TAX COMPLIANCE AND THE NEUROECONOMICS OF INTERTEMPORAL SUBSTITUTION

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Tax Compliance and the Neuroeconomics of Intertemporal Substitution

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This article argues that the relationship between the timing of tax payments and the decision of how much tax will be paid may have a greater impact on the level of tax compliance than would be predicted under standard exponential discounting models. To the extent that taxpayers exhibit hyperbolic or quasi-hyperbolic time discounting, compliance may be improved by separating the time at which tax returns are filed from the time in which it is paid or in which previously paid tax is refunded.

It is well understood that human decisions are more complicated than standard economic models assume. Indeed, the reason for modeling a problem is to simplify it in such a way that we can understand some portion of the problem and, from this understanding, obtain some degree of predictive power. A model that incorporates all of the complexities of the real world might be useless because it may be too complicated for us to understand.¹

There have been a variety of methods by which social scientists have attempted to address the problem of the complexity of decision-making. In general, economists have attempted to adopt assumptions about individual behavior that allow one to make predictions of the behavior of groups of individuals. These simplifications have been made in part because we do not truly understand how individuals make decisions and in part because complicated models often are intractable when confronted with anything but the simplest situations.

When the basic models currently used in economics were developed, it was assumed that it was not possible to understand the actual physical processes that occur within the brain. (Camerer, 2007) As a result, economists were forced to make

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¹ Indeed, this is the point of the incident of the discussion of the map in Brobdingnag. Swift (1735).
assumptions about these processes or, more accurately, about how decisions are made, and what affects these decisions. However, more than a century has transpired since the development of these basic neoclassical models and neurological research has advanced significantly in that time. While one cannot say that we fully understand all of the relevant processes, neuroscience has advanced to the point where it can give significant insights into the nature of the processes we use utilize in making various types of decisions. A relatively new discipline referred to as neuroeconomics seeks to understand the physical processes in the brain that are involved in decision-making in order for allow us to develop more accurate models of human behavior. Once one considers that there are limits to ability of humans to process information, and that these limits are the result of particular neuromechanisms, then one can see the potential importance of understanding these neuromechanisms. That is, if we understand the cognitive abilities of individuals to understand comprehend the world and respond to it, then we can better understand the actions they take in response, and possibly how to influence them if we so choose.

The most important question for the study of tax compliance is what causes people to pay taxes. The standard models assume that at least some element of this decision is based on the level of benefits that follow from artificially reducing reported taxable income as compared to the penalties for so doing, discounted by the probability of detection. (Allingham and Sandmo, 1972) Scholars have long understood that while standard models based on simple microeconomic assumptions are useful in many ways, they do not fully capture all aspects of the decision concerning the payment of taxes. This

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2 For examples of the literature in this area, see Slemrod (1991).
3 The so-called “tax gap” (defined as the difference between what the government ought to collect in tax revenue and what it does in fact collect) is calculated at approximately 17% of total revenue owed the government. Internal Revenue Service (1996) (“TCMP study”).
article will attempt to demonstrate how recent research in neuroeconomics can help to illuminate at least one aspect of this decision, namely how individuals discount for time.

The discussion begins by examining the traditional Allingham-Sandmo model of taxpayer compliance and discusses both its assumptions and its predictions about behavior (Allingham and Sandmo, 1972). Section I of the article also discusses some of the extensions and problems with the application of this model. Section II of the article discusses the implications of various models of intertemporal discounting for issues of tax compliance, in particular the effect of the timing of the payment of tax or refunds as well as the payment of penalties for underpayment of tax. It examines some of the more prominent models of intertemporal discounting and their effects under the Allingham-Sandmo model of tax compliance. In particular, it explores the implications of exponential discounting, the quasi-hyperbolic model of discounting, as well as a model developed by Benhabib and Bisin which considers the notion of the cost of cognitive control and how this impacts the nature of intertemporal discounting. It also considers an alternative model proposed by Rubinstein (Rubinstein, 2001) which posits that individuals make intertemporal decisions based on the similarities and differences of salient features of the available choices. A more extensive discussion of the reasonably large literature on the subject is beyond the scope of a short article such as this.

