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Economics and Rational Conservation Policy

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Energy analysts have long been concerned with the apparently low level of energy-efficient investments and have suggested the presence of various market barriers and failures that hinder investment. The concept of a barrier as defined here is some force that is working against investment in energy-efficient technologies. Market failures, on the other hand, are failures of the competitive paradigm that lead to economically inefficient outcomes. Market barriers require no particular response on the part of government while market failures may call for some policy response.

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Many analysts have pointed to the apparently high discount rates used by investors to evaluate energy-efficient improvements as evidence of market failure. Studies such as Gates's indicate that investors routinely pass up investments with very high after-tax rates of return.[1] Studies in the economics literature appear to back up this finding. For example, Train cites studies that estimate discount rates on the order of 20 to 50% (or even higher).[2]

There are three explanations for the high discount rates that would follow from some market failure: risk, capital market imperfections and myopia. The high discount rates could reflect private risk that is non-diversifiable but which is socially diversifiable. In this case, the government could enact policies to spread risk in ways that individuals cannot. Lack of access to capital for investment could be alleviated by public lending programs. A lack of understanding of discounting might be rectified by an education campaign or by some subsidy to offset irrational intertemporal decision making. Below, I will discuss each of these explanations in some detail.

As a result of this empirical work, modelers have incorporated high hurdle rates for predicting the diffusion of new conservation technologies. For example, the LBL REM uses market discount rates ranging from 78 to 278% for model runs discussed in the technical support document that implemented standards for refrigerators and freezers as required by the National Appliance Energy Conservation Amendments of 1988.[3] Note that discount rates of this magnitude will yield conclusions that support the view that consumers are very slow to adopt new conservation technologies. Moreover, standards are likely to have a substantial impact on conservation in that they create minimal levels of conservation that all appliances must achieve, regardless of the level of conservation desired by consumers.[4]

Whether and why the hurdle rates are high is an important set of questions. What I will do in this paper is examine some of the common explanations and consider whether they are important factors in inhibiting conservation. I will then give a simple example of an option based explanation and discuss how modelers might fruitfully incorporate such a theory into their models. Finally, I discuss various policies toward conservation with an eye toward identifying the problems that require intervention.

Some commonly proposed explanations of high hurdle rates

As noted above, there are three common explanations of the high discount rates: that conservation investments are inherently risky and must earn a high risk adjusted rate of return; that capital market imperfections limit access to borrowing to invest in these technologies; and that investors have a downward biased estimate of the returns that they will receive from their investment in conservation. Let me discuss each in turn.

Risk

Recently, Sutherland argued that risk can explain the high discount rates that people apply to conservation investments.[5] He argues that 'household investments in a building shell, such as insulation or storm windows,

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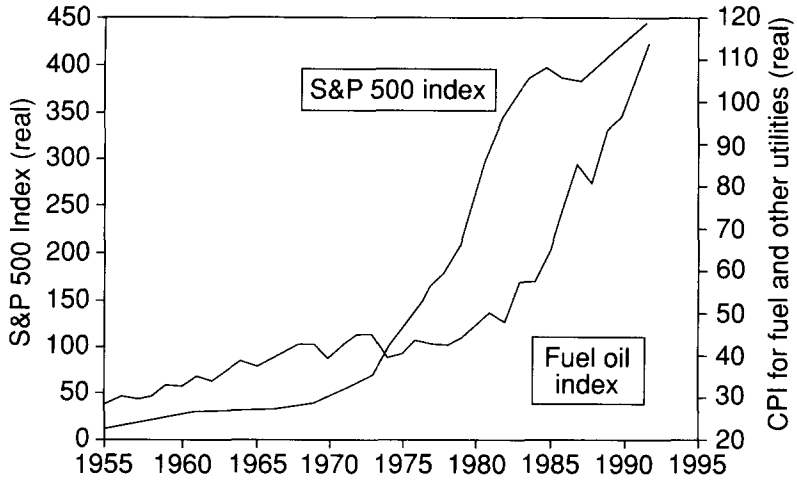

Figure 1. Fuel prices and the Stock Market.

have high transaction costs; they are illiquid, with essentially no marketability, and the payoff is risky' (p 28). He then goes on to state that households will require higher rates of return for these investments than for liquid securities held in diversified portfolios. Two issues are raised by Sutherland: liquidity and diversification. Let me return to the issue of liquidity as I think this is a relevant issue and will affect the required rate of return on the investment. Sutherland really focuses on the issue of diversification. For example, he writes, 'The household may not have a sufficient portfolio of earning assets to diversify away this risk' (p 29). This point is particularly aimed at low income households and serves as an explanation for Sutherland of the phenomenon of the inverse relationship between discount rates for energy-efficient technology and income.

