

*E-ZTAX: TAX SALIENCE AND TAX RATES**

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Abstract: This paper examines whether the salience of a tax system affects equilibrium tax rates. I analyze how tolls change after toll facilities adopt electronic toll collection (ETC); drivers are substantially less aware of tolls paid electronically. I estimate that, in steady state, tolls are 20 to 40 percent higher than they would have been without ETC. Consistent with a salience-based explanation for this toll increase, I find that under ETC, driving becomes less elastic with respect to the toll and toll setting becomes less sensitive to the electoral calendar. Alternative explanations appear unlikely to be able to explain the findings.

Key Words: tax salience; size of government; tolls, electronic toll collection

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1. Introduction

For every dollar of revenue raised by the US income tax system, taxpayers incur about 10 cents in private compliance costs associated with record keeping and tax filing (Slemrod 1996). These compliance costs impose a dead-weight burden on society. Yet policies that would reduce these costs are frequently opposed by policy-makers and economists who believe that compliance costs play an important role in keeping taxes visible and salient to the electorate, who then serve as an important check on attempts to raise the scale of government activity beyond what an informed citizenry would want.

For example, Milton Friedman has publicly lamented his inadvertent contribution to the growth of government by encouraging the introduction of the visibility-reducing Federal income tax withholding system during the Second World War (Friedman and Friedman, 1998 p.123). More recently, in 2005, The President's Advisory Panel on Federal Tax Reform failed to reach consensus on whether to replace part of the existing income tax system with a value-added tax (VAT) in part because of concerns about how the lower visibility of a VAT would affect the size of government. As the Advisory Panel noted in its report:

“[Some] Panel Members were unwilling to support the [VAT] proposal given the lack of conclusive empirical evidence on the impact of a VAT on the growth of government. Others were more confident that voters could be relied on to understand the amount of tax being paid through a VAT, in part because the proposal studied by the Panel would require the VAT to be separately stated on each sales receipt provided to consumers. These members of the Panel envisioned that voters would appropriately control growth in the size of the federal government through the electoral process.” (The President's Advisory Panel on Federal Tax Reform 2005, p.203-204).

The idea that a less visible tax system may fuel the growth of government can be traced back at least to John Stuart Mill's 1848 *Principles of Political Economy*. It has its modern roots in the public choice tradition of “fiscal illusion”. In a series of influential books and articles, James Buchanan and co-authors have argued that citizens systematically under-estimate the tax price of public sector activities, and that government in turn exploits this misperception to allow it to reach a size that is larger than an informed citizenry would want. The extent of the tax misperception – and thus the size of government – is in turn affected by the choice of tax instruments, with more complicated and less visible taxes exacerbating the

extent of fiscal illusion and thereby increasing the size of the government (e.g. Buchanan 1967, Buchanan and Wagner 1977, Brennan and Buchanan, 1980).

Empirical evidence of the impact of tax salience on tax rates, however, has proved extremely elusive. Most of the evidence comes from cross sectional studies of the relationship between the size of government and the visibility of the tax system, where the direction of causality is far from clear (Oates 1988, Dollery and Worthington, 1996). Moreover, as I discuss in more detail below, the sign of any effect of tax salience on tax rates is theoretically ambiguous. The link between tax salience and tax rates is therefore an open empirical question.

In this paper, I examine the relationship between tax salience and tax rates empirically by studying the impact of the adoption of electronic toll collection (hereafter, “ETC”) on toll rates. Electronic toll collection systems – such as the eponymous E-ZPass in the Northeastern United States, I-Pass in Illinois, or Fast-Trak in California – allow automatic deduction of the toll as the car drives through a toll plaza. Because the driver need no longer actively count out and hand over cash for the toll, the toll rate may well be less salient to the driver when paying electronically than when paying cash. Indeed, I present survey evidence which indicates a strikingly lower awareness of the amount paid in tolls by those who pay electronically relative to those who pay using cash. This discrepancy in toll awareness exists even among regular commuters on a toll facility. As a result, toll facilities’ adoption of ETC – and the resultant switch by many drivers to paying electronically – provides a setting in which to examine the impact of tax salience on tax rates.

Different toll facilities in the United States have adopted ETC at different points in time over the last several decades, and some have not yet adopted it. To study the impact of ETC, I examine the *within toll-facility* changes in toll rates associated with the adoption and diffusion of ETC. To do so, I collected a new data set on the history of toll rates and ETC installation for 123 toll facilities in the United States. Where available, I also collected annual, facility-level data on toll traffic, toll revenue, and the share of each that is paid by electronic toll collection.

I find robust evidence that toll rates increase after the adoption of electronic toll collection. My estimates suggest that when the proportion of tolls paid using ETC has diffused to its steady state level of about 60 percent, toll rates are 20 to 40 percent higher than they would have been under a fully manual toll collection system.

I also present evidence of two potential mechanisms by which reduced salience may contribute to increased toll rates. First, I find that the elasticity of driving with respect to the toll declines (in absolute value) with the adoption of electronic toll collection, suggesting that ETC may raise the optimal level of the toll. Second, I show that under ETC, toll setting behavior becomes less sensitive to the local election calendar, suggesting that ETC may reduce the political costs of raising tolls.

The rest of the paper proceeds as follows. Section 2 provides a conceptual framework for how tax salience may affect tax rates, and the factors that may affect the (ambiguous) sign of this relationship. Section 3 presents evidence that tolls are less salient when paid by ETC than by cash. Section 4 describes the data on toll rates and driving. Section 5 estimates the impact of ETC on the elasticity of driving with respect to the toll. Section 6 estimates the impact of ETC on toll rates. Section 7 considers non salience-based explanations for these empirical findings. The last section concludes.

2. Effects of Tax Salience on Consumers and Government: Conceptual Framework

In a fully salient tax system, individuals are aware of actual taxes as they make economic and political decisions. In a less salient tax system, individuals are not aware of the actual tax (τ), but instead have a perception of the tax, which I denote by $\tilde{\tau}$. Recent empirical evidence is consistent with individuals misperceiving taxes (Liebman and Zeckhauser 2004, Feldman and Katascak 2005, Chetty et al. forthcoming) and with the salience of the tax affecting the extent of this misperception (Chetty et al. forthcoming).

This paper focuses on the response of tax rates to tax salience. However, since an input into this response is how consumer's economic behavior is affected by tax salience, I begin – in both the conceptual framework and the subsequent empirical work – by analyzing the consumer response; I then turn to the government's response.

I denote by $\theta \geq 0$ the (lack of) salience of the tax system. A higher θ corresponds to a less salient tax system; $\theta=0$ corresponds to a fully salient system. In the empirical application I will examine the move from manual (i.e. cash) toll collection to electronic toll collection (ETC) and interpret this as a move to a less salience tax system (i.e. an increase in θ); I present survey evidence in Section 3 that is consistent with the assumption that ETC reduces the salience of tolls.

There are two types of tax salience that may affect tax setting: tax salience at the time of the consumption decision for the taxed good, and tax salience at the time of voting. These need not be the same. To capture this, I denote the perceived tax by $\tilde{\tau}_j$ where $j = \{c,v\}$ indicates perceived taxes at the time of (c)onsumption and of (v)oting respectively.

For simplicity I assume the perceived tax is a linear function of the actual tax:

$$\tilde{\tau}_j(\theta) \equiv \delta_{0j}(\theta) + \delta_{1j}(\theta)\tau \quad (1)$$

and normalize a fully salient system to be one in which the perceived and actual tax are the same (i.e. $\delta_{0j}(0) = 0$ and $\delta_{1j}(0) = 1$). I assume that $\delta_{1j}(\theta) > 0$ (i.e. the perceived tax is increasing in the actual tax). I also assume that in a less salient tax system, the link between the perceived and the actual tax is weaker (i.e. $\delta'_{1j}(\theta) < 0$). The effect of the tax salience on the perceived toll level is, however, a priori ambiguous; in other words, $\delta'_{0j}(\theta)$ can be either sign. For simplicity, I consider only cases of positive taxation ($\tau > 0$), and further assume $\tilde{\tau}_j > 0$.

