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*SOME SIMPLE GUANO ECONOMICS: CONCEPTUAL PROBLEMS
IN NATURAL RESOURCE ACCOUNTING*

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Abstract

Natural Resource Accounting - adjusting the national accounts to reflect changes in resource stocks and environmental quality - is regularly proposed as a productive way of incorporating environmental concerns into the everyday practice of economics. However, as well as fairly considerable problems of measurement, there are conceptual issues regarding NRA still being debated.

When considering NRA, it is useful to distinguish between changes in environmental quality, changes in stocks of renewable resources, and changes in stocks of exhaustible resources. The discussion in this paper focuses on the last of these. Whereas for environmental goods, there is a current choice between use *in situ* and "extraction" for consumption purposes, with exhaustible resources there is generally only an intertemporal consumption choice i.e. extract now or later. The relevant question is then: What is added to the discussion by labelling such depletion "depreciation", and how should it be measured?

From here, we can investigate how NRA might affect depletion decisions. Some preliminary, and perhaps surprising, results along these lines are contained in this paper.

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Introduction

Natural Resource Accounting (NRA) refers to the adjustments to current national accounting systems which would reflect the changes in resource stocks and environmental quality which have contributed to the aggregate income flows which are conventionally measured and published, in line with the existing System of National Accounts as designed by the United Nations. The usual reason for advocating NRA is that existing published aggregates neglect important environmental considerations, those aggregates conventionally measured in the national accounts (the usual components of national income) are regarded as at least a proxy for national or per capita well being in a country, and yet those levels of income are often being sustained by depletion of resources or environmental degradation or both. It is then argued that the misleading figures produced in the absence of NRA are used as the basis for the design of a variety of public policies, both macro and microeconomic, and that economic policies can only be as good as the information used in their formulation.¹

As an extreme example, think of what I will call a "guano economy", which will refer to a small economy which lives off its rich but finite endowments of a single natural resource.² If the guano economy indulges itself, it will consume all the earnings from its resource sales and thus by conventional accounting measures, it will have a high national income and by association, a high apparent standard of living *but* this will be purely a result of an accounting system which does not incorporate the fact that the inhabitants of

* The author thanks, with the usual caveat, Dave Aiden and Stuart Harris for helpful discussions concerning this material.

¹ For general discussions of the principles of NRA, see Repetto (1988), Repetto et al (1989), and Common (1990).

² Although no particular similarity is implied, the island economy of Nauru, which produces phosphate from its considerable guano deposits, is the inspiration for the term "guano economy". In all other respects (as they say at the start of novels), the characters and events in this work are entirely fictitious.

this country are mortgaging their future by running down their resource base. It is argued that by incorporating NRA principles into the system of national accounts, the national product net of depreciation will be much lower (in fact, as we shall soon see, it is likely to be zero), which will demonstrate that the current standard of living is actually being enjoyed on borrowed time.

An interesting question to contemplate in passing is, exactly who is this information being provided for? If the rate of depletion is very high, and the depletion decisions are being made by the ruling despot of the guano economy, presumably the despot knows that the resource base is rapidly being depleted. In such circumstances, adjusting the national accounts for "depreciation" of the resource base is going to tell the despot nothing he or she does not already know! However, citizens of the guano economy may be less well informed about the impending end of the good life, and NRA-adjusted figures may play a vital role in informing the *public*, as opposed to just the policy-makers, that the current exploitation of the asset base is imprudent. If the public is better informed about the rate, and consequences, of the resource erosion, pressure can be brought to bear to mitigate such myopic behaviour.

This reasoning presumes that a selfish and short-sighted despot is responsible for the depletion decisions, rather than an "enlightened", forward-looking one. But one of the questions that will be addressed below is, what if the policy-maker or ruling despot is directly interested in the information provided by "greened" national accounts? What signals are sent to decision-makers by taking resource depletion (literally) into account? To the best of my knowledge, this is a neglected question - the assumption seems to be that by utilising NRA, economic policies generally, and depletion policy specifically, will become more or less "efficient" relative to policies based on unadjusted national income figures. We explore this below, and find that it may not be true at all.