The article goes on to discuss the manner in which neuroeconomic research can help us to select between various models of intertemporal discounting, which we can then apply to better understand taxpayer compliance behavior. The article applies various

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4 As discussed below, it might the case that individuals overestimate the likelihood of being discovered under-reporting income, being assessed a penalty, or imprisonment. Unless other penalties such as social sanctions are so painful to the average taxpayer that the costs are much higher than those included in the standard analysis, they should not greatly affect the predictions of the model. Frey (1997).
models of temporal discounting to an Allingham-Sandmo framework to discuss how the timing of the payment of taxes and refunds can affect the level of compliance. In particular, it argues that under hyperbolic or quasi-hyperbolic models of temporal discounting one would expect to observe a lower level of compliance if the benefits of cheating are experienced immediately while the penalties are only to be experienced in the future, as compared to a system where both the benefits and the penalties will occur in the future. One prediction of the quasi-hyperbolic or $\beta - \delta$ model would be that allowing individuals to obtain essentially immediate refunds would decrease the level of compliance. This may or may not be the case with the cognitive control models, depending on the relative costs and benefits. Under exponential discounting models, the effect of accelerating refunds by a matter of weeks should have relatively little marginal effect on compliance, and any effect would likely be too small to measure.

This article will not try to establish a particular theory of human behavior. While the article introduces some evidence concerning different models of behavior, this article does not come to any definite conclusions. There is a simple reason for this; the research that has occurred to date does not allow for such conclusions. The purpose of this article is merely to introduce this research and to discuss its possible implications for tax compliance policy.

I. The Standard Model of Taxpayer Compliance

The standard models of taxpayer compliance are derived from basic microeconomic models of behavior. Because the assumptions of such models are relatively simple, one can add a fair level of institutional complexity to these models without making them unwieldy. This is one the great strengths of these models - their
ability to be adapted to a large variety of circumstances. This section reviews the most prominent of these models, the Allingham-Sandmo-Yitzhaki model.

A. The Allingham-Sandmo-Yitzhaki Model

The seminal work in the area of tax compliance is a paper by Allingham and Sandmo (1972) in which they proposed a model of the tax compliance decision based on standard microeconomic assumptions such as the notions that individuals are utility maximizers, utility increases with increasing wealth, and individuals conceive of probability in linear fashion. The model addresses the decision by individuals to comply with the tax laws. Under the Allingham-Sandmo model, the analysis of the compliance decision is based on a simple expected utility function. Under standard expected utility theory, the utility of some contingent payoff in the future is given by:

$$\delta \sum p_i u(x_i),$$

where $x_i$ represents the $i$th of state of the world in the next period, $u(x_i)$ is the utility in that state of the world, $p_i$ is the probability of that state of the world, and $\delta$ is used to discount for the fact that the payoff will occur in the future. In the simplest version of the Allingham-Sandmo model, the decision of whether or not to cheat on one’s taxes is based on the probability of detection and likely fine if detected. While the standard version of the Allingham-Sandmo model only discusses this decision in connection with income taxes, this framework can and has been applied to other types of taxes as well.

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5 This model is derived from the Becker crime model where, in fact, Becker himself notes that his model could apply to tax evasion. Becker (1968).
6 This is form of utility was first described in von Neumann and Morgenstern (1948).
7 This can also be written in a continuous version as $\int u(x)p(x)dx$, where $p(x)$ is the derivative of the cumulative density function $P(x)$. 
Under the Allingham–Sandmo model, the decision can be framed as maximizing expected utility, where expected utility is equal to:

\[
(1 - p)U(y(1 - t) + t(y - x)) + pU(y(1 - t) - f(y - x)),
\]

where \( p \) is the probability of detection, \( y \) is pre-tax income, \( y(1 - t) \) is true after-tax income, \( x \) is the amount of income reported to the government, therefore \( y - x \) is unreported income, and \( U \) represents a standard utility function. The model states that the individual’s expected utility is the utility of the individual if an audit occurs multiplied by the probability of being audited, plus the individual’s utility if they are not audited multiplied by the probability of not being audited (which is to say, essentially the expected value of the taxpayer's utility).

