

Honesty in a Regulatory Context - Good Thing or Bad?

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Abstract

It is often taken for granted that if more firms were innately honest or ethical in the way they behaved, this would be a good thing. In this paper we use the example of environmental regulation to show that such a claim cannot, in general, be sustained. If regulation is by pollution tax we show that - once optimal agency response is taken into account - social welfare is non-monotonic in the proportion of firms that report emissions honestly. The choice of policy instrument may itself be characterised by 'reversals' with command-and-control methods being preferred for intermediate values of population honesty, a tax system being preferred at the extremes. This means that if - because of the spread of "ethical shareholding" or for whatever reason - the honesty of the corporate population increases through time, we should not be surprised to see at first a switch away from market-based instruments, and then a switch back.

The model is argued to be consistent with a number of the stylised features of American regulatory history. It may also provide a defence of the USEPA's willingness to tolerate a 'distasteful culture of dishonesty' amongst those it is supposed to police (Yaeger (1991)). Though environmental regulation is used as an example for the purposes of exposition, the results are of more general interest.

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1 Introduction

It is often taken for granted that if more firms were innately honest or ethical in the way they behaved this would be a good thing. In this paper we use the example of environmental regulation to show that such a claim cannot, in general, be sustained. If regulation is by pollution tax we show that - once optimal agency response is taken into account - social welfare is non-monotonic in the proportion of firms that report emissions honestly. The choice of policy instrument may itself be characterised by "reversals" with command-and-control methods being preferred for intermediate values of population honesty, a tax system being preferred at the extremes. This means that if - because of the spread of "ethical shareholding" or for whatever reason - the honesty of the corporate population increases through time, we should not be surprised to see at first a switch away from market-based instruments, and then a switch back.

A straight-forward heterogeneity argument underlies the key results. Consider a simple model of a tax regime based on (imperfectly verified) self-reports in which tax plays an incentive role, as in the case of a tax designed to internalise an externality. It is not too surprising that such a regime may perform best - once optimal agency response is factored in - either when everyone is inherently honest or when everyone is inherently dishonest. When everyone is inherently honest the agency can achieve first-best by setting the tax-rate equal to marginal damage (i.e. at its Pigouvian level). Supposing, instead, that everyone is inherently dishonest and is able to get away with under-reporting some fraction m of their true emissions, the agency can achieve the same outcome simply by raising the tax-rate to $(m/[1 - t])$ such as to maintain the effective rate. The regime performs less well when the population is a mixture of some people who are routinely honest (i.e. do not exploit opportunities for evasion presented to them) and others who are not. Whilst the framework developed in this paper is somewhat more complex than this - incorporating differences in compliance costs, evasion opportunities etc - the basic story is unchanged.

The model is argued to be consistent with a number of the stylised features of American regulatory history. It may also provide a defence of the EPA's willingness to tolerate a 'culture of dishonesty' amongst those it is supposed to police (Yaeger (1991)).¹ Though environmental regulation is

used as an example for the purposes of exposition, it is apparent that the results are likely to be of more general interest.

It is conventional in economics to model agents as rational cheaters - undercomplying with laws or under-reporting tax liabilities when enforcement parameters are such as to make such behaviour financially profitable.² There is compelling empirical and anecdotal evidence, however, to suggest that some individuals and firms are inherently honest or ethical.³ A feel for the scale of 'honesty' in a compliance context can be had by setting all of the enforcement parameters (size of penalty, probability of apprehension etc) in econometrically estimated compliance functions equal to zero. So doing invariably implies a positive level of 'unenforced' compliance which can be substantial (see, for examples, Magat and Viscusi (1990) and Jones (1993)).

Limited attempts have been made to model the implications of routine honesty in enforcement contexts. Gractz, Reinganum and Wilde (1986) included a sub-group of routinely honest agents ("habitual compliers") in a standard income tax enforcement framework. Varying the prevalence of routine honesty in their model has no effect on optimal policy nor expected net tax revenue. Erard and Feinstein (1994) use numerical simulation to show

(e.g. Yaeger 1991: 276-283). Out of a sample of 251 reporting violations uncovered by EPA Region II, for example, either issuance of a warning letter or no action was the sanctioning response in 94.7% of cases. There were no civil or criminal referrals. Whilst these results relate to a licensing rather than tax-based regime the presence of a self-reporting component mean that the same principles apply.

