing process more explicit and to provide a more systematic set of expository terms.}

When government makes an outright purchase of water rights, the resulting user charge may include scarcity value. Such is presumably the case with Phoenix's recent purchases of Arizona farm land in order to get the associated water rights. Since scarcity rent was probably part of the transaction price, it will be reflected, along with other out-of-pocket costs, in Phoenix water user charges. Even so, as time proceeds and these water rights increase in value, the City will have no incentive to raise user charges to reflect such increasing scarcity value. In the more typical case where a city's water rights have long been in government hands there is no reason to adjust for the long-term rise in in-situ value; no reason to set price high enough to incorporate the scarcity value.
B. Analytical Specification of Scarcity Value

In many cases, scarcity rent on a natural resource can be estimated empirically by simply subtracting extraction cost from market price data. Unfortunately, most urban water utilities lack market determined prices. However, the efficiency price path of resource economics (Hanson, 1980; Bohi & Toman, 1984) is a function of the time paths of extraction costs and of a "backstop" source of supply. As a result, one can use cost data to calculate the correct price\(^6\) and thus, indirectly, scarcity value itself.

Consider a water utility drawing on an aquifer as its source of supply.\(^7\) Let \(z_t\) = cumulative extraction from the aquifer, up to time \(t\); \(q_t = dz/dt\) = the extraction rate; and \(C_t = g(z_t)\) = unit cost of extraction. Total extraction cost, net of distribution and treatment, is then \(q_t g(z_t) = C^*(q_t, z_t)\). Suppose that the aquifer will be exploited to capacity by some time \(T\). Thereafter, the utility will have to engage some "backstop" source to meet any additional demand.\(^8\) Denote unit cost of the backstop as \(C_T\), and assume this remains constant for the foreseeable future.

Now, to achieve efficiency in use of the resource, the utility should set price equal to marginal cost. In the present instance, marginal cost can be viewed as having two components: the change in cost due to extracting at a higher rate, \(\partial C^*/\partial q\); and the effect

\(^6\)The efficiency of this price path stems from the fact that it is a manifestation of marginal cost pricing, as shown below.

\(^7\)Intuitively, one may wish to think of increasing quantity in the following discussion as involving a sequence of wells drilled and brought into operation one by one as demand grows over time, eventually withdrawing the entire sustainable yield or capacity of the aquifer. The formal analytics, however, lends itself best to continuous variables as stated below.

\(^8\)Alternatively, suppose marginal cost rises steadily over time, although some capacity remains unexploited. When conventional source cost finally attains the backstop cost, the system will switch; this then defines \(T\).
of this higher current output on future costs, $\partial C^*/\partial z$. The latter term enters because increasing today's rate of output by one unit forces the system to capacity of the aquifer, and thence to the higher cost backstop, sooner. Alternatively, if today's rate of extraction were to decline, so as to postpone $T$, the system could realize a current decrease in user cost in the form of lower present value of future costs. Moreover, $\partial C^*/\partial z$ continues to have an effect in each time period from now (time $t$) until $T$, when capacity is reached. Thus the sum of discounted future values of $\partial C^*/\partial z$ is a necessary part of marginal cost, and the pricing rule becomes

$$P_t = \frac{\partial C^*}{\partial q} + \int_t^T e^{-(r-\delta)\tau} \frac{\partial C^*}{\partial z} d\tau$$

$$= g(z_t) + e^{r(t)} \int_t^T e^{-r\tau} q_t g'(z_t) d\tau$$

Integrating (by parts) and substituting $C_t$ for $g(z_t)$ yields

$$P_t = e^{-r(T-t)} C_t + \int_t^T re^{-(r-\delta)\tau} C_t d\tau$$

This is Hanson’s (1980) equation for the efficiency price path. Given a functional form for $C_t$ in the integral above, (2) provides an estimate of efficiency price $P_t$, which under appropriate conditions emulates market price. Hence, subtracting $C_t$ from this estimate of $P_t$ yields an appraisal of scarcity rent itself.