The predictions of the Allingham-Sandmo model depends crucially upon the probability of detection, \( p \), and the amount of the penalty, \( f \). Under standard optimizing assumptions, the taxpayer will choose to report income such that:

\[
\frac{U'(y_A)}{U'(y_B)} = \frac{t(1 - p)}{pf},
\]

where \( y_A \) is the amount of income in the state of being audited and \( y_B \) is income in the state where the taxpayer successfully evades taxation. Each dollar of understatement increases the argument of the utility function in state \( A \) by \( t \), and decreases it in state \( B \) by \( f \). Under this model, if and only if \((1 - p)f - pf\) is positive, every risk-averse taxpayer will engage in some evasion. In many ways, this is analogous to the portfolio choice problem.\(^8\)

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\(^8\) Frank Cowell refers to this as the Taxpayer as Gambler model. See Cowell (2003). If the expected value of an investment is greater than that of a riskless asset, every risk-averse investor will continue to retain an interest in the asset in their portfolio.
Yitzhaki (1974) introduced a slight modification to this model by pointing out that, under most tax systems, the penalty is not based on the amount of unreported income but rather on the amount of tax unpaid. The maximand would thus become:

\[
(1 - p)U(y(1-t) + t(y - x)) + pU(y(1-t) - tf(y - x)),
\]

and the expected payoff per dollar of unreported income would become:

\[
(1 - p) - pfI.
\]

Under such a modification, the tax rate has no effect on the level of tax compliance, because it appears on both sides of the equation and so cancels out. The first order condition is then:

\[
\frac{U'(y_A)}{U'(y_B)} = \frac{(1 - p)}{pf},
\]

where \(y_A = y(1-t) + t(y - x)\) and \(y_B = y(1-t) - tf(y - x)\).

If taxpayers are risk neutral, they should almost always choose a corner solution of either complete compliance or reporting zero income, depending on the relative probabilities and penalties. Because it is often the case that individuals are not either entirely compliant or report zero income, under this model, one would predict either that (i) many individuals are risk averse, (ii) the probability of being audited is dependent on the amount of income reported, (iii) some assumptions of the model is violated, or (iv) some combination of these.

**B. Extensions: Risk Aversion, Imperfect Information, and Ambiguity**

An important feature of standard economic models is the notion that individuals are averse to penalties. More than that, one can also argue that individuals are averse to the risk of a penalty being imposed. Thus risk aversion might be used to help to explain...
some of the level of compliance we observe. However, risk aversion alone does not appear to be sufficient to explain the observed level of compliance. Feld and Frey (2002) argue that the coefficient of risk aversion\(^9\) would have to be many times higher than that which is typically revealed in other contexts in order to explain the observed levels of compliance.\(^{10}\) One modification to the model which might address this concern is the existence of penalties unaccounted for in the model such as social sanctions which follow from being discovered cheating on your taxes. If these additional penalties are viewed as so undesirable that even a small increase in the risk might prevent one from evading taxes, then we might be able to explain the observed levels of compliance. (Hollopanien, 2003)\(^{11}\) However, it is unclear whether most individuals in fact consider the possibility of going to prison for small acts of evasion nor does it appear likely that most people even know if those with whom they deal on a regular basis have been caught cheating on their taxes. Furthermore, such explanations have a *deus ex machina* feel to them. It is difficult to quantify the value of social sanctions, and therefore the value placed on such sanctions could take on any value needed to plug the hole in the model.

Another possible extension of the Allingham-Sandmo model is the endogenous determination of audit probability. In particular, it seems reasonable to assume that the probability of detection of evasion is monotonically increasing in the amount of unreported income. This can be modeled as increasing the probability either as a function of: the amount of income not reported \(p = F(y - x)\), tax evaded

\(^9\) Feld and Frey (2002). This is calculated under standard Arrow-Pratt calculation. Here, the coefficient is the second derivative of the utility function divided by the derivative, or \(U''/U'\).

\(^{10}\) Feld and Frey (2002) calculate that the risk aversion coefficient would have to exceed 30 in order to explain the levels of compliance that we observe.