There are two problems with this line of reasoning. First, the capital asset pricing model on which Sutherland bases his argument assumes that households can construct portfolios. Yet the risk that low income households face in Sutherland's analysis results from the inability to construct portfolios. More important, it is incorrect to argue that poor people do not have portfolios of assets. They are unlikely to have financial assets, but they do own automobiles and appliances and possibly their home. Moreover, their human capital (job specific skills) is an asset in their portfolio. We might argue that low income households are highly diversified with respect to energy-efficient appliances as their major asset is likely to be a gas guzzling automobile. A fuel-inefficient car is a near perfect hedge to an energy-efficient appliance.

More generally, purchasing energy-efficient appliances is likely to be a good hedge for anyone. The return to conservation investment is directly related to future energy prices. Energy prices, on the other hand, tend to be negatively correlated with stock returns. Figure 1 graphs the consumer price index for household fuel and other utilities (1982–84 = 100) and the Standard and Poor 500 Index (1941–43 = 10). Periods of rapid increases in energy prices are correlated with flat periods in the stock market.

This pattern is more evident when annual returns are graphed for the period 1956–91. The return is simply the percentage change in price from year to year. While the fuel price return is not equivalent to an annual return measure for conservation investments, it should serve as a rough proxy. What Figure 2 illustrates is the negative correlation between returns on the stock market and returns to energy holdings. The correlation equals −0.22 over the sample. We can also run a regression to compute the beta of the return on investments in energy prices. Beta measures the degree to which an asset's return moves with the stock market. An asset with a beta of one on average will go up (down) 1% for every 1% increase (decrease) in the stock market. Beta is formally defined as

$$\beta = \frac{\mathrm{Cov}(\textit{Excess stock return, excess market return})}{\mathrm{Var}(\textit{Excess market return})} \qquad (1)$$

where the excess return is defined as the difference between the actual return and a risk free rate of return (real). I use the return on three-month Treasury bills deflated by the *ex post* inflation rate for the risk free rate of return.[6] The estimate of beta from this regression is −0.12 with a standard error of 0.09. A negative beta

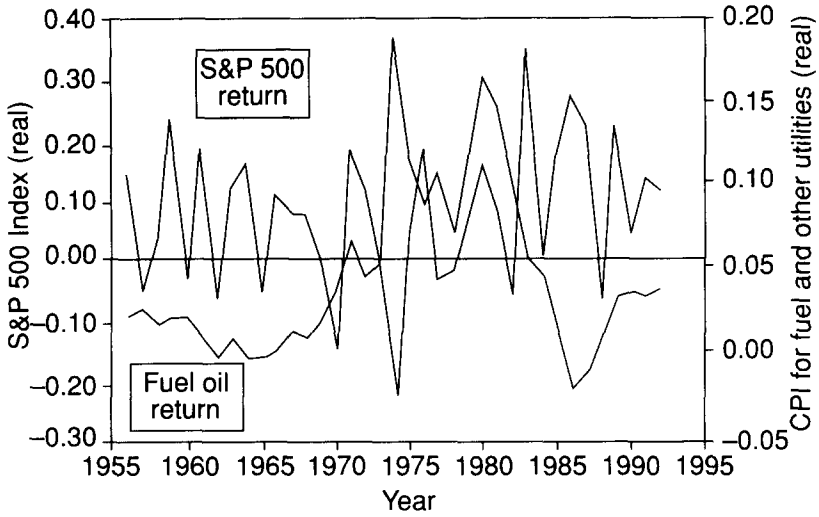

Figure 2. Returns on conservation versus the Stock Market.

indicates that investors should be willing to receive a lower rate of return on conservation investments than on market investments since this investment can be used to hedge the market. Thus a CAPM analysis indicates that hurdle rates should be lower than the market rate of return.[7]

Capital market imperfections

One important barrier facing potential investors in energy-efficient capital is a lack of access to credit markets (or access only at very high rates). While there may be some validity to this concern, it is hard to reconcile the very high discount rates cited in Train with this explanation. There are two problems with this theory. First, consumers often buy appliances such as refrigerators or air conditioners on credit. The additional cost of purchasing an increment of energy efficiency is minimal relative to the overall cost of the appliance. Once the consumer has made the decision to make a purchase, the appropriate discount rate for evaluating the amount of energy efficiency to purchase should be the cost of carrying the purchase – perhaps a nominal rate in the range of 18%. While not an insignificant rate, it is low relative to the hurdle rates estimated in the literature.