For concreteness, suppose that unit cost $C_t$ takes the stepwise-constant form depicted as $C_{1:0}$ in figure 1:
This cost path is extremely simple and yet broadly realistic for many urban water utilities. For example, consider a water system whose capacity can be augmented at constant extraction cost, up to a point, by simply duplicating conventional extraction facilities—say, drilling additional wells in the existing aquifer. Eventually, however, additional wells breach the aquifer capacity itself. Thereafter, the system must employ some expensive technology such as desalination. Once engaged, desalination will provide virtually unlimited amounts of water at the higher, but essentially constant, cost. $C_1$ represents explicit unit extraction cost of conventional groundwater sources, and $C_T$ the cost of desalination. Substituting (3) into (2) yields the efficiency price

$$P_t = C_1 + (C_T - C_1)e^{-r(T-t)}$$

(4)

Scarcity rent $\Phi_t$ is the difference between price and extraction cost, so for $t < T$

$$\Phi_t = P_t - C_1 = (C_T - C_1)e^{-r(T-t)}$$

(5)

Once the backstop is engaged, of course (i.e., for $t \geq T$), $\Phi_t = 0$.

III. An Application: Water for Urban Honolulu

The Honolulu Board of Water Supply (BWS) provides water to the City and County of Honolulu, on the island of Oahu, Hawaii. The Board’s pumpage, which accounts for about
two-thirds of non-agricultural withdrawals on the island, has grown from 69 million gallons daily in 1961 to 170 million gallons daily in 1991 (Wilson Okamoto & Associates, 1990; Honolulu Advertiser, 1991). The water comes almost exclusively from wells and other structures drawing on various underground aquifers. Planning studies have long foreseen a time when additional wells will exceed the sustainable yield of these aquifers. To continue meeting demand, BWS and the State have begun researching desalination processes, using brackish groundwater as feedstock. The cost of desalination is estimated at two to three times that of conventional sources.

Demand projections underlying this conclusion assume average cost pricing for water and zero price elasticity of demand. Pumping is restricted to sustainable yield of the aquifers. Also, water currently used to irrigate sugar cane—which accounts for nearly half of the island's water withdrawals—cannot be transferred to municipal purposes.

Thus in roughly twenty years the Board must switch to the "backstop" source of water, namely desalination, to meet subsequent growth in urban demand. However, if time T can be postponed, say by an increase in price to induce conservation or by some new conservation technology, the Board can realize a savings in the present value of its future costs; conventional lower cost sources will suffice further into the future. This saving defines scarcity rent on the in situ water resource (see Moncur & Pollock, 1988).

BWS accounting data (Board of Water Supply, 1985, 61-65, 106-113) provide an estimate of extraction cost of the lower-cost technology, $C_1 = $0.19/1000 gallons, net of any distribution costs. Engineering studies estimate desalination cost at $C_T = $1.25/1000 gallons (Park Engineering, Inc., 1983). Using these two data and discounting at a real interest rate
of two percent yields the estimates of scarcity rent in the upper-left quadrant of Table 1. Scarcity rent is $.71/1000 gallons at present (t = 0) but will rise as the system approaches switch time T = 20 to $1.06. Thus the efficient price is $.71 + .19 = $.90/1000 at t = 0, rising gradually to the desalination cost of $1.25 in t = T = 20.

Of course, the C₁ and C₂ data just noted are only estimates. Extraction cost C₁ should be adjusted at least to account for the effect of inflation and other accounting anomalies (Moncur and Pollock, 1988). A conservative appraisal of these adjustments would double C₁, to $.38/1000 gallons, resulting in the θ₁ values shown in the bottom-left quadrant of table 1. The higher C₁ value results in somewhat lower θ₁'s than before. Efficiency prices are slightly higher in earlier years, but converge, as before, to the desalination cost C₂ at switch time T = 20.

