Hyperbolic discounting in analyzing investment in groundwater irrigation in India

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Abstract

Considering the associated risks and uncertainties in agriculture in general and in groundwater irrigation in particular, financial institutions can adopt hyperbolic discounting method to compute the dues in long term groundwater irrigation loans including agriculture loans. This will reduce the loan burden on farmer borrowers and serve the purpose of equity. While amortizing investment on irrigation wells, resource economists need to consider a realistic nominal rate of interest, which is around 3 to 6 percent. However the real interest rate is negative ranging from –0.17 percent to –2.50 percent. Natural resource economists valuing contribution of groundwater irrigation on farms irrigated by wells need to use a realistic interest rate of around 2 percent considering the intergenerational equity and sustainability in groundwater use.

JEL Codes: D9, Q25, M4

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Preamble

Financial institutions have been charging simple interest rate on regular agricultural borrowings. However, when borrowers default, they are charged the compound (exponential) interest. Due to recurrent droughts in agriculture, default has been a rule than an exception. Thus, farmers are put to financial stress in addition to drought. The 'exponential' discounting overestimates the interest payable by borrowers due to the exponential growth. In addition here, the 'interest rate' used is subsumed to incorporate (i) opportunity cost of capital, (ii) uncertainty in investment and (iii) intensity of time preference. However, the 'hyperbolic' discounting separately incorporates the intensity of time preference.

This article has two purposes: (a) to analyze the differences in loan repayment using exponential and hyperbolic discounting for groundwater irrigation to financial institutions and (b) to compute the real rate of interest on investment per irrigation well.

Hyperbolic discounting

Hyperbolic discounting was first used by psychologists (Chung and Herrnestein, 1967) to characterize animal behavior and later applied to humans. Others used hyperbolic discounting to intergenerational utility flows and for intra personal utility flows (Laibson, 1996). Researchers are finding that discounting is more like hyperbolic than an exponential function. For instance, if a farmer is offered choice of choosing between Rs. 500 right now and Rs. 700, a year from now. Most likely that farmer chooses Rs. 500 right now, since money right now is worth more than money in future. This is 'exponential' discounting. If farmer is offered choice of choosing between Rs. 500 in 5 years from now or Rs. 700 in six years from now, then, most likely that farmer prefers Rs. 700 in six years from now, because farmer would have already spent 5 years any way and for an additional one year, s/he gets Rs. 200 extra. This is 'hyperbolic' discounting. This difference between exponential and hyperbolic discount rate is due to dynamic inconsistency as demonstrated above.

Hyperbolic discount function is characterized by high discount rate over short time horizon and a relatively low discount rate over long horizons. From today's perspective, the discount rate between two far off periods 't' and 't+1', is a long-term low discount rate. From the perspective of time t, the discount rate between 't' and 't+1' is a short-term high discount rate. Thus, if borrowers are 'hyperbolic', (i) they prefer low levels of liquid wealth, (ii) indulge in frequent credit card borrowing, (iii) consumption and income co-move, (iv) consumption drops at retirement.