\(^{11}\) Actually, Allingham and Sandmo (1972) mention this possibility. To the extent that this is true, when we double the fines for tax evasion we do not double the penalty.
\[ p = F(t(y - x)), \] or a percentage of income not reported \[ p = F\left(\frac{y - x}{y}\right). \] Depending on the shape of this function, it may introduce many of the same considerations as risk aversion. This is to say that it may help to explain why evasion does not reach predicted levels. Importantly, the Allingham-Sandmo model does seem to give the correct predictions in that cheating appears to be much more prevalent among those who have a greater ability to cheat. (TCMP study, 1996) Furthermore, as noted by Joel Slemrod, because a fair amount of income is subject to automatic reporting, some of the observed level of compliance may be involuntary, and therefore should not be used as evidence against the Allingham-Sandmo model. (Slemrod, 2002) On the other hand, endogenous audit probability might actually increase the likelihood of small acts of evasion, because if one is not cheating at all, the likelihood of being audited would approach zero, increasing the marginal incentive to cheat at least a little. Yet, most taxpayers seem to pay the correct amount.

II. THE NEUROECONOMICS OF TEMPORAL DISCOUNTING AND TAX COMPLIANCE

This section first discusses neuroeconomics and, in particular, the research conducted on intertemporal discounting. It then applies this research to the Allingham-Sandmo model to discuss the implications for the timing of refunds and penalties.

A. The Contribution of Neuroeconomics

As an initial matter, why do we care about subjective experience or about patterns of brain activity? That is, why should we care about whether a particular portion of the prefrontal cortex is involved in any particular action, as long as we know the elasticity of response to a particular change in the rules? If we had perfect information about the
elasticity of response to taxation, then perhaps we would not. Unfortunately, this is not the case. Econometrics can be quite helpful in giving us a great deal of information about how taxpayers behave, but one of the reasons for the growth in the use of economic experiments is to gain insight about why people pay their taxes at the levels they do. An important limitation on econometric evidence is that one cannot easily test counterfactuals; one can only test what has occurred given the available information. As a result, econometric evidence often does not have an ability to discriminate among the most prominent extant theories. The data and techniques that have been developed often simply do not have the requisite sensitivity.

Neuroeconomic research can help us to understand the neural mechanisms that people use to make decisions, including those that relate to taxes. Neuroeconomics can be thought of as the application of cognitive neuroscience to economic decisions. Researchers in this area seek to understand what factors go into decisions and how the information that is taken in by the nervous system is processed inside the brain. One can also think of neuroeconomics research as simply an extension of methodology of economic experiments where we obtain a great deal more information about each of the subjects in the experiment. This research is still at a very early stage and, before there are truly definite concrete applications, much more research will need to be conducted. However, the research that has already been conducted can give us some insight into the processes by which individuals make decisions.

B. The Nature of Time-Discounting and the Influence of Neuroeconomic Models

One of the most active areas of neuroeconomic research has been in the area of intertemporal substitution. An important experiment published in 2004 dealt with the
neural mechanisms used in time preference (McClure et al. 2004). In order to understand the significance of this work, we need to place it in context of the proposed models of intertemporal discounting. The economics literature has long discussed instances in which individuals appear to exhibit inconsistent time preferences (Strotz, 1956). This phenomenon is often referred to as hyperbolic discounting – in contrast to standard exponential discounting – because a graph of the rate of time discount appears to resemble a hyperbola. Specifically, it has been found that in many contexts individuals seem to exhibit a higher rate of discount between periods of time close to the current period as compared to periods of time in the distant future. For example, the discount rate between receiving an amount of money today versus receiving it tomorrow appears to be larger than the discount rate between receiving the same amount of money a year from now versus a year and one day from now. One relatively simple method of modeling such preferences is represented by the quasi-hyperbolic model of David Laibson, which is also referred to as the $\beta - \delta$ model. (Laibson, 1997). Like many standard models, this model assumes that time periods can be represented in a discrete fashion and that time preferences are separable. It represents the utility to be received from a stream of consumption from the vantage of a time period at the beginning of the stream as being broken up into the value of the consumption at each of the individual time periods, discounted back to the present time. In discrete time, this can be represented as $U(C(t)) = U(c_1) + \beta \left[ \delta U(c_2) + \delta^2 U(c_3) + \cdots \right]$, where $C(t)$ represents the time path of consumption and $c_i$ represents the level of consumption in the $i$th period.
Under this model, one can easily show that the rate of time discount between the first period and the second period is \( \frac{U'(c_1)}{U'(c_2)} = \beta \delta \), while the discount rate between the second and third period is \( \frac{U'(c_2)}{U'(c_3)} = \delta \). At time period 2, the utility from future consumption can be represented as \( U(C(t)) = U(c_2) + \beta[\delta U(c_3) + \delta^2 (c_4) + \cdots] \), and now the rate of discount between the second and the third period is \( \frac{U'(c_2)}{U'(c_3)} = \beta \delta \). That is, the rate of discount between period one and period two changes as we move into period one from period zero from \( \delta \) to \( \beta \delta \). Because the rate of discount between these two periods changes, this is a dynamic inconsistency in the rates of time preference. Not surprisingly, the thesis that individuals exhibit non-exponential discounting has also been subject to challenge by scholars arguing that other factors are responsible for these results.\(^\text{12}\)