Early researchers have also found that discount rates tend to fall with income. Poor people appear to discount the future more heavily than do higher income people. This may suggest some market segmentation. Low income households may have more difficulty financing purchases than high income households and be forced to use expensive revolving debt. Note though, that researchers have estimated high discount rates across the income spectrum. Hausman, for example, has estimated a discount rate of 17% for households with income of roughly US$62 000 in current dollars.

Even if it is true that low income households employ a higher discount rate than high income households, we must be cautious before concluding that this implies a credit market failure. There is a provocative argument that rather than having high discount rates because they are poor, people may be poor because they have high discount rates. The point of the argument is that heterogeneity in discount rates can explain differences in human capital formation, savings behavior and ultimately the income distribution. Put simply, those with high discount rates will not invest in human capital or save and will be poor as a result. While this is by no means a proven thesis, it suggests that more work is needed in understanding the roots of poverty and the relation to investment propensities by different income groups.

Myopia

A third explanation is that consumers are simply short sighted and do not take account of the future benefits that they will receive upon investment in energy conservation. While there may be some element of truth to this argument, it is difficult to accept as the entire explanation. People make intertemporal trade offs all the time: should I buy a home or rent? Should I finish high school or college? To argue that people simply do not make intertemporal trade offs rationally is to beg the larger question of how they do make these decisions.

Moreover, non-rational decision making need not imply low rates of conservation. We could argue that people will be more easily swayed by claims of large energy savings resulting from conservation activities or that they may inappropriately perceive a short-term

energy price increase as a permanent increase and as a result overinvest in energy-efficient capital.

A preferable approach to assuming non-rational behavior is to ask whether there is a rational optimizing strategy that will explain what at first glance appears irrational. In previous papers I have argued that traditional estimates of discount rates overestimate the rate by ignoring the option value of associated with waiting to invest.[8] Let me discuss a simple example to illustrate.

An options based explanation for high discount rates

Consider an investor who is contemplating making an investment in conservation capital that will cost US$795. The return on the investment depends on the future price of energy. There is a 50-50 chance that energy prices will go up next year and stay at this higher level forever and that they will fall and stay at the lower level forever. If energy prices go up, the annual return on the investment will be US$120 while if they go down, the return will be US$40 per year. Assume the investor uses a discount rate of 10%. What should the investor do? One strategy is to compute the net present value of the investment today using the expected annual return of US$80. Assume the investment is put in today and begins providing reduced energy costs next year. The expected present discounted value of the energy savings equals US$800 and the net present value of this investment is positive. This looks like a good investment that should be undertaken today.

Alternatively, the investor could wait a year and see what future energy prices will be. If energy prices go up so that the annual return equals US$120, she could invest next year and receive a stream of returns equal to US$1200 in next year's dollars. The net present value in next year's dollars is US$1200 − 795 = US$405. In today's dollars, the net present value is 405/1.1 = US$368.

However, if energy prices go down, she should not invest. The net present value in next year's dollars is only US$400, less than the cost of the investment. The expected value of this strategy now is the average of the value conditional on investing (US$368) and the value conditional on not investing (US$0) or US$184. Waiting a year increases the net present value of this investment. The increase in net present value results from the ability to exercise the option not to invest once more information has been obtained about future returns.[9] This insight underlies the option pricing approach to investments. An important element of the theory is that the investment has high sunk costs: once it has been installed it cannot be taken out and resold. For many home conservation investments, this element of irreversibility is quite important. Blown-in wall insulation cannot be resold. To an outsider ignoring the option value of waiting and observing the decision not to invest in the first year, it would appear that the individual is using a discount rate that exceeds 10%. Put differently, ignoring option value leads to an upwardly biased estimate of the discount rate.