2.1 Response of consumer economic behavior to tax salience

The individual chooses consumption of the taxed good based on the perceived tax at the time of the consumption decision, $\tilde{\tau}_c(\theta)$. To simplify the analysis, I assume the individual maximizes a utility

function that is quasi-linear in the taxed good and exhibits constant elasticity of demand.¹ The individual thus solves:

$$\max_{x_1} \gamma_0 x_1^{\left(\frac{1}{\gamma_1} + 1\right)} + x_2 \text{ subject to } x_2 + (p + \tilde{\tau}_c(\theta))x_1 \leq m \quad (2)$$

where x_1 denotes the taxed good (with producer price p), x_2 denotes all other goods (whose price has been normalized to 1), and m is consumer income. I denote by $\eta(\tilde{\tau}_c) \equiv \gamma_1$ the (constant) elasticity of demand for x_1 , which I assume is negative. Note that $\eta(\tilde{\tau}_c)$ is the elasticity of demand with respect to the *perceived* price $p + \tilde{\tau}_c(\theta)$; I denote by $\eta(\tau)$ the elasticity of demand with respect to the *actual* price $p + \tau$.

To see how consumer responsiveness to the tax changes with the salience of the tax, I will estimate empirically how the elasticity of demand with respect to the actual price ($\eta(\tau)$) varies with tax salience (θ). The sign of this relationship (i.e. the sign of $\frac{\partial \eta(\tau)}{\partial \theta}$) is ambiguous. To see this, note that the relationship between $\eta(\tau)$ (which I will estimate empirically) and $\eta(\tilde{\tau}_c)$ (which I have assumed is constant) can be derived as follows:

$$\eta(\tau) \equiv \frac{\partial x_1}{\partial (p + \tau)} \frac{(p + \tau)}{x_1} = \frac{\partial x_1}{\partial (p + \tilde{\tau}_c)} \frac{\partial (p + \tilde{\tau}_c)}{\partial (p + \tau)} \frac{(p + \tau)}{x_1} \frac{p + \tilde{\tau}_c}{p + \tilde{\tau}_c} = \eta(\tilde{\tau}_c) \frac{p + \tau}{p + \tilde{\tau}_c} \frac{\partial (p + \tilde{\tau}_c)}{\partial (p + \tau)} \quad (3)$$

Under the assumption of fixed producer prices (i.e. p does not vary with either τ or θ), the relationship between the perceived tax and actual tax in equation (1) implies:

$$\frac{\partial (p + \tilde{\tau})}{\partial (p + \tau)} = \frac{\partial \tilde{\tau}}{\partial \tau} = \delta_{1c}(\theta) \quad (4)$$

Using equation (4) we can simplify the relationship between $\eta(\tau)$ and $\eta(\tilde{\tau}_c)$ in (3) to:

¹ The assumption of quasi-linear utility seems a reasonable one when the taxed good is a small part of the overall consumer's budget (such as the toll case I consider). It is not, however, an innocuous assumption for the political response to tax salience; I discuss this in more detail in Section 2.2.

$$\eta(\tau) = \eta(\tilde{\tau}_c) \left(\frac{p + \tau}{p + \tilde{\tau}_c} \right) \delta_{1c}(\theta) \quad (5)$$

Differentiating both sides of (5) with respect to salience (θ) gives:

$$\frac{\partial \eta(\tau)}{\partial \theta} = \underbrace{\eta(\tilde{\tau}_c)}_{-} \underbrace{(p + \tau)}_{-} \left(\underbrace{\frac{-1}{(p + \tilde{\tau}_c)^2}}_{-} \underbrace{(\delta'_{0c}(\theta) + \delta'_{1c}(\theta)\tau)}_{?} \underbrace{\delta_{1c}(\theta)}_{+} + \underbrace{\frac{1}{(p + \tilde{\tau}_c)}}_{+} \underbrace{\delta'_{1c}(\theta)}_{-} \right) \quad (6)$$

Equation (6) shows that sign of the impact of tax salience on the elasticity of demand (i.e. the sign of

$\frac{\partial \eta(\tau)}{\partial \theta}$) is ambiguous, since the impact of salience on the level of the perceived tax (i.e.

$\frac{\partial \tilde{\tau}_c}{\partial \theta} \equiv (\delta'_{0c}(\theta) + \delta'_{1c}(\theta)\tau)$) is of ambiguous sign.² In the empirical work below I find evidence that

consumption behavior becomes less elastic as salience decreases (i.e. $\frac{\partial \eta(\tau)}{\partial \theta} > 0$). Equation (6) indicates

that a sufficient (although not necessary) condition for $\frac{\partial \eta(\tau)}{\partial \theta} > 0$ is that $\delta'_{0c}(\theta) + \delta'_{1c}(\theta)\tau > 0$ (i.e. the

perceived tax is increasing as salience decreases). In Section 3 I present survey evidence that is consistent

with this condition, suggesting that these empirical findings are internally consistent.

To estimate $\frac{\partial \eta(\tau)}{\partial \theta}$ empirically, I multiply equation (5) through by $\partial \log(p + \tau)$ to obtain

$$\partial \log x_1 = \eta(\tilde{\tau}_c) \left(\frac{p + \tau}{p + \tilde{\tau}_c} \right) \delta_{1c}(\theta) \partial \log(p + \tau) \quad (7)$$

Taking a linear approximation to (7) around $\theta = 0$ and explicitly separating out the main effects from the interaction effect of interest, I estimate:

$$\Delta \log(x_1) = \beta_1 \Delta \log(p + \tau) + \beta_2 \theta + \beta_3 \theta \Delta \log(p + \tau) + \Delta \varepsilon \quad (8)$$

² The other components of (6) are signed by the assumptions discussed earlier in this Section.

The parameter β_1 provides an estimate of the estimated elasticity of demand in a fully salient system (i.e. $\theta = 0$), in which case $\eta(\tilde{\tau}_c) = \eta(\tau) = \beta_1$. The parameter of interest is β_3 ; it indicates how the elasticity changes with salience.

2.2 Political response to tax salience

The political response of tax rates to tax salience may depend not only on how the consumer's behavioral responsiveness to tax changes with salience (i.e. $\frac{\partial \eta(\tau)}{\partial \theta}$) but also how the political costs of taxes change with tax salience. Section 2.1 showed that the sign of the effect of tax salience on the consumer's behavioral responsiveness is ambiguous. Moreover, any effect of tax salience on political costs need not be the same sign as any effect of tax salience on consumer behavioral responsiveness, since salience at the time of consumption and salience at the time of voting may be different; this creates further ambiguity in the sign of the relationship between tax salience on tax rates. This ambiguity motivates the empirical work that is the focus of this paper.

To gain some intuition into the determinants of the sign of the relationship between tax salience and tax rates, I consider a government who sets the tax to maximize a weighted sum of some economic objective and the (negative of) any political costs of the tax. For concreteness, I assume the economic objective of the tax is to raise revenue. I discuss other possible economic objectives – and how these affect the implications of tax salience – in Section 2.4 below.

The government chooses τ each year to maximize

$$\max_{\tau} \lambda \tau Q(p + \tilde{\tau}_c) - (1 - \lambda) f(E) C(\tilde{\tau}_v) \quad (9)$$

where $0 \leq \lambda \leq 1$ represents the weight the government places on the economic objective of the tax (i.e. raising revenue) relative to the political cost of the tax, C denotes the political cost of the tax, and E is an indicator variable for whether or not it is an election year. I assume $f(E) > 0$ and $f'(E) > 0$; in other words, the political costs of taxes are exogenously higher in election years, so that we expect a “political

business cycle” in taxes (Nordhaus, 1975); in the empirical work, I provide evidence of a political business cycle in toll setting.