By focusing on a guano economy, we will be ignoring a number of complicating factors. The only natural resource of concern here will be the depletable (non-regenerating) stock available to the economy. Although some of the foregoing analysis may be generalisable to the case where a resource

is renewable, we will stick with the non-renewable case. Furthermore, there is no discussion here of resources or environmental assets which have alternative *in situ* values. In most relevant cases, exhaustible resources only contribute to utility when extracted and used in consumption or production. Where environmental amenities have value both as inputs to production (including as waste sinks) and as "consumption goods" in their natural state, there is a balance to be struck daily between alternative uses for such resources; but in the case we will be examining, there is only an *intertemporal* question to consider. There is no alternative to use today, except use some time in the future. Thus when accounting for resource usage today, we are therefore only interested in its value if stored until later.

Accounting for Exhaustible Resources

To understand the basics of how to incorporate exhaustible resources into NRA, one needs to understand the basic notion of efficient resource depletion as initially developed by Hotelling (1931). This is most easily expressed as an asset arbitrage condition, as follows (an excellent intuitive treatment can be found in Solow 1974). The stock of the resource is simply an asset like any other, and in equilibrium it should yield a rate of return to its owner equivalent to that accruing to any other asset (ignoring risk differentials). Many assets yield their total returns as a combination of current dividend and accrued capital gain. However, a resource stock yields no current income from being held, and so must instead yield a capital gain equal to the prevailing rate of return, otherwise the resource owner would be well advised to sell and invest elsewhere.

This simple condition defines the path of depletion which an exhaustible resource will follow to satisfy equilibrium: deplete at such a rate as to cause the resource price to appreciate at the market interest rate. To find *which* appreciating price path to follow, the condition is that the initial price should be chosen so that, after rising at the rate of interest, it hits the "choke price" just as the reserves of the resource are exhausted. The choke price is the price at which some "backstop technology" becomes viable, or, if no such backstop exists, the price at which the demand for the resource falls to zero.

Of course, fluctuations in demand, new discoveries of reserves, new technologies etc. will lead to changes in the depletion path and its associated price path, but the logic of the Hotelling path applies throughout.

So, if we use the reasoning that resource depletion is tantamount to "depreciation" of the natural asset base, we can use the Hotelling principle to measure the *net effect* on national income of resource extraction along an efficient depletion path. The revenue, net of extraction costs, from current sales of the units of the resource extracted today will be measured as income and included in today's GDP. The depreciation is simply going to be the present value of the future sales of those units, *had they been extracted and sold later*. Since, at the margin, a unit of the resource can be either sold today at today's price, or else sold later at today's price appreciated up by a discount factor, then the present value of a unit sold in the future is just equal to the current (net) price! So, as is pointed out by Dasgupta (1990) and El Serafy (1989), a guano economy depleting its resources "optimally", consuming all the proceeds, and producing nothing else will have a measured NDP of zero (albeit with a positive GDP which counts the receipts from the resource sales but ignores the depreciation). Some more detail on the depreciation approach to accounting for exhaustible resource depletion is contained in Repetto et al (1989).

As an aside, El Serafy (1989) has criticised the depreciation approach on two grounds, which relate to the net and gross income effects of resource extraction and sale. The first is that (as shown above) it implies that a resource-rich economy has a *net* income of zero which implies, implausibly, that it has no real advantage at all over a resource-poor economy. The second is that it implies the *gross* income accruing to the resource economy is equal to the entire receipts from the sale in that period, less the extraction costs, which El Serafy argues is an overstatement of the true sustainable income represented by the resource stock. He has proposed what he calls a "user cost" approach to accounting for resource depletion which, he suggests, overcomes both of these defects. Interested readers are referred to El Serafy (1989), as well as to the brief comparative discussion in ABS (1990). This paper will, however, concentrate on the depreciation approach.