Moving to a more realistic model of energy conservation investment, we must modify the model while keeping two key elements. First, the returns to conservation investment are uncertain even if there is full information about the degree of saving arising from the investment. The return depends on future energy prices and future energy prices cannot be predicted with certainty. Second, there is an element of irreversibility (sunk costs) in the investment. As noted above, sunk costs will be a factor even for appliances with a resale market.[10]

To model this, let P_t equal energy prices and $R_t = dP_t$ be the annual value of energy savings from the investment. The factor d is the fraction of energy savings resulting from the investment. We will model energy prices (and thus the return) as stochastic and following a random walk in logs:

$$\ln IR_t = \ln IR_{t-1} + \varepsilon_t \tag{2}$$

If the price of the investment equals K_t, the net present value rule for investment (ignoring the option value approach described above) is to invest when the present discounted value of the returns exceeds the cost or

$$E_t \int_t^T R_s \exp(-rs) ds > K_t \tag{3}$$

If the return follows a random walk in logs and we assume that the investment lasts forever, then we can solve (3) for

$$\frac{R_t}{r} > K_t \tag{4}$$

where r is the hurdle rate net of the depreciation rate in the capital good.

It is from such relationships as in Equation (4) that researchers have estimated individual discount rates for conservation investments. We can add considerable complexity to the model – randomness in capital costs, or uncertainty over the expected life of the appliance. However, the essential estimation strategy follows from Equation (4).

Our simple example above, however, suggests that we are missing something from this rule. To the extent that the investment cannot be undone and the returns are uncertain, then the potential investor may wish to take a

more cautious approach. In fact, it can be shown that the correct benefit cost rule is to invest when

$$\frac{R_t}{r} = K_t(1 + w(\sigma)) \tag{5}$$

where s is the volatility of the return process and w is a function of the volatility with a positive first derivative.[11]

We have added a new cost of investment – the amount $K_t w(s)$. This cost represents the cost of exercising a financial option. Prior to making the purchase, the investor holds an option to make an investment (the energy-efficient appliance). Since the investment is irreversible, once the investment is made, the option is no longer available (the option has been killed). So long as the return on the investment is uncertain, the option has some value. Hence part of the cost of making the investment is the value of the option that is lost when the option is killed. It is easy to show that the option is more valuable the more variable are energy prices. This is consistent with option pricing principles in finance: the ability to exercise an option is more valuable if there is greater uncertainty over the future state of the world.

An econometrician observing investment behavior should use (5) to estimate the consumer's underlying discount rate. If the econometrician ignores the irreversible nature of the investment, then he will compute the discount rate on the basis of Equation (4). If r is the measured discount rate from Equation (4), this measured rate will be given by the formula

$$\rho = r(1 + w(\sigma)) > r \tag{6}$$

One interpretation of the high hurdle rates measured by researchers in the past is that they are measuring ρ rather than r.

Up to this point, we have focused on variation in the return to conservation. At the same time, there may be uncertainty over the cost of the investment and likely increases in the future energy efficiency of the investment. If there is some likelihood that insulation prices will fall in the future, this will increase the option value of waiting (anyone that has purchased a personal computer understands the value of waiting to purchase!). By the same token, if future technology will make the investment more efficient, it may be rational to delay investment. Refrigerator efficiency, for example, has increased at a rapid rate since the early 1970s. The average energy factor for refrigerators (the volume of space that can be cooled for one day by one kilowatt-hour of electricity) has grown at an annual rate of over 6% between 1972 and 1991 (see Metcalf and Rosenthal for details). This downward trend in capital costs (equivalently, greater efficiency) will increase w – that is, increase the adjusted required rate of return that must be earned before the investment should be made.

The policy implications of this model are straight forward. High observed discount rates are not evidence *per se* of a market failure and the need for government intervention. There is a clear role for economic research here. The option value explanation of high discount rates has a testable implication. Holding all else the same, increases in the volatility of the return to a conservation investment or its price should increase the measured discount rate in an econometric framework of the type described in Train. Along with Kevin Hassett, I am engaged in such an analysis at present.