The government’s optimization problem yields the following first order condition for the tax rate:

$$\tau^* = \frac{-Q(\tilde{\tau}_C)}{Q'(\tilde{\tau}_C)} + \frac{(1-\lambda)f(E)C'(\tilde{\tau}_V)}{\lambda Q'(\tilde{\tau}_C)} \quad (10)$$

where to simplify notation I have defined $C' \equiv \frac{\partial C}{\partial \tilde{\tau}} \frac{\partial \tilde{\tau}}{\partial \tau}$ and $Q' \equiv \frac{\partial Q}{\partial \tilde{\tau}} \frac{\partial \tilde{\tau}}{\partial \tau}$. To ensure an interior solution to the optimal tax, I assume that $C' > 0$ (i.e. political costs are rising in the actual tax) and $Q' < 0$ (i.e. demand is falling in the actual tax). Note that both consumption salience and voting salience affect the choice of tax rate: the amount of revenue raised depends on the perceived tax at the time of the consumption decision (i.e. $\tilde{\tau}_C$), and the political cost of the tax depends on the perceived tax at the time of voting (i.e. $\tilde{\tau}_V$).

Differentiation with respect to θ of the first order condition for the government’s optimal tax level in (10) indicates that the sign of any effect of tax salience on the choice of tax rate is a priori ambiguous:

$$\frac{\partial \tau^*}{\partial \theta} = \left(\underbrace{\frac{\partial \left(-\frac{Q}{Q'} \right)}{\partial \theta}}_{?} + \underbrace{\frac{(1-\lambda)f(E)}{\lambda}}_{+} \underbrace{\left(\frac{\frac{\partial C'}{\partial \theta} Q' - \frac{\partial Q'}{\partial \theta} C'}{(Q')^2} \right)}_{?} \right) \quad (11)$$

Although the sign of (11) is theoretically ambiguous, there are intuitive findings concerning how the relationship between tax salience and tax rates is likely affected by the effect of salience on the consumer’s behavioral responsiveness to taxes, and by the effect of salience on the political costs of taxes. To see this, consider first the simplest case in which $\lambda = 1$, so that the government only maximizes revenue. In that case, the politically optimal tax in equation (10) reduces to the standard inverse elasticity optimal tax equation

$$\frac{\tau^*}{p + \tau^*} = \frac{1}{\eta(\tau)} \quad (12)$$

and thus (under the assumption of fixed producer prices):

$$\text{sign of } \frac{\partial \tau^*}{\partial \theta} = \text{sign of } \underbrace{\frac{1}{\eta(\tau)^2}}_{+} \underbrace{\frac{\partial \eta(\tilde{\tau}_c)}{\partial \theta}}_{?} \quad (13)$$

Equation (13) indicates that, when the government sets taxes to maximize revenue, the sign of how taxes vary with salience is the sign of how the elasticity of demand with respect to the tax varies with salience (which as we saw in equation (6) can be of either sign). Intuitively, if a decline in salience lowers the behavioral response to the tax (i.e. $\frac{\partial \eta(\tau)}{\partial \theta} > 0$), then the tax rate set by the government will be rising as salience declines. Note that the assumption of quasi-linear utility is important for this result, as it removes any distortionary effect of reduced salience on consumption of the taxed good that arises from the budgetary consequence of the misperceived tax. In the more general case, where such distortionary effects will exist, Chetty et al. (forthcoming) show that even if reduced salience reduces the behavioral response to the tax, this is not sufficient for the optimal tax to increase; this is likely to be particularly important for taxes that are a large share of the individual's budget, such as income taxes.

Moreover, if the government puts some weight on the political costs of taxes (i.e. $\lambda < 1$), this introduces another source of indeterminacy in the sign of the relationship between tax salience and tax rates. However, the model suggests that we can learn more about the likely sign of $\frac{\partial \tau^*}{\delta \theta}$ in (11) by examining how any political business cycle in tax setting changes as tax salience declines. To see this, note that

$$\frac{\partial^2 \tau^*}{\partial \theta \partial E} = \underbrace{\left(\frac{1 - \lambda}{\lambda} \frac{f'(E)}{f'(E)} \right)}_{+} \underbrace{\left(\frac{\frac{\partial C'}{\partial \theta} Q' - \frac{\partial Q'}{\partial \theta} C'}{(Q')^2} \right)}_{?} \quad (14)$$

and observe that the first term in parentheses is positive by assumption, and that the second term in

parentheses (whose sign is unknown) also appears in (11). Thus if $\frac{\partial^2 \tau}{\partial \theta \partial E} > 0$, this implies that the second

term in parentheses in (14) is positive so that the entire second term in (11) is positive. In other words, if the political business cycle attenuates as salience declines (i.e. $\frac{\partial^2 \tau}{\partial \theta \partial E} > 0$, for which I find evidence in the empirical work below), this makes it more likely that a decline in tax salience raises taxes (i.e. $\frac{\partial \tau^*}{\partial \theta} > 0$).

To investigate the relationship between tax salience and tax rates empirically, I note that the first order condition for the tax rate in (10) indicates that the tax rate will depend on tax salience (θ), whether it is an election year (i.e. $E=1$ or $E=0$), and the interaction of these two effects. Because of the serial correlation properties of taxes in my empirical application (which I discuss in more detail below) I estimate the relationship between taxes and salience in first differences, estimating:

$$\Delta \tau = \beta_1 \Delta \theta + \beta_2 E + \beta_3 E(\Delta \theta) + \Delta \mu \quad (15)$$

Estimation of equation (15) allows a comparison of the effect of tax salience on tax rates in non election years (i.e. β_1), and in election years (i.e. β_3).

2.3 Identification

An examination of the two main estimating equations – equation (8) which comes from the driver optimization problem, and reveals how behavioral responsiveness to the tax changes with salience and equation (15) which comes from the political optimization problem and reveals how the tax varies with salience – highlights two important identification problems. First, taxes are taken as exogenous to demand in the demand estimation equation (8), but are determined as the endogenous result of the political optimization problem (see equation 10). Identification of the demand equation requires that the error term $\Delta \varepsilon$ in the demand equation (8) is uncorrelated with the error term $\Delta \mu$ in the tax setting equation (15); in other words, identification requires that changes in demand do not contemporaneously affect changes in taxes. For example, if demand follows a random walk, then as long as the government tax setting process

takes at least one year to respond to demand, current changes in taxes will be uncorrelated with current changes in demand and the demand equation (8) will be identified.³

This identifying assumption seems reasonable for a (bureaucratic) government that may not be able to make and implement decisions quickly. In the empirical application, I will show that, in practice, taxes are changed only about once a decade, which is consistent with the assumption of a lagged response. Furthermore, any changes in taxes that are driven by changes in any of the non-demand factors which equation (10) indicates affect tax rates – i.e. the sensitivity of political costs to the tax rate (C'), the electoral calendar (E), or the relative weight (λ) which the government places on the political costs of taxes –do not pose a problem for identification (as long as changes in these factors are themselves exogenous to changes in current demand).

The second identification problem is that I allow the tax (τ) to be chosen endogenously by the political optimization problem in (9), but assume that the salience of the tax system (θ) is exogenously determined. If the government endogenously chooses θ (e.g. on the basis of any of the factors that determine τ), the tax setting estimating equation (15) is not identified. The validity of the assumption that the choice of tax salience is exogenous with respect to the choice of tax rate is ultimately an empirical question, and one that I explore in depth in Section 6.1.3 below.