Benhabib and Bisin (2005) propose that the key to understanding intertemporal substitution is that cognitive resources are scarce, and in particular long-term planning requires the use of resources that require more energy than other systems. Under this model, individuals have essentially two different systems for assessing intertemporal substitution. For relatively less important decisions, individuals allow automatic processes, which are subject to a variety of non-rational temptations, to operate. However, in the case of decisions for which individuals perceive a great deal of potential regret in the future, other mechanisms come into play which exhibit greater levels of foresight and therefore mute the utility loss that might occur if the automatic processes

\(^\text{12}\) If individuals exhibited non-exponential discounting, such preferences would not exist in equilibrium because they would be arbitraged away. See Terrence Chorvat on the "Dutch book" argument (forthcoming, 2007). Moreover, a number of scholars have argued that such preferences can be rationalized in a number of ways. See Gul & Pesendorfer (2001) and A. Rubinstein (2003).
were to control these decisions. They give as a simple example of operation of this model the situation where there are two choices available $c^*$, the more considered choice, and $c'$, the more impulsive choice, and where $\beta$ is a discounting factor for some future time period and $w$ is the current level of wealth which must allocated between two time periods and finally $b$ can be thought of as parameter measuring the level of the cost of cognitive control, then if $U(c^*) - U(c') - \beta[U(w - c^*) - U(w - c')] > b$, the individual will not allow the automatic process to function. If left hand side is less than $b$, then automatic or impulsive choice is permitted. Under this model, small decisions like those typically seen in experiments or perhaps at the grocery store are often governed by these automatic processes. However, decisions like whether to cheat on your taxes might be governed by the control processes, and we might then observe something more like exponential discounting. Even when the control processes are determinative, it is not necessarily the case that individuals will operate exactly as exponential discounters. There may still be issues of costs of the energy required to exert cognitive control in future periods in order to effectuate a planned level of consumption. They argue that strategies that are simple to implement require less cognitive energy, and therefore are more likely to be adopted. Therefore, the consumption paths adopted by individuals may still not be exactly the same as that of perfect exponential discounters, but rather may merely resemble one within the limits of cognitive control. Consequently, individuals may attempt to adopt simple rules such as to never cheat on their taxes, rather than the more complicated rules of only cheating up to a certain level. They argue that the evidence for this cognitive control model includes the fact that individuals do not
generally borrow from their home equity, except for purposes of home improvement, as well as the fact that individuals do not generally borrow against their insurance policies.

Under an alternative to this framework was presented by Rubinstein (2001), individuals make the choices observed in experiments based on comparisons of quantities that appear similar and those that appear dissimilar. For example from the perspective of the present, receiving an amount a year from now versus receiving it a year and a day from now appear to be essentially the same, consequently if the amount received a year and a day from now is even slightly larger, a person will choose to the delayed reward. On the other hand, any delay from the present is quite easy to distinguish from an immediate receipt, and so a higher level of reward will be required in order to foregoing current consumption in favor of receiving an award tomorrow.