²Thus Cowell (1990) defines the rational taxpayer to be one predisposed to dishonesty: ". . . the expression predisposed to dishonesty is used because we do not impute to the taxpayer any views about duty, honor or civic pride that would compel him to put some responsibility to the state ahead of his own money-grubbing interests . . . Whilst virtue for its own sake may be laudable it is unexciting in terms of economic content" (Cowell (1990: 50)). For two examples of the rational cheater in the environmental regulatory context see Harford (1987) and Heyes (1996).

³See, for examples, Gractz *et al* (1986), Levi (1988) Erard and Feinstein (1994), and many of the citations there-in. It is useful to distinguish individual from corporate honesty - though the former may be a key determinant of the latter (in the specific context of honesty of environmental reporting practices in the US Dimento (1986), for example, emphasises "the individual idiosyncracies of top management . . . the preferences of top managers are a key factor in behaviour in this context" (Dimento (1986: 84)). See also Yaeger (1991) for excellent case study and institutional evidence. It is also possible that firms may have self-serving motives for wanting to be more honest than enforcement stringency would appear to deem necessary. They may, for example, have shareholders, employees or customers who would be particularly unwilling to tolerate unethical behaviour.

¹Yaeger catalogues very widespread under-reporting of effluent discharges in the US

$$SL(x_{CC}^*) = c(x_{CC}^*) + dx_{CC}^* \quad (2)$$

where x_{CC}^* is implicitly defined by

$$c_x(x_{CC}^*) = -d. \quad (3)$$

Under a CC regime regulation is input-based and α and β are not relevant. The EPA sets (optimally) the pollution target to be satisfied and the technology to be used in achieving it, and polices it directly.

The shortcomings of CC regulation in this context are the usual ones. For a given distribution of abatement effort choice of technique is not cost-effective - some fraction of firms $F(1)$ (i.e. those with $\theta_i \leq 1$) use the back-stop technology despite knowing a cheaper way of doing the same thing. Furthermore, the distribution of effort across firms is inefficient - no mechanism exists for firms with lower marginal cost to reduce emissions more than do those with higher marginal costs.⁸ The calibration of the CC regime and the level of welfare delivered do not depend upon β .

2.2 A pollution tax regime

A tax regime does not share these problems, but has other ones of its own.

We will differentiate between "cheaters" and "non-cheaters" (C and NC respectively). A cheater is a firm which under-reports its emissions under a tax regime. To do this it must be (a) able and (b) willing to do so. Cheaters and non-cheaters constitute proportions $\alpha(1 - \beta)$ and $(1 - \alpha(1 - \beta))$ of firms respectively. Note that analytically there is no difference between firms which report truthfully because they are inherently honest, and those that do so because they have no option. The distinction will matter when we come to comparative statics, however, and will also motivate some of our later discussion of alternative policy instruments.

Assume firm i is a cheater. For a given tax rate t , its problem is to choose a level of emissions to minimise the sum of abatement expenditures plus tax payments, i.e. to minimise

$$F(x_i, t|C) = \min\{\theta_i, 1\}.c(x_i) + t.(1 - m).x_i. \quad (4)$$

⁸These are the two 'usual' shortcomings associated with CC (see e.g. Baumol and Oates (1988:171-180)). CC regimes are tied to the use of the back-stop technology and do not, by construction, perform well under technological heterogeneity of the sort here.

The interior solution $x^*(t|C)$ is implicitly defined by

$$\min\{\theta_i, 1\}.c_x(x^*(t|C)) = -(1 - m).t \quad (5)$$

The analogous problem faced by the non-cheater is to minimise

$$F(x_i, t|NC) = \min\{\theta_i, 1\}.c(x_i) + t.x_i \quad (6)$$

such that $x^*(t|NC)$ is implicitly characterised by

$$\min\{\theta_i, 1\}.c_x(x^*(t|NC)) = -t \quad (7)$$

Equation [7] is conventional in the case of a fully-enforced tax. The firm chooses a level of emission such as to equate the marginal cost of abatement (the left-hand side) with the marginal rate of tax, the marginal cost term being conditioned on optimal choice of technique. Equation [5] is the same condition adapted to take account of the fact that the effective marginal tax rate for a C is $(1 - m).t$.