Market failures, market barriers, and public policy

What are the appropriate government policies toward energy-efficient investment? The proper policy depends on what the problem is. While somewhat fatuous, this response is prompted by a sense that the goals and problems attendant to energy consumption are poorly defined. Calls for increased energy efficiency are motivated by (1) a concern for energy security; (2) negative externalities associated with energy consumption or production; and (3) an inability to measure the benefits of conservation, among other things. These different problems dictate different responses.

Energy security concerns follow from our vulnerability to disruptions in oil supply from the Middle East. Increased conservation is certainly one appropriate response. However, an explicit oil security policy would probably be more effective at diminishing our dependence on foreign energy suppliers. Note that the wrong policy would be to implement a tax on imported oil. When he served as a member of the Council of Economic Advisors under Ronald Reagan, Michael Mussa described this policy as the 'Drain America First' policy.[12]

Over the long run, this policy leads to greater vulnerability as we deplete our reserves of oil without creating replacements (either through other fuels or conservation). A better policy would be to import oil extensively while prices are low (thereby conserving domestic supplies) and at the same time develop a strategic petroleum reserve. During an oil crisis, the reserve could be used to minimize supply dislocations until domestic production could be increased. Note that one of the externalities created by dependence on foreign oil – US need to play a stabilizing role in the Middle East, with the resulting military expenditures – could be reduced.

Environmental externalities arise in several ways. Sulfur dioxide from dirty coal is of concern with respect

to acid rain. Global warming has become an increasing concern and may follow from our extensive use of fossil fuels. While subsidies to (or mandates for) conservation can reduce fossil fuel use, a more direct way to address the problem is a tax on the specific externality. A carbon tax, for example, would increase the price of oil and coal and lead to increased conservation. In addition, it would spur research and development for alternative energy sources that a conservation policy would not.

An inability to evaluate the benefits of energy-efficient investments can come from a couple of sources. First, people may have poor information about the magnitudes of savings that can be obtained from different investments. For example, it has been pointed out that people buy houses infrequently and have little experience at evaluating the energy they will consume upon buying a particular house or in determining the amount of energy savings they could obtain with different investments (eg additional ceiling insulation). The problem with this argument is that while individuals purchase houses infrequently, houses are sold quite frequently. Thus there is scope for a market in energy analysis and auditing to develop. Just as there is a thriving business in home inspections, there can easily be (and in fact is) a thriving business in energy audits. Currently low energy prices may be reducing the demand for these services but this is a market barrier, not a market failure. There is an informational problem though that might warrant some government role.

How are we to know if the energy auditor we hire is any good? A certification program – either by the government or by some nationally reputable organization – could screen out shoddy inspectors. Such a practice occurs for home inspections with certification by the American Society of Home Inspectors (ASHI).

For appliances, we have seen a move toward better and standardized information on the amount of energy savings in refrigerators, air conditioners and the like. This is a welcome development and can help in stimulating educated purchases of energy-efficient appliances. The difficulty with processing this information, however, is that future energy prices are uncertain – and thus so is the return to the conservation embedded in the appliance. This will lead to lower investments in energy efficiency (the options explanation above). But – and this is very important – from an *ex ante* point of view, this is socially optimal.

While additional information is certainly welcome, I think that the movement toward energy standards in appliances is socially undesirable. Energy standards follow from an effort to minimize the lifecycle costs of an appliance. In effect, the idea is to take the cost–benefit calculation out of the hands of the consumer (who may have difficulty making the calculation) and put it in the hands of a standard setter. If everyone has the same discount rate, this is an innocuous policy and may in fact improve welfare if people are incapable of performing the cost–benefit calculation correctly. Aside from the fact that standard setters may set the standard incorrectly (or fail to change the standard speedily if economic conditions change), the policy is flawed if there is any heterogeneity in discount rates. In effect, minimum standards put an upper bound on the discount rate for which the standard can improve welfare. People with very high discount rates may find themselves being forced to purchase more efficient appliances than they desire. Moreover, if discount rates are inversely related to income, this acts as a regressive policy. I think the challenge for supporters of conservation standards is to explain what market failure requires the mandating of the standards.

Energy modeling

Finally, let me return to the options explanation of high discount rates and discuss the implications of the theory for energy modelers. Current models of energy policy (eg the models incorporated in the Energy Modeling Forum 13 report on energy conservation) do not incorporate optimal investment behavior by individuals in the presence of future price uncertainty and sunk costs. How might modelers proceed? A beginning step is to recognize that there are two groups of investors in the world at any moment: window shoppers and crisis shoppers. Window shoppers know that they should replace their refrigerator at some point in the future and when they do so, they would like to increase its efficiency. These people should make investment decisions in which the return on the conservation component of the investment exceeds the required rate of return by the value of the option that is killed upon investment.