More formal treatments of the theoretical issues underlying NRA, for a variety of resource types, are contained in Hartwick (1990) and Maler (1991). Both of these employ optimising frameworks to find the correct shadow price of resource consumption, although Maler assumes (perhaps "cheating" a little) that the extant resource stock contributes to utility in its natural state. However, many of the interesting questions about NRA arise in cases where resource use is, for some reason, "sub-optimal".

Depreciation, "Green" Accounts, and the Benevolent Despot

The simple guano economics I propose to discuss can best be illustrated using the most elementary guano economy that can be envisaged. Just about everything can be assumed to be known and constant (resource stock, demand conditions etc.); there are no extraction or transactions costs (including no costs to the environment from extraction); the resource is completely used in production (we could even assume that it is used purely as a consumption good, as long as there are no consumption benefits until the resource is extracted) so that no recycling or re-use is possible; there exists a backstop technology with a constant marginal cost of production; the economy is closed to international trade in the resource (we can relax this later); and we will ignore any reinvestment of proceeds of resource sales, although it does not especially matter either way to the following discussion.

We will also assume that the control of the guano depletion is entirely in control of the all-powerful leader of the guano economy. When it is useful to do so, we will regard this person as a textbook "benevolent despot", such that the despot will deplete the resource in the perceived best interests of the citizens of the economy. What will be interesting is how those interests will be perceived by the despot with and without NRA.³

The starting point of our discussion is that to employ the depreciation approach, the national accountant is likely to require accurate knowledge for

³ We will also be ignoring the question of whether there is any divergence between private and social discount rates.

at least, make an educated guess) about the future path of prices. In the case of our guano economy selling domestically, this means knowing the pattern of extraction over time. Consider first the example of depletion along the efficient Hotelling path. The accountant knows that the discounted future price is just the current price and makes calculations accordingly - as described above, with our simple assumptions, GDP is boosted by the receipts from resource sales, but NDP is left unchanged.

There remains, however, the question of what is to be done if the current rate of extraction is *not* compatible with Hotelling-efficient depletion. Here, it would seem to depend on the national accountant's awareness of where current depletion was in relation to efficient depletion, *and* their expectation of where actual depletion would go in the future relative to efficient depletion. For example, if depletion is currently faster than Hotelling-efficiency would dictate, then the resource price today will be below that along the efficient path, and sometime in the future, there will exist the possibility of the price going *above* the efficient price path as stocks are exhausted "prematurely". Of course, this possibility does not have to be taken advantage of - the despot may exhaust the resource as quickly as physically possible, getting a low price all the way along a short depletion path.

Let us now assume our despot is benevolent, and for the sake of argument, let us assume that this benevolence manifests itself as a desire to follow the guidelines of Hotelling and deplete so that the price rises at the prevailing interest rate. This is done at the behest of advisors who explain to the despot that this will ensure efficiency in asset markets, and thus maximise the value of the resource to society, and that this is good for the country. Just to make things interesting, we will further assume that the advisors (and the despot) understand Hotelling's argument better than they understand basic arithmetic, and they are incapable of determining the appropriate starting price and quantity which will ensure depletion just occurs when the resource price hits the backstop (or choke) price, $P(b)$.

This means we have three possible cases, along each of which the price rises at the interest rate. These are shown in Figure 1. The starting price may be below the "correct" $P(0)$, which we will label $P(e)$, and thus if the Hotelling

condition is scrupulously followed, exhaustion will occur earlier than the time T which characterises "efficient exhaustion". If the starting price is above $P(e)$, and an appreciating price path is followed, then the despot will eventually be in the awkward position of being left with surplus stocks of the resource when its price hits the choke price, above which it cannot rise. These stocks will have to be sold off at or below the price of the backstop. The third case, efficient depletion, lies between the other two.