Similarly, $1.25 is a lower-bound estimate of desalination costs C₂. Depending on quality of the feedstock and other parameters, engineering estimates of C₂ run to $2.55/1000 gallons (Marske, 1985). The right hand side of table 1 shows the effects: considerably higher scarcity rents and efficiency prices.

Scarcity rent rises as the system approaches full exploitation of the resource, then falls suddenly to zero when the backstop is implemented. This pattern is a result of the particular shape of the extraction cost function. As Hanson (1980) shows, if extraction costs rise linearly or exponentially, scarcity rent is initially somewhat higher than for the stepwise-constant case assumed here, but declines gradually to zero as extraction costs rise to the backstop.

In sum, given the extraction costs posited here, scarcity rent on municipal water at the
present time \((t=0)\) lies between $0.58 and $1.58/1000 gallons of water. These limits would increase the user charge of $0.84 per thousand gallons by 69% or 188%. Even with a generous allowance for price elasticity, these increases promise a substantial increment over BWS earnings of about $40 million.

There are caveats. First, the model above assumes that demand grows over time along with income and population, but with zero price elasticity. An optimal control model would incorporate the feedback effect of higher prices on growth in demand. Alternatively, scarcity value should be re-estimated periodically. Second, the switch time \(T\) as used here was set, according to a particular policy choice about optimal withdrawal rates, at the time when pumping equals sustainable yield. In principle, it may prove optimal to undertake withdrawal rates above sustainable yield, and in any case \(T\) is itself a decision variable. Third, these calculations have assumed that water cannot be transferred from other uses. Existing Hawaii institutions make it difficult or impossible to do so, (see Bowen, Moncur & Pollock, 1991) but clearly, welfare-enhancing institutional changes are called for and would decrease scarcity values on municipal water sources.\(^9\) Finally, a general model would incorporate external costs and third-party effects; these might be quite significant, especially in areas more dependent than Honolulu on surface water sources.

IV. Recoupment Issues, Choices, and Effects

A. Modes of Recoupment

\(^9\) Any increase in conventional sources available for urban uses would permit a delay in \(T\), thus increasing the effect of discounting in equation (2) and decreasing \(\phi_t\).
We have shown both conceptually and empirically that costing out scarcity value can provide a reasonable basis for increasing non-tax revenues of government entities. While we have emphasized the means for identifying and valuing such possible scarcity value, the actual mode of charging for such cost elements is open to several possibilities. While Figure 2 and the data in Table 1 suggest simple addition to get a uniform quantity charge, other pricing arrangements are certainly possible. The primary logical possibilities can be easily cataloged:10

a. The fixed part of the periodic user charge, i.e., some flat amount per period per user. (Analytically this might be viewed as a sort of head tax if all residents were paying customers.)

b. The quantity charge part of the user charge if the user charge is uniform, as is frequently the case. The addition to the quantity charge would be the amounts indicated in Table 1.

c. Add the appropriate per unit scarcity value to the rate in each block of an increasing bloc rate structure.

d. In addition, attributable costs can be recouped from one time, up front charges on land owners or developers, i.e., development charges, impact fees, etc. This charge would be commensurate with the present value of the scarcity value attributable or assignable to new residents over some relevant time frame into the future.

It is fairly obvious that because of its marginal character, scarcity value should not be

10While general revenue sources such as the property tax are another logical possibility for cost recoulement, they are not relevant in this context.
recovered through any constant periodic or lump sum charge. While most of the other elements of the various charging modes do lend themselves to the recovery of marginal cost elements, a variety of analytic and policy issues have to be sorted out before any clear guidelines emerge as to the efficient and equitable avenue of recoupment of scarcity value once it is recognized.

If user charges are intended to recoup scarcity value, they would be paid by existing residents who make up the bulk of the consumers at any point in time. This would be appropriate if extensive growth of the community were limited for whatever reason, and any prospective growth could come only from more intensive use by existing users or residents. If the scarcity value is recouped only through development charges, then only new residents or "club" entrants would bear the incremental cost. Or the recoupment mode could be split between user charges and development charges so that existing residents and new residents would each pay a pro rata share as a function of the relative prospective use by each group of users, thus reflecting their relative responsibility for drawdowns of the scarce resource in question. The link between the nature and/or cause of the scarcity value on the one hand, and means and situs of recoupment forces a comprehensive review of the issues involved.