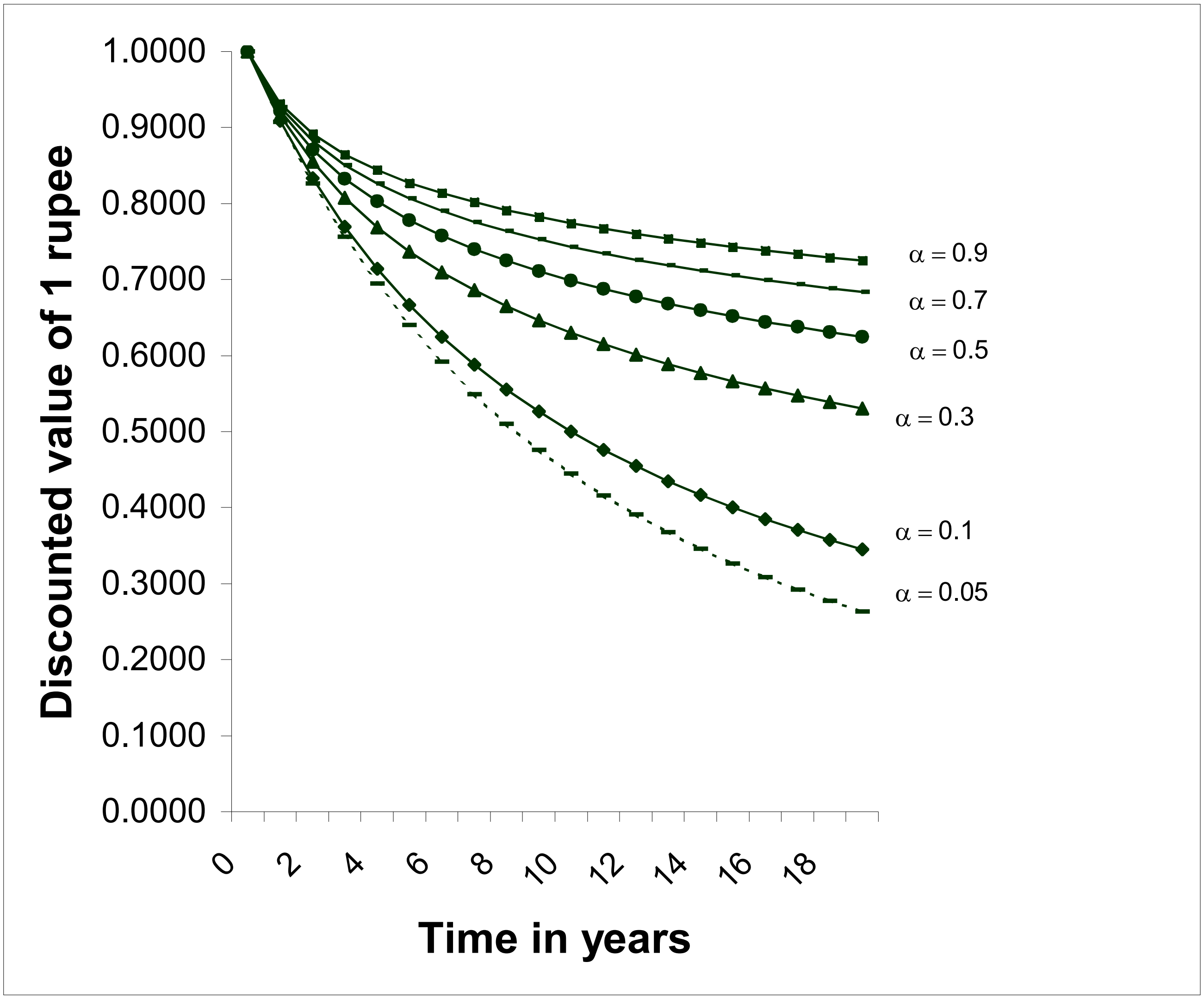
Hyperbolic discounting is a declining function, where the degree of discounting is inversely proportional to time qualified by degree of time preference, as given in:

$\text{Present value}_t = \text{Future value} / [1 + \alpha t]^{(r/\alpha)}$ Where t = time, r = interest rate and α = intensity of time preference, varying between 0 and 1, with 0 representing low or no time preference and 1 representing high time preference. As time t is not exponential expression in 'hyperbolic' discounting, the degree of discounting (compounding) in 'hyperbolic' is lower than 'exponential' method. Here, the higher the value of α, lower is the difference between the discounted values obtained in the near and distant future. The lower the value of α, wider is the difference between discounted values obtained in the near and distant future. Due to hyperbolic discounting the present values fall less drastically compared to exponential discounting as the interest rate is weighted by alpha, the parameter, indicating degree of time preference. Hyperbolic discounting provides smoothened cash flows (Table 1 and Fig 1). The exponential discounting is as usual given by $\text{Present value}_t = \text{Future value} / [1 + r]^t$

Table 1: Hyperbolic discount functions under varying values of intensity of time preference 'α' (at r =10percent)