For purposes of comparison, it is instructive to represent these price paths in present value terms, as is done in Figure 2. By definition, the discounted price stays constant along each of the Hotelling paths. In the "profligate" case, the present value of every unit sold is less than in the efficient case, and we can disregard it for the moment. The two other cases, efficient and "conservative", are more interesting to compare. The efficient path has the discounted price of $P(e)$, and stops at time T . The conservative path starts and continues at a higher price, until the date at which the choke price is hit. From that time, the discounted price must fall since the undiscounted price cannot rise above $P(b)$. In the case drawn, the remaining stocks are sold at $P(b)$, which means that at time T (if there are still stocks being sold), the discounted price is equal to $P(e)$.

It should be apparent that there is scope for increasing the present value of revenue by extracting along a conservative path. Up until the point at which $P(b)$ is reached, all the units sold earn a higher present value price than the same number of units sold along the efficient path. As well, the units which are then sold at price $P(b)$ up until time T will also earn a higher discounted price than those being sold under the efficient depletion plan, even though that price is falling. The last units sold after time T will earn less than $P(e)$.

Although this simple diagram alerts us to the possibility that a conservative extraction path can earn higher rents, we cannot use it to determine the path which maximises rents in present value terms. Not only do we have no way of knowing the quantities associated with any point on the price paths illustrated - we can only see the price *per unit*, not total revenues, at any point in time - but the rent-maximising path will not follow Hotelling behaviour, at least not in prices. Instead, it is *marginal revenues* (given zero extraction costs) which

will appreciate at the discount rate, and the resource price will appreciate at *less than* the discount rate, making the most profitable path flatter than the conservative path drawn. Notwithstanding all of this, the fact that the diagram makes clear that prices can be held up for an extended time suggests that the efficient path does not maximise discounted receipts.⁴

On reflection, this is all hardly surprising - it is simply reflective of the fact that monopoly power can be exploited in resource markets, just as it can be elsewhere. Are there, however, any ramifications for NRA in our guano economy? Let us put this another way. Since using the depletion approach seems to necessitate knowing the optimal depletion path, what is the point of going to the trouble of calculating a whole set of adjusted accounts if the depletion path is already known. The possible circumstances which spring to mind where publishing NRA figures may fulfil a role is when the accountants know that the economy is off the efficient depletion path, and wish to alert either the despot, or the public at large.

Let us check the cases in turn. For the profligate case, we have just seen that it now matters whether the accountants know that depletion is too rapid for efficiency. If they do know this (which with our assumption, is just a matter of doing some elementary sums), then they know that with each period of profligate depletion, the efficient path for the *remaining* (reduced) stock is "pushed up", as shown in Figure 3. The marginal unit being sold today is worth more in present value terms if left in the ground, and the difference between these two values becomes greater the longer profligate extraction occurs. Thus the revenue being received today is less than the depreciation which that extraction results in, and the impact on NDP is *negative*, not zero, and if extraction continues following the profligate path, the negative impact will be increasing through time. This will serve as an alert to a benevolent despot, and certainly to the wider public, that slower depletion will increase the net benefits to society.⁵

⁴ What the efficient path does maximise is the sum of discounted surpluses.

⁵ Let us stretch our assumptions beyond the limits of plausibility for a moment, and assume that the national accountants are as capable of being fooled as the despot. This is a deliberately artificial thought experiment, but, as mentioned in Repetto et al (1989), using the present value method for depreciation is equivalent - assuming efficient H-telling depletion - to simply assessing the value of the remaining stocks at the present

Now we turn to the conservative case. The price starts at $P(c)$, rises to $P(b)$ as the conservative path is followed, and then (we will assume) stays there until exhaustion occurs.