B. Landowners vs. New Users as Payors of Development Charges

One other relevant issue deserves some comment even if it cannot be resolved in the space available. This concerns the possibility that the early owners of the land being developed may bear the development charges or impact fees as these charges are capitalized into lower land values; i.e., the charges are paid out of land rents. In this pure backward
shifting case neither the existing nor new users in the community would bear the development charge; it would fall primarily on the predevelopment land owner. The revenue of the government will go up regardless of the ultimate incidence of the charge and many would feel that both equity and efficiency was enhanced; capturing such economic rents is one of the most efficient, least distorting means of financing government.

In view of the uncertainties about the supply elasticities of developable urban land and about the nature and degree of capitalization in such cases it is difficult to predict the general financing role of land owners that will result from a particular development charge regime. Moreover, some would argue that efficiency would be enhanced if the full cost of the good or service being supplied were internalized into prices confronting the ultimate user. However, if one wanted to enhance the likelihood that any development charge would be borne by early landowners, the development charge should be certain, predictable and well anticipated by all.

C. Cost Nexus

This cost and attribution issue becomes very important in the context of Supreme Court decisions that require a close nexus between attributable costs of a new development, and the magnitude and incidence of the development charge. e.g., see Nollan vs. California Costal Commission, 1987. If scarcity value were ever accepted by the courts as a legitimate cost, it would be easier for local governments to augment development charges so that they became a viable source of revenue. Regardless of what was done with the new revenue from more complete development charges (i.e., either put in a sinking fund to finance the
new higher cost technology when it arrived, or used to finance infrastructure required by the development) the higher revenue available to the local government would help to redress budgetary difficulties.\(^\text{11}\)

D. Relation to Demand

It is conceivable and perhaps desirable that the increment in user and/or development charges is significant enough relative to the demand situation that demand growth would be restricted. This would be the case if the number of new houses were reduced and/or less water intensive apartments or townhouses were substituted for single detached houses. The resulting savings in expenditures will help the local government budget as much as an increase in revenue. However this desired outcome does lead to a difficulty in precise costing of the scarcity value. The movement forward in time for the change in technology or location may require re-estimation of the time frame over which the low cost resource is expected to dissipate, thus possibly requiring a re-estimate of the relevant scarcity value at different points in time. Underlying changes in costs and demand may tend to require changes in the precise scarcity value relevant at any point in time even though there is always some positive scarcity value in particular cases.

However, even if the demand elasticity is low enough so that incorporation of the scarcity value in the price does not significantly affect growth of demand or use, the imposition of scarcity value in the price is still economically valid. The government involved

\(^{11}\)On the one hand this assumes that maximum willingness to pay or tax/user charge tolerance level was not being violated in the context of the perceived value of services being provided. On the other hand it assumes that local government does not view the enhanced revenues as a windfall that can be used in some wasteful manner.
will both a) get more revenue and b) moreover get it from members of the community responsible for the increase in costs and government expenditures; cross subsidies among users would be avoided or minimized.

V. Conclusion

As the budgeting problems facing subnational governments increase, more attention should be given to the rationalization and augmentation of user and development charges. This paper has provided a rationale along with the means for recognizing and estimating scarcity value, virtually always overlooked in the administrative price setting procedure typical of government entities.12 Scarcity value is not always relevant or significant as a cost element or dimension. But there is a strong enough possibility of its significance and relevance that both analysts and policy makers should give more attention to the scarcity value dimension of costs and prices.

If present political and legal hurdles can be overcome the endemic undercosting might be reversed. Assuming more complete and correct costing results in higher user charges or development charges, more revenue would become available to the governments involved. And under most permutations of charge design and context, both equity and efficiency would be enhanced by local governments recognizing and recouping scarcity value where it is relevant.