Time 't' in years	Hyperbolic discount value of Re 1 at r = 0.1 and		Hyperbolic discount value of Re 1 at r = 0.1 and		Hyperbolic discount value of Re 1 at r = 0.1 and	
	α =0.05	α =0.1	α = 0.3	α =0. 5	α =0. 7	α =0. 9
0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1	0.9070	0.9091	0.9163	0.9221	0.9270	0.9312
2	0.8264	0.8333	0.8550	0.8706	0.8824	0.8919
3	0.7561	0.7692	0.8074	0.8326	0.8508	0.8647
4	0.6944	0.7143	0.7689	0.8027	0.8264	0.8440
5	0.6400	0.6667	0.7368	0.7784	0.8066	0.8274
6	0.5917	0.6250	0.7095	0.7579	0.7902	0.8136
7	0.5487	0.5882	0.6858	0.7402	0.7760	0.8018
8	0.5102	0.5556	0.6650	0.7248	0.7637	0.7915
9	0.4756	0.5263	0.6465	0.7111	0.7528	0.7824
10	0.4444	0.5000	0.6300	0.6988	0.7430	0.7743
11	0.4162	0.4762	0.6150	0.6877	0.7341	0.7669
12	0.3906	0.4545	0.6013	0.6776	0.7261	0.7602
13	0.3673	0.4348	0.5888	0.6683	0.7187	0.7540
14	0.3460	0.4167	0.5772	0.6598	0.7118	0.7483
15	0.3265	0.4000	0.5665	0.6518	0.7055	0.7429
16	0.3086	0.3846	0.5566	0.6444	0.6995	0.7380
17	0.2922	0.3704	0.5473	0.6375	0.6940	0.7334
18	0.2770	0.3571	0.5386	0.6310	0.6888	0.7290
19	0.2630	0.3448	0.5304	0.6248	0.6838	0.7249

Figure 1: Hyperbolic discount function under varying levels of α
(r =10 percent)



<u>Comparison of loan repayment amount according to 'simple' 'exponential' and hyperbolic' interest rates.</u>

In Eastern Dry agro climatic Zone of Karnataka, in 2000, sample farmers borrowed an average of Rs. 75,095 from financial institution to drill irrigation bore well, 430 feet deep, and installed a 12 HP/12 stage submersible pump set. This irrigated around 3.8 acres. The financial institution charged an interest rate of 9 percent for a repayment period of 10 years. As this is an agricultural loan, the total repayment on simple interest rate basis amounts to Rs. 1,42,680 (Table 2, Table 3).

Table 2: Total repayment due on irrigation well loan, from financial institution on the basis of simple interest, compound interest and hyperbolic interest

Sl. No	**Dry agroclimatic zones of Karnataka**	**Total repayment due on simple interest basis**	**Total repayment due on 'exponential' or compound interest basis**	**Total amount due on 'Hyperbolic' interest basis**		
				α **= 0.1**	α **= 0.5**	α **= 0.9**
1	Northern	101608	126602	99793	73831	67324
2	Central	85500	106531	83973	62126	56652
3	Eastern	142680	177777	140132	103676	94539

However, as farmers usually are unable to repay the loan in time due to groundwater overdraft and associated scarcity factors, the repayment will no longer be on simple interest basis due to default. Thus, the repayment will then be based on 'exponential' or 'compound' interest basis at which the total repayment works to Rs 1,77,777. This substantially increases the burden on farmer due to compounding process.

However, using the hyperbolic basis, for 10 years, at 9 percent, for $\alpha = 0.9$, the total repayment amounts to Rs. 94,539, while it amounts to Rs. 1,40,132, for $\alpha = 0.1$. Thus, weighting the interest rate by intensity of time preference in computing repayment amount will benefit farmers in hyperbolic basis. In addition, irrespective of the value of α, the intensity of time preference, the hyperbolic basis repayment will be lower than even the 'simple interest' basis, *ceteris paribus* the discount rate and the period t of repayment.

The purpose of 'hyperbolic' basis of discounting is to reflect the reality of the future / present valuation of long term lending to irrigation, where in by accommodating the intensity of time preference, the future value is allowed to oscillate in a narrow plausible range, unlike exponential discounting, where future values not only range widely but are also unrealistic. Thus, by adopting 'hyperbolic' basis, financial institutions lending at least for agriculture purposes will have adopted a procedure, which is equitable for farmers to invest in agriculture.