2.4 Other Government Objective Functions and Normative Implications

For concreteness, in Section 2.2 I assumed the government's objective function in choosing the tax rate was a weighted average of the revenue raised by the tax (its economic objective) and the (negative of) the political costs of the tax (its political objective). Of course, the government may well have other economic objectives such as redistributive taxes or Pigouvian corrective taxes; the latter is potentially quite relevant for the toll case that is the subject of the empirical work. Like a revenue raising tax, the optimal level of these other types of taxes also varies inversely with the behavioral responsiveness to the

³ In my empirical application I find that changes in (residual) demand have an AR1 coefficient of 0.045 suggesting that demand is (close to) a random walk. I also explore robustness of the demand estimation to alternative specifications with weaker identifying assumptions (see Section 5).

tax. For example, if the tax is set as an optimal Pigouvian externality correction, the optimal tax will be increasing as the behavioral responsiveness to the tax declines. Therefore the same empirical prediction concerning how the impact of salience on the behavioral responsiveness to the tax likely affects the impact of tax salience on tax rates should apply (qualitatively) to these other economic objectives.

In contrast to the positive empirical predictions, the normative implications of any effect of tax salience on tax rates will be quite sensitive to the government's objective function. One critical issue for the normative implications of tax salience is whether the government operates as a benign social planner or whether it is (partially or fully) maximizing independent objectives (such as staying in office or increasing the size of government); in the latter case, the government's response to a decline in salience may be self-serving, but not socially optimal. The evidence I present below, that the political business cycle in toll setting attenuates when salience is reduced, suggests that part of the impact of tax salience on tax rates comes from reducing the political costs of raising tolls; this suggests that the government's response to a reduction in tax salience may not be that of a fully benign social planner.

Even when the government operates as a fully benign social planner, the normative implications of a decline in salience will also depend on the economic component of the government's objective function. If the economic objective is to raise revenue, then if salience reduces the behavioral responsiveness to the tax this is likely to be welfare improving since it allows the government to raise a given amount of revenue at lower distortionary costs. However, if the economic objective of the tax is a Pigouvian externality correction, the normative implications may be quite different. For example, if salience reduces the behavioral responsiveness to the tax, this has no effect on welfare if the tax is set solely as a Pigouvian corrective tax, utility is quasi-linear in the taxed good and the revenue raised is rebated back to consumers as a lump sum; the government would raise the tax to the (new) higher optimal externality-correction tax and rebate back the resulting (higher) revenue as a lump sum, with no change in aggregate welfare. However, in more general models in which utility is not quasi-linear and/or the government does not rebate back the revenue raised as a lump sum, a lower behavioral responsiveness to the Pigouvian tax due to reduced salience can be welfare reducing.

3. Impact of ETC on toll salience: survey evidence

The empirical analysis is predicated on the assumption that ETC reduces the salience of the tolls (i.e. increases θ). I therefore begin by presenting survey evidence consistent with this assumption.

Evidence from two separate surveys indicates that individuals are substantially less aware of tolls if they pay them electronically rather than with cash. One survey is an in-person survey that I designed and conducted in May 2007 of 214 individuals who had driven to an antiques show in western Massachusetts on the Massachusetts Turnpike (hereafter, “MA Survey”). The other is a telephone survey conducted in June and July 2004 of 362 regular users from New Jersey of any of the six bridges or tunnels of the Port Authority of NY and NJ that cross the Hudson river (hereafter “NYNJ Survey”). More details on the MA Survey can be found in the online Appendix (section A); more details on the NYNJ Survey can be found in Holguin-Veras et al., 2005 (especially pages 116 – 126 and pp 383 – 394).

Each survey asked drivers their estimate of the toll paid on their most recent trip on the relevant facility, their method of payment, and a variety of demographic characteristics; information about the exact trip was also collected so that the actual toll paid could be calculated.

Table I summarizes the results. Both surveys show a strikingly lower awareness of tolls among drivers who paid with ETC than those who paid with cash. The differences are both economically and statistically significant. In the MA survey, 62 percent of drivers who paid using ETC responded to the question about their best guess of the toll they paid that day on the Turnpike with “I don’t know” and would not offer a guess without prompting from the surveyor to please “just make your best guess”;⁴ by contrast, only 2 percent of drivers who paid with cash had to be prompted to offer a guess. In the NYNJ survey, 38.1 percent of ETC users reported “do not know” or “refused” when asked how much they paid at the toll in their most recent drive across the Hudson from New Jersey to New York, compared to 20.0% of cash users.⁵

⁴ Indeed, many of the ETC drivers literally responded “I don’t know, I used EZ-Pass [or Fast Lane].”

⁵ It is interesting that the discrepancy in toll awareness between ETC and cash drivers is larger in the MA survey. One possible explanation is that the NYNJ Survey asked about the toll paid on a regular commute, while the MA

Moreover, the ETC drivers' belief that they did not know how much they had paid for the toll was born out by their subsequent guesses. In the MA Survey, 85 percent of drivers who paid using ETC estimated the toll they paid incorrectly, compared to only 31 percent of drivers who paid using cash. In the NYNJ survey, 83 percent of ETC drivers estimated the toll incorrectly, compared to only 40 percent of cash drivers. Conditional on making an error, the magnitude of the error was also larger for ETC users; ETC users over-estimate tolls by more than cash users.⁶

These findings of markedly lower knowledge of tolls among people who paid electronically compared to those who paid with cash are consistent with the maintained assumption that tolls are less salient under ETC. In other words, the results are consistent with ETC reducing the link between the actual and perceived toll (i.e. $\delta'_{1j}(\theta) < 0$). These findings are also consistent with other work on "payment decoupling" which finds that technologies such as credit cards, which decouple the purchase from the payment, reduce awareness of the amount spent and thereby encourage more spending (e.g. Thaler 1999, Soman 2001).

Several caveats are in order. First, neither survey is representative of the nationwide population. Nonetheless, it is reassuring that the finding of lower toll awareness among ETC drivers persists in two very different populations, including a population of regular commuters. Second, cross-sectional differences in awareness of tolls between ETC drivers and cash drivers could reflect differences in these drivers besides their payment method. Reassuringly, a comparison of the results in columns 3 and in column 4 of Table I shows that none of the differences in toll awareness in the MA Survey are sensitive (in either magnitude of statistical significance) to adding controls for demographic characteristics of drivers, including age, gender, education, median household income of zip code, and value of their car.

Survey asked about the toll paid on a presumably idiosyncratic trip. Differences in the survey method (e.g. telephone vs. in person) may also have an effect on the individual's willingness to guess.

⁶ This finding that ETC is associated with over-estimation of the toll is consistent with the finding in Section 5 that ETC is also associated with reduced behavioral responsiveness to the toll. See equation (6) in Section 2.1, and the discussion that follows it.

Finally, a survey response on toll perception does not necessarily reflect either the perceived toll at the time of consumption ($\tilde{\tau}_C$) or the perceived toll at the time of voting ($\tilde{\tau}_V$). However, given the large percentage of cash drivers relative to ETC drivers who are spot-on in estimating the toll paid correctly, it seems plausible that ETC may reduce one or both of these types of salience. I now turn to direct evidence of the impact of ETC first on consumer behavior and then on toll setting.

4. Data and Descriptive Statistics

This section provides some brief background on the sample construction and variable definitions; considerably more details on the facilities in the sample and the variable definitions can be found in the online Appendix (section B) or in the working paper version of this paper (Finkelstein, 2007).

4.1 Sample construction

The target sample was all 183 publicly-owned toll facilities in the U.S. (excluding ferries) that were charging tolls in 1985, which predates the introduction of ETC in the U.S. In 1985, toll revenue in states that levied tolls was about 0.8% of state and local tax revenue, roughly the same revenue share as state lotteries (US Department of Transportation 1985, 1986; U.S. Census Bureau 1985; Kearney 2005). Statutory authority for toll setting is usually vested in toll operating authorities. These are typically appointed by state or local governments, who therefore, in practice, retain influence on toll setting.

By contacting each toll authority, I was able to collect data for 123 toll facilities.⁷ These 123 facilities are run by 49 different operating authorities in 24 different state-like entities; these include 22 states and 2 joint ventures (one between NY and NJ and one between NJ and PA); I refer to all 24 hereafter as “states”. On average, the data contain 50 years of toll rates per facility.