It is apparent that, other things being equal, a C emits more than does a NC, since the effective tax rate it faces is lower. Choice of technique in equilibrium is cost-effective - each firm chooses the least cost way of doing the abatement its doing. The distribution of abatement effort across firms remains inefficient. Combining [5] and [7] yields

$$\frac{c_x(x^*(t|NC))}{c_x(x^*(t|C))} = \frac{1}{(1 - m)} > 1$$

- marginal abatement costs are not equalised across firms. An NC abates more than does an identical C.

The incentive effects of tax changes are qualitatively conventional. Implicit differentiation of [5] and [7] yields

$$\frac{\partial x_i^*(t|C)}{\partial t} = - \left[\frac{(1 - m)}{\min\{\theta_i, 1\}.c_{xx}(x^*(t|C))} \right] \quad (8)$$

and

$$\frac{\partial x_i^*(t|C)}{\partial t} = - \left[\frac{1}{\min\{\theta_i, 1\}.c_{xx}(x^*(t|C))} \right] \quad (9)$$

respectively. Both derivatives are negative: A marginal increase in t induces a decrease in emissions from both types of firms, the reduction is greater, *ceteris paribus*, for an NC.

2.2.1 The EPA's tax-setting problem

The EPA chooses t to minimise an expected social loss function;

$$SL(t|\alpha, \beta) = (1 - \alpha(1 - \beta)).SL(t|NC) + \alpha(1 - \beta).SL(t|C) \quad (10)$$

where

$$SL(t|NC) = \int_0^{\bar{\theta}} [\min\{\theta_i, 1\}.c(x^*(t|NC)) + x^*(t|NC)d]f(\theta)d\theta \quad (11)$$

and $SL(t|C)$ is defined analogously.⁹ The optimal tax is implicitly defined as a function of β , the proportion of honest firms in the population, by the first-order condition associated with the EPA's problem;

$$(1 - \alpha(1 - \beta)).\frac{dSL(t^*(\beta)|NC)}{dt} + \alpha(1 - \beta).\frac{dSL(t^*(\beta)|C)}{dt} = 0 \quad (12)$$

which, after substitution and simplification becomes

$$\begin{aligned} & \alpha(1 - \beta). \int_0^{\bar{\theta}} \frac{\partial x^*(t^*(\beta)|C)}{\partial t} f(\theta).d\theta.(t^*(\beta)(1 - m) - d) \\ & = (1 - \alpha(1 - \beta)). \int_0^{\bar{\theta}} \frac{\partial x^*(t^*(\beta)|NC)}{\partial t} f(\theta).d\theta.(t^*(\beta) - d) \end{aligned} \quad (13)$$

It is straight-forward to infer from [13] that $t^*(1) = d$ - if all firms are honest the optimal tax is Pigovian - and that this achieves first-best for the usual reasons.¹⁰

⁹ $SL(t|NC)$ is, then, the expected SL from a randomly chose NC . Note that when we drop the i subscript it will be taken to mean that we are moving to an expected value and that optimal response from the firm is assumed. This is less notationally intensive than carrying Equations [5] and [7] as explicit incentive compatibility constraints.

¹⁰Setting $\beta = 1$ means that we require the round bracket on the right-hand side to equal zero. The same result is obtained, of course, if $\alpha = 0$. This is the familiar first-best tax in the absence of enforcement problems.

If all firms are dishonest, the picture is more complicated. If all firms were C 's the EPA could achieve first-best by setting a tax $t = [d/(1 - m)]$ thus ensuring that every firm faced an *effective* tax rate d .¹¹ Setting $\beta = 0$ does not, however, imply this since a probability $(1 - \alpha)$ that a firm will not have the scope to cheat even though it has the inclination. $t^*(0)$ is implicitly defined by substituting $\beta = 0$ into [13]. Implicit differentiation yields

$$\text{sgn} \left(\frac{dt^*(\beta)}{d\beta} \right) = \text{sgn} \left(-\frac{\partial}{\partial \beta} \left(\frac{dSL(t^*(\beta)|\alpha, \beta)}{dt} \right) \right) < 0 \quad (14)$$

- the optimal tax is everywhere decreasing in β - implying that $t^*(0) > t^*(1) = d$. This is intuitive.