Crisis shoppers invest because something broke. They do not have the luxury of waiting to invest. A crisis shopper may have been a window shopper until the compressor on his refrigerator broke. This suggests heterogeneity among consumers. One group uses a hurdle rate for investment that incorporates the option value of waiting while the other group ignores the option value. Modeling the distributions of these two groups is not a trivial task. What is required is information on the depreciation patterns of the various investments as well as the pattern of new entrants into the market for a particular investment. For example, the higher the depreciation rate of the technology, the larger the crisis shopper group will be. There will be more crisis shoppers relative to window shoppers for a new refrigerator than for attic insulation in residential housing.

The pay off to this modeling approach is to make the

models internally consistent. Rather than making *ad hoc* adjustments to hurdle rates, there would be an economic basis for the adjustment that takes into account future price uncertainty, changes in technology, and depreciation patterns among other things.

In sum, there is a role for conservation policy within the broader framework of an energy policy. It is important, however, to distinguish between conservation discouraging factors for which there is no need for policy intervention and those factors that follow from some market failure. More generally, the discussion of the appropriate amount of energy conservation must take place within a cost–benefit framework. While there are certainly benefits to increased energy conservation, they come at a cost: higher appliance and housing costs, resources diverted from the production of other commodities etc. What complicates the analysis is the inherent uncertainty over the benefits of conservation. Some of the uncertainty can be diminished through better education and information dissemination. But some uncertainty is inevitable due to future energy price uncertainty. Accepting and recognizing the role that this uncertainty plays in affecting the path of conservation investment will encourage rational and welfare enhancing conservation policies as we enter the next century.

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[1]Robin Gates, 'Investing in energy conservation: are homeowners passing up high yields?', *Energy Policy*, Vol 11, No 1, March 1983, pp 63–71.

[2]Kenneth Train, 'Discount rates in consumers' energy-related decisions: a review of the literature', *Energy*, Vol 10, No 12, December 1985, pp 1243–1253.

[3]US Department of Energy, *Technical Support Document: Energy Conservation Standards for Consumer Products: Refrigerators, Furnaces, and Television Sets*, DOE/CE-0239, November 1988.

[4] There may be very good reasons for conservation standards. For example, if it is difficult for consumers to process information and determine the rate of return implied by the conservation embedded in the appliance, standards may be welfare enhancing. More on this below.

[5]Ron Sutherland, 'Market barriers to energy-efficiency investments', *The Energy Journal*, Vol 12, No 3, 1991, pp 15–34.

[6]Ideally, one should use an *ex ante* measure of inflation.

[7]Sutherland recognizes this point in arguing for a lower social hurdle rate for evaluating energy conservation investments (p 30). The point here is that private discount rates should also be reduced by the risk reducing nature of the investment.

[8]Kevin Hassett and Gilbert Metcalf, *Energy Tax Credits and Residential Conservation Investment*, National Bureau of Economic Research Working Paper No 4020, March 1992, 'Energy conservation investment: do consumers discount the future correctly?', *Energy Policy*, Vol 21, No 6, June 1993, pp 710–716; Gilbert Metcalf and Donald Rosenthal, 'Green lights and cold refrigerators: an analysis of optimal energy conservation policy in an uncertain world', mimeo 1994.

[9]In this example, there is perfect information after one period. There could still be a distribution of future returns. What is crucial is that (1) your actions depend upon the information revealed by waiting; and (2) the investment cannot be undone. In the example, once next year's price has been revealed, either she invests or she doesn't, depending on the price.

[10]An additional factor limiting resale potential is the lemons problem described by George Akerlof, 'The market for lemons: qualitative uncertainty and the market mechanism', *Quarterly Journal of Economics*, Vol 84, No 1970, pp 488–500. A potential buyer of a used appliance does not know if you are selling because you do not need the appliance or because it is a lemon. This will result in an lower equilibrium price upon resale.

[11]See *op cit*, Ref 8, Hassett and Metcalf, for a derivation of this result.

[12]I thank Avinash Dixit for this information.