4.2 Key variables

4.2.1 ETC Adoption and Diffusion. Figure I shows a histogram of ETC adoption dates, which range from 1987 through 2005, with a median of 1999. By 2005, 87 of the 123 facilities had adopted ETC. Almost all of the variation in whether and when ETC is adopted is between rather than within operating authorities;

⁷ A toll “facility” is a particular road, bridge, or tunnel; about 60 percent of the responding facilities are bridges or tunnels.

there is, however, substantial variation across authorities within a state (not shown). On average for a facility with ETC, I observe about 6 years of ETC.

Table II shows that relationship between facility characteristics and ETC adoption. ETC adoption rates are highest in the Northeast (78 percent) and lowest in the West (57 percent). The high adoption rates in the Northeast may reflect greater urbanicity (since ETC may help reduce congestion) as well as higher labor costs (since ETC reduces labor costs of toll collection). ETC is adopted with the same probability on roads as on bridges and tunnels; however, conditional on adopting ETC, roads adopt about 3 years earlier on average. Older facilities are more likely to adopt ETC and, condition on adoption, to do so earlier (not shown).

Once a facility adopts ETC, use of the technology diffuses gradually across drivers. I was able to obtain the ETC penetration rate (defined consistently within each facility as either the fraction of toll transactions or of toll revenue collected by ETC) for about two-thirds of facility-years with ETC. Figure II shows the within-facility ETC diffusion rate. It takes about 14 years for ETC to reach its steady state penetration rate of 60 percent.

4.2.2 Toll histories. I define the toll as the nominal toll for passenger cars on a full length trip on a road, or on a round-trip on a bridge or tunnel. I collected data on both the “manual” (i.e. cash) toll and any discount offered for the electronic toll; the electronic toll is never more than the cash toll.⁸ Over half (53 out of 87) of facilities with ETC offer a discount at some point. Discounts are presumably offered to encourage use of the technology; indeed, they are more common on facilities that adopt ETC earlier. The discounts may also be rationalized as a Pigouvian subsidy if ETC has positive externalities on congestion reduction. The average discount offered is about 15 percent.

The primary toll measure in the analysis is the lower envelope of the manual and electronic toll (hereafter, “minimum toll”). I also present results for the sub-sample of facilities that never offer ETC discounts, and for which the minimum and manual toll are therefore always the same. On average, the

⁸ High frequency discounts (i.e. commuter discounts) are not coded. None of the facilities in the sample offer time-of-day varying prices.

minimum toll increased by 2.0% per year. This is substantially below the facility-year-weighted average inflation rate of 4.2%. Toll changes are lumpy; on average only 7.7 percent of facilities increase their minimum toll and only 1 percent of facilities decrease it each year.

4.2.3 *Revenue and traffic data.* I was able to collect traffic (revenue) data for 76 (45) for the 123 facilities. On average, for a facility with these data, I obtained 34 years of data.

5. The impact of ETC on the elasticity of driving with respect to the toll change

To examine how ETC affects the elasticity of driving with respect to the tax, I adapt the demand equation (8) to the toll context as follows:

$$\begin{aligned} \Delta \log(\text{traffic})_{it} = & \gamma_t + \beta_1 \Delta \log(\text{minimum toll}_{it}) + \beta_2 \Delta \log(\text{minimum toll}_{it}) * \text{Never_ETC}_i \\ & + \beta_3 \Delta \log(\text{minimum toll}_{it}) * \text{ETC_Penetration}_{it} \\ & + \beta_4 \text{Never_ETC}_i + \beta_5 \text{ETC_Penetration}_{it} + \Delta \varepsilon_{it} \end{aligned} \quad (16)$$

I proxy for demand for the taxed good (i.e. x_1 in equation (8)) with the amount of traffic on facility i in year t (i.e. traffic_{it}), and for the salience of the tax system (i.e. θ in equation (8)) with the ETC Penetration rate on facility i in year t (i.e. $\text{ETC_Penetration}_{it}$). For purposes of practicality, I estimate the demand responsiveness to τ in equation (16) rather than to $p + \tau$ as in equation (8), since I do not observe the non tax costs (p) of driving. As long as p does not vary with taxes or with tax salience (i.e. the fixed producer prices assumption discussed in Section 2), this modification will affect the magnitude of the estimated elasticities but not their sign. As noted, I use the minimum toll as my measure of τ .

Equation (16) examines the relationship between the annual percent change in facility's traffic ($\Delta \log(\text{traffic})_{it}$) and the annual percent change in its toll ($\Delta \log(\text{minimum toll})_{it}$), and how this relationship changes with the ETC penetration rate. To strengthen the inference, it also allows the elasticity to vary across facilities based on whether the facility ever adopted ETC (Never_ETC_i is 1 if the facility never adopts ETC and zero otherwise), and it allows for secular changes in demand over time (the γ_t represent a full set of year fixed effects). The key coefficient of interest is β_3 ; this indicates how the elasticity changes on a facility as ETC use diffuses. Finally, $\Delta \varepsilon_{it}$ is a random disturbance term capturing all omitted

influences. I allow for an arbitrary variance-covariance matrix within each “state” and give equal weight in the regression to each operating authority.

As discussed in Section 2.3, identification of equation (16) is based on the assumption that changes in tolls are not affected by contemporary changes in demand. This is probably a reasonable assumption. Traffic – and presumably underlying demand for driving – changes continuously each year, while a facility’s toll is raised on average only every 8 to 9 years. The infrequency of toll adjustment likely reflects both general lags in price setting by government enterprises as well as political constraints; for example, I show in Section 6.2 that toll increases are significantly lower during state election years. Although tolls may be adjusted in part based on past demand shocks (i.e. lagged values of changes in traffic), changes in traffic within a facility show very little serial correlation; a regression of the residuals from equation (16) on their lags produces a coefficient of only 0.045. Any adjustment of tolls to past changes in demand is therefore unlikely to pose much of a practical problem for the estimation. However, as a robustness check, I also report results in which I limit the sample to the years in which a toll changes or the 2 years before or after a toll change; I refer to this as the “+2/-2 sample”. The assumption in this more limited sample is that the timing of the toll change is random with respect to short-run traffic changes, although it may reflect longer run demand changes.

I estimate equation (16) on approximately one-quarter of the facilities in the data. By necessity, the analysis is limited to the approximately 60 percent of facilities for which I obtained traffic data. I further limit the sub-sample of facilities with traffic data to the approximately 40 percent of them that never offer an ETC discount. This allows me to include the ETC penetration rate directly on the right hand side, without worrying about omitted variable bias from any potential effect of an ETC discount on both the ETC penetration rate and traffic. An added advantage of looking only at facilities that never offer an ETC discount is that in this sample there is only one toll rate (i.e. the minimum toll and the toll are always the

same), which avoids the measurement error that ETC discounts would otherwise introduce in the right hand side toll variable once ETC is introduced.⁹

Table III reports the results. Columns 1 and 2 show the results from regressing $\Delta \log(\text{traffic})_{it}$ on $\Delta \log(\text{minimum toll})_{it}$ and year fixed effects. Column 1 shows the results for the full sample of facilities with traffic data, including those that offer ETC discounts. The coefficient on $\Delta \log(\text{minimum toll})_{it}$ of -0.049 (s.e. = 0.015) indicates that a 10 percent increase in tolls is associated with a statistically significant but economically small 0.5% reduction in traffic. Column 2 shows the result is quite similar for the sample of facilities that never offer ETC discounts; the coefficient on $\Delta \log(\text{minimum toll})_{it}$ of -0.058 (s.e. = 0.018). These results suggest that tolls are set below the profit maximizing rate, which is consistent with Peltzman's (1971) observation that there will be a downward bias in the prices set by government-owned enterprises. More generally, it suggests that – as modeled in Section 2.2 – the government objective function is not pure revenue maximization.¹⁰

Column 3 shows the results from estimating the complete equation (16). The coefficient on $\Delta \log(\text{minimum toll}_{it}) * \text{ETC_penetration}_{it}$ is 0.134 (s.e. = 0.038); this indicates that a 5 percentage point increase in the ETC penetration rate (which is the average increase per year of ETC) is associated with a (statistically significant) 0.0067 decline in the elasticity of driving with respect to the toll, or about 10 percent relative to the average estimated elasticity prior to ETC of -0.061.