Along a conservative depletion path, the higher unit price is going to be matched by larger remaining stock than would be the case with the efficient path, much of which will earn a discounted price of greater than $P(c)$, as was discussed above. Depending on just how conservative the path is, the impact of extraction on depreciation of the resource stock will be less than in the efficient case. Thus, current sales are balanced by reduced depreciation, meaning that the effect on NDP is *positive*. As argued above, this is just analogous to the accepted notion that a monopolistic resource owner can increase the present value of resource rents. Intuitively, the path that maximises the resource rents will be the same one which maximises the impact of resource depletion on NDP.⁶

All this information is summarised in Figure 4, which shows the NDP impacts resulting from alternative Hotelling-depletion paths which the despot of the guano economy could choose from. Excessively profligate paths have a negative NDP impact, reaching zero if the efficient path is followed (that is, the starting price is equal to $P(c)$), rising to the maximum positive impact on NDP when following the private monopolist's preferred path, declining again

price. Thus, if myopic accountants simply *presume* that depletion is currently efficient, without doing the sums to check whether the choke price will be reached by the exhaustion date, then they will continue to measure NDP as zero, quite incorrectly. This argument is a little far-fetched if we allow for complete certainty as we have been, but is perhaps more compelling once uncertainty is introduced. The fundamental point is that the calculated depreciation will depend on the assumptions made by the national accountants, and that depletion can be characterised as profligate or conservative in the accounts due to those assumptions rather than due to reality.

⁶ Just to confirm this, consider the case of extraction along some *extremely* conservative depletion path (which still follows the Hotelling rule, at least until $P(b)$ is reached). Early sales will attract very high unit prices, but only few units would be sold, meaning that sales revenues would be quite low. The remaining stock is very large, and the scope for the price to appreciate is limited - soon it will hit $P(b)$ and start to decline in discounted terms. If the initial price path is sufficiently conservative, the depreciation will be as much due to the price-depressing effects of low extraction, as of lower physical stocks. It should be clear that an extremely slow depletion path, low current sales revenues can be matched by lower depreciation, resulting in a *negative* impact on NDP.

as the chosen path becomes more conservative, eventually becoming negative again.

This seems reasonably intuitive, but is perhaps missed in many of the discussions of NRA which focus on depreciation under a competitive optimum. If our benevolent despot knew that the Hotelling rule of price appreciation was worth following, but used the adjusted national accounts (in particular, the impact of extraction on NDP) as the main guide as to how to deplete, this despot would behave more like a monopolistic resource firm rather than a competitive one. If the despot was not constrained to follow the Hotelling rule, then he or she would act basically just like a monopolist.

Summing Up

The key conclusions that arise from our analysis of a very simple guano economy are as follows.

1. Depletion which is excessively rapid or excessively slow can yield negative impacts on NDP. Efficient depletion has no effect on NDP, while there is a range of slower depletion paths which would increase NDP if followed. Also, zero impact of depletion on NDP need not imply that efficient depletion is occurring.⁷
2. A benevolent despot who wishes to exploit the resource so as to maximise the benefits to the citizens, and uses the NDP measure as a guide to the impact of resource depletion on the economy, will deplete more slowly than the "efficient" Hotelling depletion path - in fact, they would follow a monopolistic depletion path (Whether this does or does not maximise the benefits to the citizenry is discussed below.)

Some qualifying and clarifying comments are in order here. The idea of a benevolent despot was purely rhetorical, to allow us to work through these

⁷ In particular, zero impact on NDP can occur for two accurately perceived depletion paths, as in Figure 4, or, as argued in Footnote 5, due to a *misperception* of the depletion path.

examples. In particular, there is no reason to expect *any* policy-maker, with despotic powers or not, to make extraction decisions solely on the basis of the impact according to NRA. What the second conclusion suggests is that NRA may provide incentives for resource extraction that are even more "conservationist" than may have been expected by many advocates of NRA. If this reasoning is correct, then NRA may well be the greenie's best friend!