2.3 Honesty - good thing or bad?

Of interest to us here are the welfare impacts of variations in β . Expected social loss conditional on the operation of an optimally calibrated tax regime can be written

$$SL(t^*(\beta)|\alpha, \beta) = (1 - \alpha(1 - \beta)).SL(t^*(\beta)|NC) + \alpha(1 - \beta).SL(t^*(\beta)|C) \quad (15)$$

Complete differentiation yields (after application of the envelope theorem)

$$\frac{dSL(t^*(\beta)|\alpha, \beta)}{d\beta} = \alpha [SL(t^*(\beta)|NC) - SL(t^*(\beta)|C)] \quad (16)$$

It is apparent from the structure of the model that

$$SL(t^*(1)|C) > SL(t^*(1)|NC) \Rightarrow \frac{dSL(t^*(1)|\alpha, 1)}{d\beta} < 0, \forall \alpha > 0. \quad (17)$$

When $\beta = 1$ the EPA is able to implement a first-best outcome by setting a Pigovian tax $t = d$. Any decrease in β implies an increase in t^* and an increase in expected social loss. Without additional restriction we are unable, however, to provide an unambiguous sign for the analogous derivative evaluated at $\beta = 0$. It is shown in an Appendix, however, that

¹¹This can be seen by setting $\alpha = 1$ and $\beta = 0$.

$$\frac{\partial}{\partial \beta} \left(\frac{dSL(t^*(\beta)|\alpha, \beta)}{d\beta} \right) < 0, \forall \alpha, \beta > 0. \quad (18)$$

These results together imply the following:

Proposition 1 *The relationship between the expected social loss associated with an optimally-calibrated tax regime and β can be described, qualitatively, by one of the two curves in Figure [1].*

The more 'interesting' case is the non-monotonic one. Given the results in [17] and [18] it is apparent that a necessary and sufficient condition for that to be the applicable one is that $dSL(t^*(0)|\alpha, 0)/d\beta$ - the slope of the curve in Figure [1] evaluated at $\beta = 0$ - be positive.¹² The following is established in an Appendix:

Proposition 2 *A sufficient but not necessary condition for the expected social loss associated with an optimally-calibrated tax regime to be non-monotonic in β is that α be sufficiently close to 1.*

The parameter α , recall, measures the availability of the evasion technology - defined as "the fraction of firms which have access to some method of evasion which allows them to 'hide' (not report) some fraction m of their true emissions". Thus Proposition [2] says that provided a large enough fraction of firms have access to the evasion technology, the welfare properties of the best implementable tax-based regime will be non-monotonic in the proportion of firms that are honest. For many specifications of F the non-monotonicity will be characteristic for all values of α . For the rest of the analysis we will restrict our attention to the more interesting case by retaining the assumption that the sufficiency condition in Proposition [2] is satisfied - that 'enough' firms have access to the means of evasion.¹³

The non-monotonicity of $SL(t^*(\beta)|\alpha, \beta)$ in β is of some interest implying that over some ranges increases in population honesty are welfare-reducing.

¹²This derivative is zero if $\alpha = 0$ and strictly positive if $\alpha = 1$. Without further restriction, however, it cannot be assured that it is monotonically increasing in α - i.e. $d(dSL(t^*(0)|\alpha, 0)/d\beta)/d\alpha$ is of ambiguous sign.

¹³In an earlier version of the paper α was implicitly assumed to equal unity (i.e. it did not feature). The sufficiency condition in the Proposition is, of course, a strictly weaker condition than this.

Consider, first, the case in which all firms have the ability to evade ($\alpha = 1$). In that case it makes no difference to the EPA whether all firms are honest ($\beta = 1$) or all are dishonest ($\beta = 0$). In either case the first-best outcome is implementable - albeit that when $\beta = 0$ implementation will require the setting of a higher tax ($(d/(1-m))$ as opposed to d). In either case all firms face efficient incentives and $SL(t^*(1)|1, 1) = SL(t^*(0)|1, 0)$. Moving to some β interior to the unit interval implies an injection of heterogeneity which makes regulation more difficult and generates a welfare loss. The EPA sets t to balance the marginal dead-weight loss due to honest firms doing too much abatement against that due to dishonest firms doing too little. At the resulting $t(0) > t^*(\beta) > t(1)$ no firm faces the "correct" marginal incentives.