Column 4 shows the results when the ETC_Penetration variable in equation (16) is replaced by the number of years the facility has had ETC (ETC_Year); this variable is zero prior to ETC adoption, 1 in the year of adoption, 2 in the second year of ETC, and so forth. The coefficient on

⁹ I show below that the estimated impact of ETC on toll rates is robust to limiting the sample to facilities that never offer discounts. When I limit to those for whom I have traffic data, the effect is very similar in magnitude to the estimates in the full sample, although no longer statistically significant at conventional levels (not shown).

¹⁰ Of course, I am only measuring the short run response to a small change in tolls; this behavioral response may merely reflect the route chosen on a particular day. Longer run responses to (possibly larger) toll changes may be larger, reflecting among other things decisions that affect regular commuting patterns.

$\Delta \log(\text{minimum toll}_{it}) * \text{ETC_Year}_{it}$ is 0.006 (s.e. = 0.001), indicating a quite similar decline in elasticity of 0.006 per year of ETC to that estimated in column 3.¹¹

The last two columns of Table III repeat the analysis in columns 3 and 4 on the +2/-2 sample. The point estimates on both the elasticity of driving under manual toll collection and the change in the elasticity associated with ETC_Year (or ETC_Penetration) remain virtually unchanged. The change in the elasticity associated with ETC remains statistically significant, although at the 10 percent level in the +2/-2 sample (columns 5 and 6) rather than at the 1 percent level as in the larger samples (columns 3 and 4).

As noted in Section 2.2, for taxes that are small as a portion of income, if a decline in salience reduces the behavioral responsiveness to the toll, this will tend to cause tolls to rise when salience declines. However the net impact of salience on toll rates is ambiguous; it also depends on how salience affects the political costs of toll setting. I now turn to an examination first of the net effect of ETC on toll rate and then to the effect of ETC on the political costs of tolls.

6. The impact of ETC on political behavior

6.1. The impact of ETC on toll rates

6.1.1 Baseline specification

To estimate the impact of ETC on toll rates, I begin with a simplified version of the estimating equation for tax setting (equation 15) in which I omit any measure of whether it is an election year from the right hand side. Since the election calendar is set exogenously, this does not introduce any omitted variable bias, and allows me to capture the average impact of ETC on toll rates; I augment the analysis to include electoral effects in Section 6.2 below.

¹¹ One potential concern in interpreting these results is that the finding of a decline in the (absolute value) of the elasticity of driving with respect to the toll under ETC might spuriously reflect a general time trend in the elasticity of driving with respect to the toll. To investigate this, I re-estimated the regressions shown in columns 3 and 4 of Table III with the inclusion an additional interaction term $\Delta \log(\text{minimum toll}_{it}) * \text{year}_t$ on the right hand side; this allows for a time trend in the elasticity of driving. The inclusion of this interaction term weakened the precision of the estimated decline (in absolute value) of the driving elasticity under ETC, but did not substantively affect the finding. For example, for the specification shown in column 3, the coefficient on $\Delta \log(\text{minimum toll}_{it}) * \text{ETC_penetration}_{it}$ became 0.137 (standard error = 0.067). In column 4, the coefficient on $\Delta \log(\text{minimum toll}_{it}) * \text{ETC_Year}_{it}$ became 0.005 (standard error = 0.002).

I therefore begin with the estimating equation:

$$\Delta y_{it} = \gamma_t + \beta_1 ETCAdopt_{it} + \beta_2 ETC_{it} + \Delta \mu_{it} \quad (17)$$

In the baseline specification, the dependent variable is the change in the log of the minimum toll ($\Delta \log(\text{min toll})_{it}$); I estimate the dependent variable in logs rather than in levels (as in equation (15) in Section 2.2) so as not to constrain toll rates in different facilities to grow by the same absolute amount each year; this seems undesirable, given the considerable variation in toll rates across facilities.¹² The γ_t 's represent year dummies which control for any common secular changes in toll rates across facilities.

The key coefficients of interest are those on $ETCAdopt_{it}$ and ETC_{it} , which represent my parameterization of the change in tax salience ($\Delta \theta$ in equation 15). Specifically, $ETCAdopt_{it}$ is an indicator variable for whether facility i adopted ETC in year t . The coefficient on $ETCAdopt_{it}$ thus measures any level shift in the minimum toll associated with the introduction of ETC; this might include, for example, the effect of any ETC discounts. However, since ETC use among drivers diffuses gradually, it is likely that any impact of ETC on toll rates will also phase in gradually. To capture this, I include the indicator variable ETC_{it} for whether facility i has ETC in year t ; it is 1 in the year of ETC adoption and in all subsequent years. The coefficient on ETC_{it} thus measures the average annual growth in a facility's toll once it has ETC. Thus I parameterize $\Delta \theta$ with $ETCAdopt_{it}$ and ETC_{it} in the first year of ETC, and I parameterize $\Delta \theta$ with ETC_{it} in all subsequent years with ETC.

¹² In practice, the sign and statistical significance of the impact of ETC on tolls is robust to specifying the dependent variable as the change in the level of the minimum toll rather than the change in the log of the minimum toll; the magnitude of the effect is slightly more than double in this alternative specification (not shown). One potential concern with the log specification is that the dependent variable is censored when a toll is set to 0. Indeed, 15 of the 123 facilities that are charging a toll in 1985 subsequently set the toll to zero. I treat all facility-years with zero tolls as censored (both in the log and in the level analysis). This likely biases downward any estimated impact of ETC since I find that ETC is associated with a negative and marginally statistically significant decline in the probability the toll rate is changed from non-zero to zero (not shown).

Finally, $\Delta\mu_{it}$ is a random disturbance term capturing all omitted influences.¹³ I estimate equation (17) allowing for an arbitrary variance-covariance matrix within each “state” and give equal weight in the regression to each operating authority.

The first column of Table IV shows the results from estimating equation (17). The coefficient on ETC_{it} is 0.015 (s.e. = 0.006). This indicates that once a facility has ETC, its toll increases by 1.5 percentage points more per year than it otherwise would have. This effect is both statistically and economically significant. Relative to the average annual 2 percent increase in tolls, it implies that after installing ETC, the facility’s toll rate rises by 75 percent more per year than it did prior to ETC.¹⁴

The toll change in the first year of ETC is given by the sum of the coefficients on $ETCA_{it}$ and ETC_{it} . These indicate that there is a (statistically insignificant) 3.6 percent decline in tolls the year that ETC is adopted. The results in the next two columns suggest that this decline in the year of ETC adoption is due to ETC discounts. Column 2 shows the results when the dependent variable is the change in the log manual toll; column 3 shows the results when the sample limited to the approximately 60 percent of facilities that never offered an ETC discount (half of which never adopt ETC), for which the manual and minimum toll are always the same. In these alternative specifications, the sum of the coefficients on $ETCA_{it}$ and ETC_{it} is either positive and insignificant (column 2) or negative and now both economically and statistically insignificant (column 3).

The fact that the growth in tolls under ETC persists in the “no discount” sample (column 3) – the coefficient on ETC_{it} is statistically significant and slightly larger in magnitude than in the full sample in column 1 – indicates that the estimated growth in tolls after ETC is installed does not merely reflect a

¹³ I estimate equation (17) in first differences rather than in levels with facility fixed effects because the residuals are much less highly serially correlated in first differences (AR1 coefficient of -0.045) than in the fixed effects version (AR1 coefficient of 0.92), making the first-differenced specification the preferred specification (Wooldridge 2002, p.274-81).