The international trade situation matters for our interpretation of the welfare effects of this conclusion. With no trade in the resource, in or out, then the despot controls supply and thus price over time. If the resource is monopolistically produced here (i.e. in the guano economy) and then sold overseas, conclusion two holds, but in such circumstances the despot inadvertently "gets it right". That is, if the entire stock of the resource over time were produced and sold domestically, using NRA gives the despot the "wrong" signals as to how to deplete the resource to maximise its value to the populace.⁸ But if the resource is to be sold overseas only, then it pays the country to act as a monopolist - exactly what NRA encourages. Matters are trickier if there are sales domestically *and* abroad. However, if the resource is also *produced* overseas competitively, then the despot has no influence over the resource price and the conclusions above do not go through.

Further discussion is needed concerning our rather literal conclusion from this simple model, about the incentives provided by NRA. The extent to which national income figures would actually affect extraction decisions would not only depend on the preferences of a public resource owner, but the degree of public ownership of key resources in the first place. Competitive resource industries will be driven by the forces of the market, irrespective of NRA unless that somehow galvanises political pressure. Monopolistic private resource-extracting firms will find that their profit maximising behaviour leads more or less by "accident" to rather flattering outcomes in the national

⁸ One more caveat is in order here. I have used the term 'efficient depletion' deliberately. The words *efficient* and *optimal* are often used in economics as completely interchangeable when they may have different meanings. Efficiency in this context means arbitrage opportunities in asset markets are being exploited, and the result of this is that discounted social surpluses are being maximised. To find the uniquely *optimal* depletion path, we would need to use an intertemporal social welfare function to judge the intra- and intertemporal distributional trade-offs involved. For discussions of this issue, see for example Citout (1981) and Howarth and Norgaard (1990).

accounts. These remarks are simply intended as a reminder, if one is needed, that some caution should be applied to these conclusions, especially the second.