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12 If the government is using some market determined price as a guide, scarcity value may be reflected since scarcity value is usually included in private sector market prices for traded natural resources. This may be the case when the government sells in-situ petroleum or timber reserves.
APPENDIX A

DISTINCTION BETWEEN SCARCITY RENT AND RICARDIAN RENT

For the sake of expositional clarity, it is useful to briefly address the distinction between scarcity rent and Ricardian rent in this context. In the quantity dimension, scarcity rent unambiguously pertains to the marginal unit of output or source while a Ricardian rent can never be earned on the marginal unit; Ricardian rent characteristics pertain only to submarginal units. Scarcity rent, however, carries over to submarginal units as well. Thus, in the stylized scarcity situation used in this paper, the efficiency price of submarginal units may include both scarcity rents and Ricardian rents.

The underlying economic rationale can be facilitated by use of Figure A1. This is the same stylized scarcity situation as used in the main body of the paper except that quantity is on the horizontal axis rather than time as in the previous figures. This transformation or linkage between time of use and quantity (source) being used is valid under the assumptions made explicit earlier: demand grows overtime in projected quantity with zero price elasticity. In terms of Figure A1 this means that it is anticipated that \( q_x \) amount of water (or \( q_{x} \) incremental source) will be used at \( t_x \), while \( q_y \) amount of water (or \( q_{y} \) incremental source) will be used at \( t_y \).

As discussed before, at time \( t_y \), the correct efficiency price is \( O_h \), consisting of \( OC_1 \) marginal cost, and \( C_1 h \) ( = \( \phi \) in our earlier notation) scarcity premium. This pertains technically only to the marginal unit of water provided; however, any unit can be considered as the marginal unit. At any point in time the use of any unit of water including a
submarginal unit will push the system closer to the time the higher cost source has to be resorted to. Thus, across quantity the efficiency price on the marginal unit or last source supplied defines the umbrella price for all submarginal units or earlier sources of water being used, regardless of when that particular source was brought on stream or regardless of the scarcity value when this submarginal unit was marginal.

At $t_y$ (quantity $q_y$), the efficiency price $Oh$ applies to all units or sources, marginal or submarginal. For a submarginal unit, say $q_m$, $Oh$ can be viewed as having three components:

1. The marginal extraction cost $q_n$ in Figure A1.

2. Scarcity value, $nr$, which is still relevant for that source, even though it is now submarginal. This amount can be viewed as the annual royalty payment which the purchaser of the $q_m$ source committed himself to pay each year commensurate with the scarcity value in year $t_x$ when the then marginal source $q_m$ was purchased.

3) Ricardian rent, $rp$, i.e., the premium recoupable by a more productive, lower cost source once higher cost sources have been utilized. This pertains even if the higher cost is due to higher scarcity value.
### Table 1
EFFICIENCY PRICE, COSTS AND IN SITU VALUES

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<td>16</td>
<td>1.18</td>
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<tr>
<td>17</td>
<td>1.20</td>
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<td>18</td>
<td>1.22</td>
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<td>19</td>
<td>1.23</td>
</tr>
<tr>
<td>20</td>
<td>1.25</td>
</tr>
</tbody>
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Note: Discount rate $r = 0.02$. All values in dollars per thousand gallons. Extraction cost is equation (1). Note also that $\delta_t$ becomes zero after $t = 20$. 


Fig. 1--Demand and Extraction Cost

Marginal Cost ($)
Fig. 2--Efficiency Price, Extraction Cost and Scarcity Value
Fig. A1--Rents: Scarcity & Ricardian

Marginal Cost ($)

\[ C_T \]

\[ h \]

\[ m \]

\[ C_1 \]

\[ j \]

\[ n \]

\[ k \]

\[ a \]

[ ]

\[ a \]

\[ b \]

\[ d \]

Quantity

\[ q_x \]

\[ q_y \]

Time

\[ t_x \]

\[ t_y \]
References