¹⁴ One might prefer to specify the percent increase in the toll associated with ETC relative to the average annual growth rate of tolls prior to ETC; this is 1.9 percent. It is quite similar to the sample average (despite an average annual growth rate of tolls under ETC of 2.8 percent) because the vast majority of facility-years in the approximately 50-year toll histories I collected on each facility do not have ETC.

recouping of first-year losses from the ETC discount. For facilities that offer ETC discounts, there does not appear to be any systematic change in the discount over time after ETC adoption (not shown). This suggests that in practice increases in the minimum toll reflect a shift of the entire toll schedule, which is consistent with the finding that the manual toll also increases under ETC (column 2).¹⁵

6.1.2 The pattern of ETC diffusion and toll increases

The preceding analysis constrains the effect of ETC to be the same across facilities and over time. However, if ETC increases tolls by reducing their salience, we would expect the effect to be increasing in the ETC penetration rate, whose diffusion rate is not constant over time (see Figure II) or across facilities (not shown). As a stronger test of the salience hypothesis, therefore, I examine how the time pattern of toll changes after ETC adoption compares to the time pattern of ETC diffusion. Specifically, I compare the coefficients from estimating:

$$\Delta \log(\text{min toll})_{it} = \gamma_t + \sum_{k=-9}^{k=9} \beta_k \mathbf{1}(\text{ETCYear}_{(k,k+1)}) + \varepsilon_{it} \quad (18a)$$

and

$$\Delta \text{ETC_Penetration}_{it} = \gamma_t + \sum_{k=1}^{k=9} \beta_k \mathbf{1}(\text{ETCYear}_{(k,k+1)}) + \varepsilon_{it} \quad (18b)$$

where $\Delta \text{ETC_Penetration}_{it}$ is the percentage point change in the ETC penetration rate on facility i in year t . The key outcome of interest is a comparison across the two equations of the time pattern of the coefficients on the indicator variables $\mathbf{1}(\text{ETCYear}_{(k,k+1)})$. These are indicator variables for whether it is k or $k+1$ years since ETC was adopted on the facility. For example, $\mathbf{1}(\text{ETCYear}_{(1,2)})$ is an indicator variable for whether ETC was adopted this year or last year (i.e. ETC Year is 1 or 2). In equation (18a), all of the indicator variables represent a two year interval, except for the first (respectively, last) indicator

¹⁵ Although it might at first appear puzzling that the manual (i.e. cash) toll – which has become no less salient – also increases under ETC, this is easily understood by the necessary linkage between cash and electronic toll rates; were the electronic rate to increase while the cash rate did not, this would presumably discourage use of ETC. The preservation of the ETC discounts once ETC is installed likely reflects continued attempts to induce more drivers to switch to ETC; the maximum ETC penetration rate in my sample is only 78 percent.

variable, which is a “catch-all” variable for whether it is 9 or more years before (respectively, after) ETC adoption; the omitted category is the two years prior to adoption (i.e. ETC Year of -1 or -2). In equation (18b) I include only the post-ETC dummies that are in equation (18a).

Figure IIIa shows the result. The solid black line shows the pattern of the log toll with respect to ETC Year implied by the estimates from equation (18a) and the dark dashed line shows the corresponding time pattern of ETC diffusion implied by the estimates of equation (18b).¹⁶ The results indicate that, after remaining roughly constant in the pre-ETC period, toll rates decline in the first two years of ETC (reflecting the discounts discussed earlier) and then climb steadily as ETC diffuses across the facility. Of course, the wide confidence intervals on the estimates caution against placing too much weight on the estimated time path. It is nonetheless reassuring that the point estimates suggest that the pattern of toll increases is similar to that of ETC diffusion.

A potential concern with this analysis is that the set of facilities that identify the different β_k 's varies with the ETC year k . It is therefore difficult to distinguish the time path of the effect of ETC on a given facility from potentially heterogeneous effects of ETC across facilities.¹⁷ Figure IIIb therefore shows the results from re-estimating equations (18a) and (18b) when the sample of ETC-adopting facilities is limited to those that adopted ETC in 1998 or earlier. In this balanced panel of facilities, all of the graphed coefficients are identified by a constant set of facilities. The results are quite similar.¹⁸

For a more parametric (and higher powered) analysis of how the time pattern of toll changes after ETC adoption compares with the diffusion of ETC, I estimate a modified version of equation (17):

$$\Delta \log(\text{min toll})_{it} = \gamma_t + \beta_1 \text{ETCA}dopt_{it} + \beta_2 \Delta \text{ETC}_{Penetration}_{it} + \varepsilon_{it} \quad (19)$$

¹⁶ The scale of the graph is arbitrary. I set the omitted category to zero. Thus, for example, the log minimum toll in ETC Year 4 is $2 * \beta_1 + 2 * \beta_3$ and the log minimum toll in ETC Year -4 is $2 * \beta_4$.

¹⁷ For the same reason, I do not extend the dummies in equations (18a) or (18b) for more years after ETC is adopted.

¹⁸ The point estimates in Figure 3b indicate no pre-period trend in the balanced panel, which is reassuring relative to the (albeit statistically insignificant) suggestive evidence of some downward pre period trend in the full sample in 3a. In Table 6 below I investigate the issue of potential pre period trends in more detail, using a more parsimonious specification to increase statistical precision.

By replacing the indicator variable for whether the facility has ETC (ETC_{it}) with the percentage point change in ETC penetration ($\Delta ETC_Penetration_{it}$), I now allow the effect of ETC to vary over time and across facilities as a function of the diffusion of ETC.¹⁹ As discussed, I must estimate equation (19) on the sub-sample of facilities that never offer an ETC discount, as changes in the ETC discount will affect both the diffusion of ETC and the minimum toll. Column 4 of Table IV shows the results. The coefficient on the change in the ETC penetration rate is 0.623 (s.e. = 0.285). This indicates that every 10 percentage point increase in ETC penetration is associated with a (statistically significant) toll increase of 6.2 percent.

For the full sample of facilities, I estimate equation (19) instrumenting for $\Delta ETC_Penetration_{it}$ with the indicator variable ETC_{it} ; this is equivalent to instrumenting for the change in ETC penetration with a linear trend. Column 5 shows these results. The coefficient on $\Delta ETC_Penetration_{it}$ is 0.557 (s.e. = 0.262), indicating that every 10 percentage point increase in ETC penetration is associated with a (statistically significant) 5.6 percent increase in the toll. To allow the effect of ETC to vary over time, in column 6 I instead instrument for the change in ETC penetration with a cubic polynomial in the number of years the facility has had ETC. The coefficient on $\Delta ETC_Penetration_{it}$ is now 0.501 (standard error = 0.261). The results are also similar if I instead instrument for $\Delta ETC_Penetration_{it}$ with a series of indicator variables for the number of years under ETC (not shown).

The magnitude of the estimated effect of ETC is quite similar across all of the various specifications shown in Table IV. The results from the baseline specification (Table IV, column 1) suggest that after 14 years, by which point ETC has diffused to its steady state level (see Figure II), ETC is associated with an increase in the toll rate of 17 percent, or about one-fifth ($\sim \exp(\beta_{ETCAdopt} + 14*\beta_{ETC})$). The IV estimates in

¹⁹ A more stringent test would be to include both $\Delta ETC_Penetration_{it}$ and ETC_{it} on the right hand side to examine whether the diffusion of ETC has an impact on toll rates that can be distinguished from a linear trend. I find that while the two variables are jointly significant, it is not possible to distinguish the effect of ETC penetration separately from a linear trend (not shown). This is not surprising since, on average, the data contain about 6 years of data on a facility with ETC, and the diffusion pattern of ETC is basically linear for those first 6 years (see Figure II).

columns 5 and 6 suggest that once ETC has diffused to its steady state level of 60%, it is associated with an increase in tolls of 26 and 23 percent respectively ($\sim \exp(\beta_{ETC_{Adopt}} + 0.6*\beta_{\Delta ETC_{Penetration}})$). When the sample is limited to facilities without ETC discounts, the implied steady state increase in tolls is 36 percent when estimating equation 3 (column 3) or 38 percent when estimating equation 5 (column 4). All of these implied steady state toll increases associated with ETC are statistically significant at at least the 10 percent level. Taken together, these estimates suggest that the diffusion of ETC to its steady state level is associated with a 20 to 40 percent increase in toll rates. Given the extremely inelastic demand for driving with respect to the toll that I estimate below, these results suggest that the associated increase in revenue for the toll authority is also about 20 to 40 percent.