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FIGURES

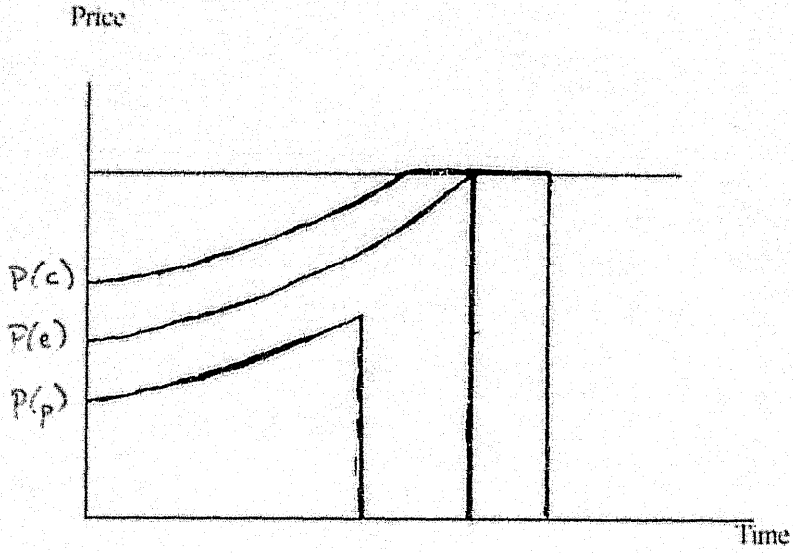


FIGURE 1

THREE (HOTELLING) PRICE PATHS

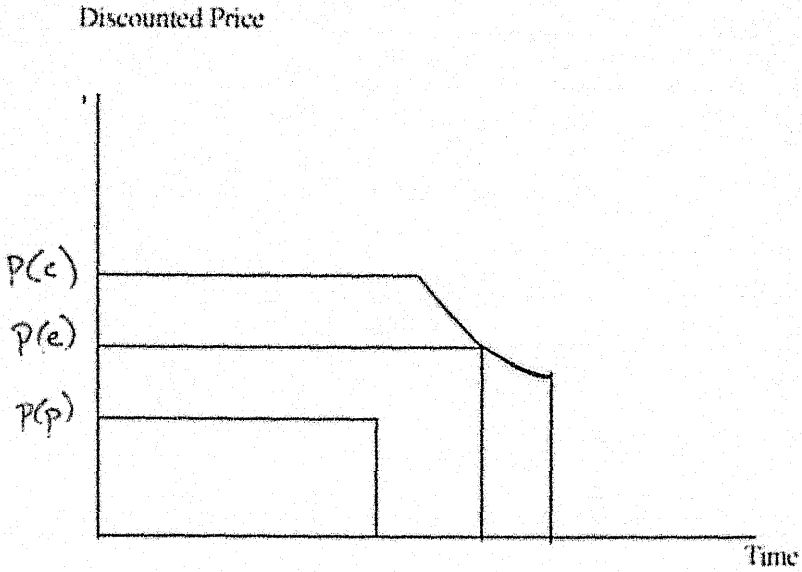


FIGURE 2

ABOVE PATHS USING PRESENT VALUE PRICES

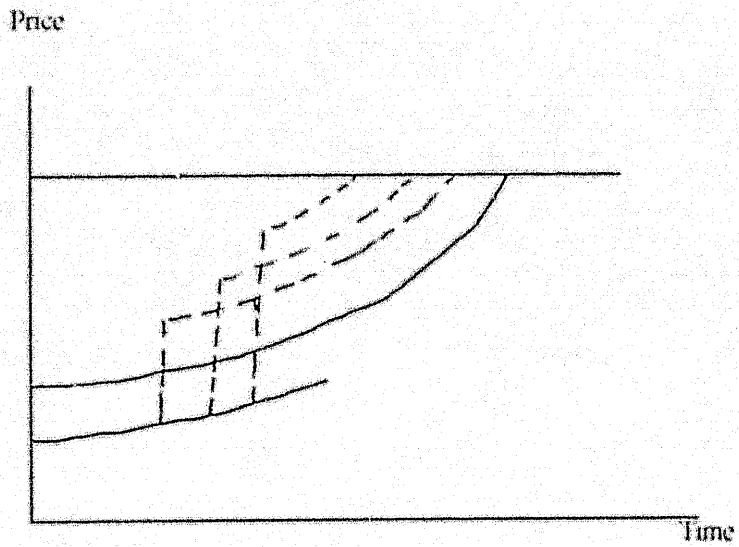


FIGURE 3

VARIOUS ADJUSTMENTS GIVEN PROFLIGATE DEPLETION

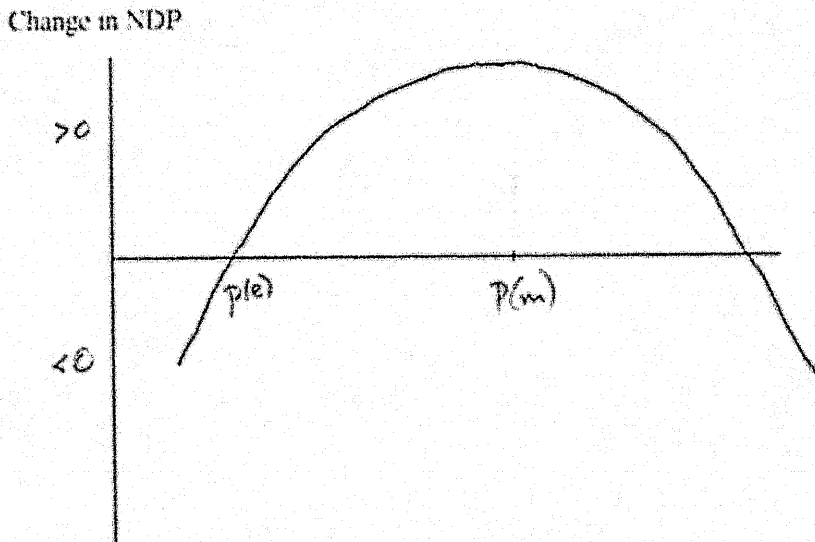


FIGURE 4

IMPACTS ON CURRENT NDP OF DIFFERENT STARTING PRICES