For $\alpha < 1$ things are more ambiguous. It is apparent from the structure of the model (and straight-forward to show formally) that $SL(t^*(0)|\alpha, 0) > SL(t^*(1)|\alpha, 1), \forall \alpha < 1$ - the best implementable tax regime works 'better' when all firms are honest than when all are dishonest. This is because when all are dishonest the EPA still has to contend with the fact that the regulated population contains both C 's and NC 's (the proportion $(1-\alpha)$ of dishonest firms will be NC 's because they are not able to evade, even though they would like to) whilst if all are honest all will be NC 's.¹⁴ It is apparent that from a base of $\beta = 1$ a marginal decrease in β should reduce welfare. More interesting is that from a base of $\beta = 0$ a marginal increase in β does likewise. This is not necessarily a surprising result. When all firms are dishonest the EPA anticipates this in setting t . With t set on this basis the replacement (in a large population) of one dishonest firm by one honest one reduces welfare because, *ceteris paribus*, that firm can be expected to be doing socially excessive levels of abatement.¹⁵

2.3.1 Variations in β and the choice of regulatory instrument

It is also interesting to think about the possible implications of variations in β for the EPA's choice of regulatory instrument and we do this by reintroducing the command-and-control option described in Section [2.1]. Expected social

¹⁴It is in this sense that the distinction between the two types of NC - those without the inclination (the 'honest') and those with the inclination but without the ability - matters. The α and β parameters interact to determine the proportions of C 's and NC 's in the population.

¹⁵Note that this is not a simple envelope theorem argument. It is possible that the substitution would reduce SL - though we choose to focus on the other case.

loss per firm under this regime is, recall,

$$SL(x_{CC}^*) = c(x_{CC}^*) + dx_{CC}^* \quad (2')$$

where x_{CC}^* is implicitly defined by

$$c_x(x_{CC}^*) = -d. \quad (3')$$

Neither the calibration of the instrument (i.e. choice of x_{CC}^*) nor the expected welfare from its operation are sensitive to β .¹⁶

$SL(x_{CC}^*)$ and $SL(t^*(\beta)|\alpha, \beta)$ can be plotted on common axes (Figure [2]). The relative location of the horizontal line $SL(x_{CC}^*)$ depends upon the productivity of the back-stop technology. We know that $SL(x_{CC}^*) > SL(t^*(1)|\alpha, 1)$ since $F(1) > 0$ (recall our assumption that at least some portion of firms have access to an abatement technology cheaper than the back-stop). Given continuity in β of both of the loss functions this can be stated thus;

Proposition 3 *When a sufficiently large fraction of firms are honest a tax regime performs better than a command-and-control regime.*

In Figure [2], for example, sufficient means $\beta > \beta_2$. It is also apparent that if $SL(x_{CC}^*) > \text{Max}\{SL(t^*(\beta)|\alpha, \beta)\}$ then a tax-based regime will always be preferred. More interesting is the scope for 'reversals' in instrument choice.

Proposition 4 *If $\text{Max}\{SL(t^*(\beta)|\alpha, \beta)\} > SL(x_{CC}^*) > SL(t^*(0)|\alpha, 0)$ then a tax regime performs better than a command-and-control regime for values of β sufficiently large or sufficiently small. For intermediate values of β the command-and-control regime will perform better.*¹⁷

This is the case illustrated in Figure [2]. Tax is the preferred instrument for values of β less than β_1 or greater than β_2 . Expected social loss conditional on optimal instrument selection and calibration is - for the interesting case (that involving reversals) - piecewise non-monotonic in β .¹⁸

¹⁶This is why we have chosen to refer to CC as the 'benchmark' regime in this paper.

¹⁷Notice that this condition is necessarily satisfied if $\alpha = 1$ - if the ability to evade is universal.

¹⁸Being the lower envelope in Figure [2].