There are of course, a large variety of models which have been developed to describe temporal discounting behavior in addition to those described above. These models described above give a reasonable idea of the types of theories that have been developed to deal with the observed rates of intertemporal discounting. One way to gain some purchase into which might be a more accurate description of the decision-making process, we might look to what we can discover about the actual processes occurring in the brain. In order to discover what neurological mechanisms are being used in the process making these types of decisions, a team of researchers at Princeton tested the level of Amazon.com gift certificates people needed to receive to be willing to delay the awarding of the certificate (McClure et al., 2004). Consistent with hyperbolic discounting, they observed that if the subject was deciding to receive the gift certificate now versus some short time in the future, or between two times with an equal difference
between them, but advanced into the future there were different rate of discount and in addition there were different neural mechanism predominantly at work in the two different decisions. Furthermore, those who made different decisions displayed different patterns of brain activation. This does indicate that different neural mechanisms are involved when individuals choose to act impulsively and when they choose to act from a more long-term perspective.

This neurological evidence would appear to argue against the similarity model of Rubinstein. If in both cases individuals were simply making comparisons of similar quantities it would seem unusual if the brain mechanisms used were quite different. In addition, this evidence seems to argue that there is a neurological basis for non-exponential discounting. Of course one simple experiment is not enough to refute any of these theories, but this evidence would appear to point in the direction of the either the $\beta - \delta$ model or the cognitive control model. Unfortunately, such an experiment would not appear to be able to discriminate between the $\beta - \delta$ and the cognitive control model, because both models posit two separate systems at work, which is consistent with the neurological evidence of this experiment.

C. The Application of Different Theories of Time Discount to the Allingham-Sandmo Framework

Under the Allingham-Sandmo model, taxpayers compare the current benefit of cheating, which is equal to the taxes they can avoid, with the later penalties that they may incur which occur with probability $p$. If we assume that the penalty will be paid in a different period, then we can account for this temporal difference by including a discount factor of $\delta$. In sum, this model assumes that taxpayers will act so as to maximize
expected utility. We can illustrate the dynamic behavior of taxpayers through use of a
two period model. Because the benefits of cheating and the penalties occur in at two
different times, we can denote the income (or wealth) in the jth period in the ith state of
nature as $y_j^i$, where the first state of nature is where the individual is not audited and the
second is where the individual is audited. The individual will then act so as to maximize:

$$ (1 - p) [U(y_1^1) + \delta U(y_2^1)] + p [U(y_1^2) + \delta U(y_2^2)] . $$

(1)

The temporal sequencing of this model is important. The formulation in equation
(1) assumes that taxpayer will receive the benefit of the reduced taxes in the current
period. Notice however that under the exponential discounting model, if the time
difference between the time that the refund is received and the time that the penalties are
imposed is not changed, even if they are moved into the future, then it should not matter
because the $\delta^n$ would factor out. Furthermore, to account for the time value of money
the tax system could just charge interest on penalty, as do most tax system.

At first blush, there would not appear to be much added explanatory value by
including hyperbolic or quasi-hyperbolic discounting to the Allingham-Sandmo
framework, because in order for interesting predictions to come from this type of model,
there would need to be at least three time periods. That is, what is interesting about non-
exponential discounting models is that the discount between two periods changes as those
periods move closer to the present time.$^{13}$ For this to occur that have to be at least three
time periods under consideration. However, in the payment of taxes there can easily
three relevant time periods. If the benefits or costs of tax are not incurred at the same
time that the return is filed, then we can have three relevant time periods: when the tax is

$^{13}$ If there are only two periods, one could simply adjust the discount rate higher or lower to account for any
observed behavior.
determined, when it is paid or refunded, and when the penalty (if any) is incurred. One common example of this is the timing of refunds of income tax, i.e. whether they are received immediately or weeks in the future. Depending on the model we use we might derive different predictions of the importance of the timing of refunds. For the $\delta - \beta$ or quasi-hyperbolic discounting model, moving the timing of the payment of the refund up to the current time period could make a difference in the level of compliance. We can see this by comparing the decision in the case where both the refund will be received in the future and the penalty will be in the future but later than the refund, with the case where the refund can be received immediately, while the penalty will be paid in the future. Using the framework from equation (1) under an exponential discounting framework, we can see that the first order conditions imply\textsuperscript{14} that:

$$U'(y_1) + (1 - p)\delta U'(y_1^2) = p\delta U'(y_2^2). \quad (2)$$

If both the refund and the penalty are in the future then the individual will apply the $\beta$ discount to both the refund and the penalty and it would factor out of the equation, leaving it exactly the same as for exponential discounting. However, if the refund is received immediately, the individual will only apply the $\beta$ discount to the penalty (and the future utility in the un audited state as well and not to the refund and equation (2) would become

$$U'(y_1) + (1 - p)\beta U'(y_1^2) = p\beta U'(y_2^2) \quad (3)$$

\textsuperscript{14} Because, at the time of the receipt of the refund, the taxpayer will not be aware of whether the return will be subject to audit, the level of income and utility in both states of nature must be the same, and the derivative of utility with respect of wealth at this point is denoted $\frac{\partial U}{\partial y_1}$. We continue to assume, as in Yitzhaki (1974), that the penalty imposed is a linear function of the amount of income unreported.
Therefore, the current positive value of the refund will be valued at a higher level that it would be relative to an exponential model, which will push in favor of a lower level of compliance because the cost of getting caught cheating is lowered.\footnote{This prediction is unambiguous as long as the taxpayer's marginal utility of wealth decreases with wealth. That is, if we rearrange (3), we have }\[^{15}\] Therefore, under the $\beta - \delta$ model the relationship between the current receipt of funds and later potential payment of penalties might be such that individuals would be more inclined to cheat, because they have a higher discount for any amount received in the future than for amounts received in the present. In such a case, one would then expect that a faster availability of refunds might have a significant effect on the willingness of individual to cheat on the taxes. This contrasts with an exponential discounting model in which the delay of a few weeks should not have a significant effect, because it will not change the present value greatly unless individuals have unreasonably large rates of discount.

Under the Benhabib and Bisin model, the timing of the payment of taxes may have less relevance than under hyperbolic or quasi-hyperbolic discounting. If tax payments are high percentage of income, then under the cognitive control model individuals will not likely greatly change their compliance levels. That is, if the costs of not complying with taxes and being caught are high, under this model, individuals would still likely adopt a strategy of full compliance, or whatever other strategy that had adopted before, in order to avoid the cognitive costs of deciding when to comply and when not to comply.

\section*{D. The Limitations of Neuroeconomics Research}

\[^{15}\] This prediction is unambiguous as long as the taxpayer's marginal utility of wealth decreases with wealth.
While there have a number of papers that have discussed neuroeconomics and
temporal discounting, one also has to be cognizant of the current and potential perpetual
limitations of this type of research. Neuroeconomics is unlikely to unseat very many
commonly accepted theories of behavior. Merely because we learn which brain
mechanisms are responsible for particular behaviors, and how these mechanisms operate,
this does not imply that the models we currently use to explain behavior are inaccurate, at
least at the level of precision we may desire. We may learn to make these models more
precise or be able to discriminate between models as a result for this research, but it
highly unlikely that if a model seems to make a number of highly accurate predictions
that neurological research will unseat such a model. Mathematical models are used to
predict behavior, and if a model continues to perform this function, neuroeconomic
research cannot change this fact. Rather, neuroeconomics can help give us additional
information about what is occurring in the decision processes of individuals, and have
perhaps a better understanding of the models that we accept and a better information by
which to judge which model is more likely to accurately predict behavior. Neuroeconomics is fairly new line of research and it is important that we not expect too
much of it too quickly. In its current state it much more of a supplement to other types of
research rather than a great engine for new hypotheses about human behavior.

One intriguing point is that to the extent that the Benhabib-Bisin model is an
accurate depiction of human behavior, then we may want to consider the interplay
between the cost of cognitive control and institutional rules. To the extent that honest
behavior in paying taxes leads to honest behavior in other areas and vice versa, because
individuals will attempt to conserve on cognitive resources by adopting one rule that
applies to many areas of human behavior, then one has to consider the effects of tax compliance policies on other aspects of the economy as well.

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