Choice of discount rate in resource economics analysis

Researchers are often confronted with the choice of discount rate as well as the method of discounting for estimating the amortized cost of long-term investment in agriculture including groundwater irrigation. The obvious choice is to use the opportunity cost of capital, which is the prevailing interest rate of around 9 percent (compounded – exponential basis), charged on long-term agriculture loans. However, using the 'exponential' basis does not provide a realistic amortized cost of irrigation as it over estimates the value of investment due to 'exponential' basis as demonstrated above. In order to obtain an empirical estimate of this interest rate, using field data from farmers three dry agro-climatic zones of Karnataka (Shamsundar (1996), Sripadmini (2001), Chaitra (2002), Rajendra (2003)) nominal investment per irrigation well is considered (Table 3). The nominal investments were deflated using the index number of wholesale prices (1993-94 base year).

Considering nominal and real growth in investment per irrigation well between the 1980's and 2000's in the three agro-climatic zones of Karnataka, using the exponential discounting, the nominal investment per well is found to be increasing between 3.7 and 5.7 percent. This shows that the amortization of groundwater investment cannot exceed say six percent. The real (exponential rate of) interest is computed by deflating the initial year investment and the terminal year investment per irrigation well using the 1993-94 as base all India wholesale price index numbers. It is found that in real terms the investment per well is falling between –2.5 percent and –0.17 percent.(Table 3). The fall in real investment is due to increased competition by rig owners in offering almost uniform rate of drilling over the years in several aquifers of Karnataka. For instance the price of drilling has been between Rs. 35 and Rs. 50 per feet between 1985 and 2005 for shallow bore wells. The phenomenon may not be very different in other states of peninsular India. A comparison of nominal investment in terminal year and the estimated cost of well in 2005 indicates that in EASTREN DRY ZONE the nominal interest rate is 3.7 percent, the real interest rate is –0.17 percent and the investment per well in 2002 (terminal year) being Rs. 53,478 and in 2005 (current year) being Rs. 59578 are comparable. But in CENTRAL DRY ZONE, while the nominal investment per well in 2000 is Rs. 45,000, the estimated investment in 2005 is Rs. 59,193, which is an unrealistically high exponential growth obtained by compounding the initial investment of Rs. 18,480 from 1984 to 2005. Similarly in EASTREN DRY ZONE, while the actual investment per well in 2000 is Rs. 75,095, the estimated investment per well in 2005 works to Rs. 97,702, which is again unrealistic.

As the real interest rate is negative in irrigation wells, this could be one of the reasons for mushrooming of irrigation wells in Karnataka, since this makes investment affordable across different classes of farmers. Thus this analysis has two messages. One, that the nominal interest rate which has to be considered for amortizing investment on irrigation well can be around 3 to 6 percent, and that the real investment per well is falling.

Table 3: Nominal and Real investment per irrigation well in different agro-climatic zones of Karnataka

Zones	**Investment per Irrigation Well**				**Nominal interest rate** **(Percent)**	**Real interest rate ***** **(Percent)**	**Estimated cost of irrigation well in 2005 at nominal interest rate# (Rs)**
	Initial year and wholesale price index number in parentheses	**Nominal (actual) Investment in initial year (Rs)***	**Terminal year and wholesale price index number in parentheses**	**Nominal (actual) investment in terminal year (Rs)**			
Northern Dry Zone (NORTHERN DRY ZONE) (Dug well)	1982 (38.71)	25833	2002 (161.2)	53478	3.7	-0.17	59578
Central Dry Zone (CENTRAL DRY ZONE) (Bore well)	1984 (43.63)	18480	2000 (150.9)	45000	5.7	-2.17	59193
Eastern Dry Zone (EASTREN DRY ZONE) (Bore well)	1985 (44.99)	32857	2000 (150.9)	75095	5.6	-2.5	97702

Note: *: Nominal investment refers to cost of well including accessories

**: Nominal interest rate refers to the estimated exponential interest rate using nominal investment per well between initial and terminal years

***: Real interest rate refers to the estimated exponential interest rate using deflated nominal investment per well between initial and terminal years using index numbers of wholesale prices with 1993-94 base.

#: Estimated cost of well in 2005 is the nominal investment per well in the initial year compounded in 2005 (using exponential interest rate)

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