3 Implications

The key advantage attributed to pollution taxation is the technological flexibility it offers to regulatees - empowering them with choice of technique - and its implied ability to "handle" technological heterogeneity. This is captured in the model presented here: In the absence of the variation in firms technological 'outside options' command-and-control would invariably be the preferred method of regulation.

The novelty in our analysis is to incorporate another type of heterogeneity - what we might refer to as 'motivational heterogeneity' - which a tax-based regime is comparatively bad at handling. The intuition is best understood by considering the $\alpha = 1$ case in which all firms have access to the means of concealment. In that case it is apparent that when all (or a sufficient fraction of) firms are *either* honest *or* dishonest then a tax regime can be expected to perform well, and certainly no worse than the optimally-calibrated command-and-control alternative. It is for intermediate values of β that command-and-control - implying, as it does, the stipulation of a technology that for some firms is not cost-effective - may work better. For values of $\alpha < 1$ the trade-offs are somewhat more complex, but the basic intuition for the non-monotonicity of welfare in β remains the same.

The significance of the analysis depends, to a large extent, upon the interpretation applied to β .

Suppose that β evolves exogenously through time, influenced by broader social trends *etc.*, then we should expect a responsive regulatory agency to adjust to take account of such evolution. This response might involve recalibrating a given instrument or - if one of the critical thresholds is traversed - switching *between* instruments. A long-term upward trend in the evolution of β - driven by, for example, the spreading influence of ethical investors - may generate 'reversals' in instrument choice, with an initial switch away from market-based instruments followed by a later switch back towards them.

What of regulatory attitudes towards changes in β ? This depends upon the starting point and the size and direction of the change - certainly the simple view that more honesty is always good cannot be sustained. Starting from $\beta = 0$ (the 'default' assumption in conventional economic analysis) marginal increases in the parameter are an impediment to the agency in its work such that 'pioneer' ethical firms might legitimately be regarded as a

nuisance, 'throwing a spanner' into the regulatory process.¹⁹ Increases in population honesty are only welfare-improving at the margin once a certain critical prevalence has been achieved.

The recognition that this is the case has particularly interesting implications in contexts where β - rather than being exogenous - is something that the regulatory agency might have scope to influence, e.g. through 'good citizenship' campaigns. A policy aimed at encouraging increased honesty from a low base is only welfare-improving if it can work on a big enough scale to get over the hill and far enough down the other side of the inverted- \sim in Figure [2].

The analysis provides a possible efficiency-interpretation for the USEPA's apparent willingness to tolerate widespread misreporting of environmental performance by those in its charge.²⁰ This is alternative to the standard view that any such tolerance must necessarily indicate incompetence, sloth or regulatory capture on the part of the agency. Provided everyone dissembles and the EPA takes account of that in its own choice of strategy (in this case by increasing the unit tax appropriately) then such dissembling need not impact system-performance. What makes regulation difficult - both in the current framework and more generally - is heterogeneity coupled with asymmetric information.

Whilst pollution control provided a context for our analysis it should be apparent that the type of story told here could be told in a variety of other contexts.

¹⁹The initial motivation for this paper came from comments made during part of an interview I conducted with an EPA enforcement strategist in the context of another piece of research in 1996: "... there is an expectation that people will play the game, get away with what they can, and that's not necessarily such a bad thing. As long as you realise you're playing a game then it's not necessarily all such a big problem".

²⁰For good empirical and institutional evidence the reader is referred to Yaeger (1991: 276-281).

Appendix

With obvious adaptation of notation we can write

$$SL(t^*(\beta), \beta) = (1 - \alpha(1 - \beta)) \cdot SL(t^*(\beta)|NC) + \alpha(1 - \beta) \cdot SL(t^*(\beta)|C) \quad (A.1)$$

Noting that the partials $\partial x_i^*/\partial \beta = 0$ then, after application of the envelope theorem;

$$\frac{dSL(t^*(\beta), \beta)}{d\beta} = SL(t^*(\beta)|NC) - SL(t^*(\beta)|C) \quad (A.2)$$

It is apparent from the structure of the model that

$$\frac{dSL(t^*(1), 1)}{d\beta} < 0. \quad (A.3)$$

We can write

$$\frac{dSL(t^*(0), 0)}{d\beta} = SL(t^*(0)|NC) - SL(t^*(0)|C)$$

which is of ambiguous sign. (Need to characterise ambiguity as in Proposition 2 here).

Differentiating (A.2) gives

$$\frac{\partial}{\partial \beta} \left(\frac{dSL(t^*(\beta), \beta)}{d\beta} \right) = \frac{\partial t^*}{\partial \beta} \cdot \left(\frac{\partial SL(t^*(\beta)|NC)}{\partial t} - \frac{\partial SL(t^*(\beta)|C)}{\partial t} \right). \quad (A.4)$$

Let the expression in brackets on the right-hand side of (A.4) be denoted Ω . Then [A.4] will have the sign opposite to Ω (since $\partial t^*/\partial \beta < 0$). Now,

$$\frac{\partial SL(t^*(\beta)|C)}{\partial t} = -\frac{\partial x^*(t|C)}{\partial t} \cdot (t(1-f) - d), \quad (A.5)$$

whilst Equation [13] implies

$$\frac{\partial SL(t^*(\beta)|NC)}{\partial t} = -\frac{(1-\beta)}{\beta} \cdot \frac{\partial SL(t^*(\beta)|C)}{\partial t} \quad (A.6)$$

such that

$$\Omega = -\frac{\partial x^*(t|C)}{\partial t} \cdot (t(1-f) - d) \cdot \left[-\frac{(1-\beta)}{\beta} - 1 \right] \quad (A.7)$$

which is positive (note from Equation [13] that $(t(1-f) - d) < 0$ for all $\alpha > 0$.)

Given continuity of $SL(t^*(\beta), \beta)$ in β , (A.3) and (A.7) together are sufficient to prove Propositions 1 and 2.

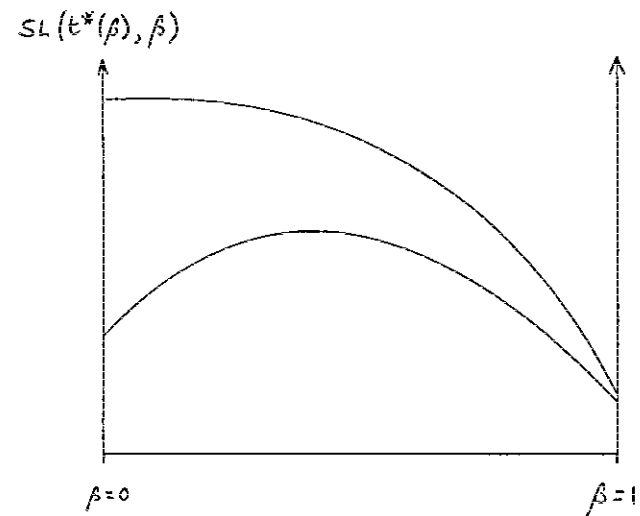


Figure [1]

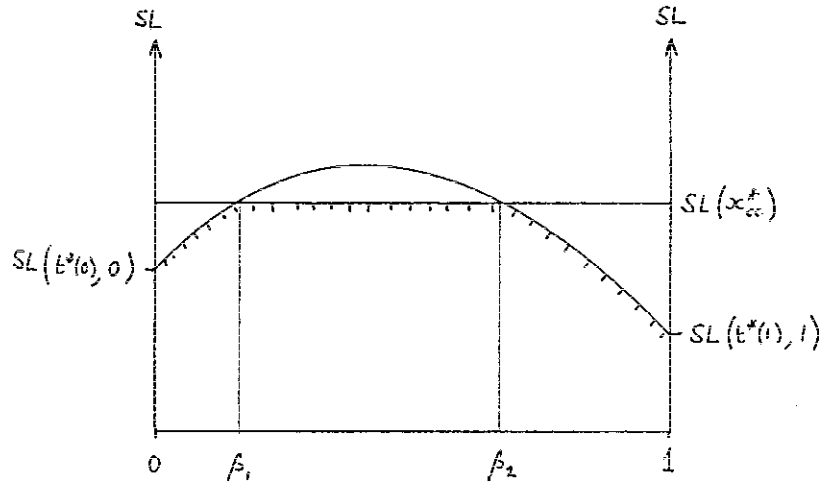


Figure [2]

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