6.1.3 Endogeneity of the timing of ETC adoption

I have analyzed the endogenous choice of tax rates while assuming that the choice of the salience of the tax system (i.e. the adoption of ETC) is exogenous. In practice, the decision to adopt ETC does not appear to be random. For example, as previously discussed, higher labor costs in the Northeast may have encouraged more ETC adoption. This does not, however pose a problem for the analysis per se, which requires only that the timing of ETC implementation is uncorrelated with changes in a facility's toll setting relative to its norm.

Nonetheless, the correlation of various observable characteristics with whether or when a facility adopts ETC (see Table II) raises concerns about the identifying assumption that absent the introduction of ETC on facility i in year t , toll rates would not have changed differentially for that facility. I therefore analyze the effect of ETC separately on samples stratified by these characteristics. Table V shows the results. Column 1 replicates the baseline specification (Table IV, column 1). Columns 2 through 7 show the effects separately by geographic region, by facility type (bridges and tunnels vs. roads), and by facility age. Not only does statistical significance generally persist across the sub-samples, but the point estimates are remarkably similar.²⁰ To more directly control for differences across facilities in the underlying rate

²⁰ As a distinct exercise, I was also interested in whether the impact of ETC varied between operating authorities which automatically send monthly statements of expenses to users and authorities from whom drivers had to

of toll growth, column 8 shows that the results are robust to the addition of facility fixed effects to equation (17), which is equivalent to allowing for facility-specific linear trends in toll rates.

One specific source of omitted variable bias that the preceding analysis does not directly address is that ETC adoption may be a part of a broader infrastructure project, or a signal that infrastructure modernization is in the works. In this case, the relationship between ETC and toll increases may be spurious, as infrastructure projects may necessitate (or provide political cover for) toll increases. To investigate this possibility, I compiled histories of infrastructure projects on 115 of the 123 individual toll facilities.²¹ These histories report the timing of a variety of infrastructure projects including renovations, replacements, repairs, widenings, extensions, and other improvements. I constructed indicator variables for whether facility i started an infrastructure project in year t ($INFRAAdopt_{it}$) and whether it had a project either started or ongoing in year t ($INFRA_{it}$). On average, a project was started in 2.2 percent of facility-years, and 10.1 percent of facility-years had an infrastructure project either starting or ongoing. I re-estimate the basic relationship between ETC and toll increases (equation 17) with these two additional variables included as covariates. Column 9 shows that the baseline results (without the additional infrastructure variables) are unaffected by restricting the sample to the 115 facilities for which I have data on infrastructure projects. Column 10 shows that the estimated increase in tolls associated with ETC is not affected in either magnitude or statistical significance by including the two infrastructure variables as controls. This suggests that the increase in tolls associated with ETC is not likely to be spuriously due to a correlation between ETC and infrastructure projects, which themselves are responsible for toll increases; indeed, the results suggest that infrastructure projects are not, in fact, associated with toll increases.

There are of course many reasons, besides infrastructure projects, why the timing of ETC adoption might be spuriously correlated with toll increases. For example, facilities may respond to increased

actively request (and in some cases pay for) ETC expense statements. The point estimates did not suggest any economically or statistically differential impact of ETC on toll rates along this dimension, although the standard errors were sufficiently large that it was not possible to rule out fairly large differences (not shown).

²¹ The primary source of data was facility web pages and annual reports, which often provide detailed histories of work on the facilities. The level of detail and the nature of the projects reported varies across facilities. However, since all of the analysis is within-facility, this should not pose a problem.

congestion by both adopting ETC and by raising tolls as complementary congestion-reducing strategies. This suggests we should observe increases in congestion (or a proxy for it such as traffic) on a facility prior to ETC adoption. Alternatively, facilities might respond to a negative revenue shock by both raising tolls and adopting ETC, with the latter a way to lower revenue losses from the administrative costs of toll collection. This suggests we should observe declining revenue (or declining traffic) on a facility in the years prior to ETC adoption. More generally, we can look for changes in toll rates in the years prior to ETC adoption as a partial test of the identifying assumption that absent the adoption of ETC a facility would not have experienced differential changes in its toll rate. Of course, if the lower salience of ETC makes it easier to raise tolls, ETC might be adopted precisely by facilities that are encountering difficulties in making needed toll increases, suggesting that facilities might experience declines in traffic, revenue or toll increases prior to ETC adoption. While evidence of such effects would therefore not necessarily be inconsistent with the salience story, the lack of any such evidence reduces concerns about omitted variable bias and spurious findings.

Table VI shows the results. I re-estimate equation (17) with three different dependent variables: $\Delta\log(\text{traffic})_{it}$ (columns 1 and 2), $\Delta\log(\text{revenue})_{it}$ (columns 3 and 4), and $\Delta\log(\text{minimum toll})_{it}$ (columns 5 and 6). In addition to the standard regressors (year fixed effects, $ETCA_{it}$ and ETC_{it}) I also include an indicator variable for whether it is 1 to 2 years prior to ETC Adoption (odd columns) or whether it is 1 to 5 years prior to ETC adoption (even columns). The coefficients on these indicator variables for years just prior to ETC adoption show no statistically or substantively significant evidence of systematic changes in traffic, revenue or tolls in the years prior to a facility's adopting ETC. These results are consistent with the results from estimating equation (18a) which show no systematic pre-existing trend in toll rates prior to a facility's adoption of ETC, particularly in the balanced panel (see Figures IIIa and IIIb). One reason why the various endogeneity concerns may not in practice be a problem

is that, as noted in Section 4.2, the different facilities run by a given operating authority tend to all adopt ETC at the same time, and yet may be experiencing different patterns of traffic and tolls.²²

There are several other results of interest in Table VII. The finding in columns 3 and 4 that revenue increases by about 3 percent per year under ETC is broadly consistent with the estimated increase in tolls under ETC and the finding that demand for driving is very inelastic with respect to the toll.²³ There is also some suggestive evidence in columns 1 and 2 that traffic declines under ETC, although these estimates are not statistically significant and are substantively quite small; a decline in traffic would be consistent with the survey evidence in Section 3 of over-estimation of toll levels by ETC users.

6.2 The impact of ETC on the politics of toll setting

The model in Section 2.2 suggested two potential mechanisms behind a finding that reduced salience is associated with increased tax rates: (i) a reduced behavioral responsiveness to taxes, and (ii) a reduction in the political costs of tolls, particularly in the differential political costs of tolls in election years compared to non election years. Section 5 presented evidence for the first potential mechanism. To investigate the political channel, I examine whether there are political costs to tolls and how these costs change under ETC.

Table VII shows the results. Since the political fallout from raising tolls may be concentrated on the extensive margin (i.e. whether tolls are raised), I report results not only for the baseline dependent variable $\Delta \log$ minimum toll (odd columns) but also for the binary dependent variable of whether the minimum toll increased (even columns). Column 1 replicates the baseline results from equation (17) (see Table IV, column 1). Column 2 shows the results from estimating equation (17) with the binary dependent variable for whether the minimum toll was raised that year; the coefficient on ETC_{it} is 0.073 (s.e. = 0.024). This suggests that, relative to the baseline 7.7 percent annual probability of a toll increase, the probability of a toll increase almost doubles on a facility once it has ETC. Combined with the

²² In a different context, Dusek (2003) examines the impact of the introduction of state income tax withholding on tax rates, but notes that the decision to introduce income tax withholding appears to be correlated with increased demand for bigger government, making the results hard to interpret.

²³ For the sample for which I have revenue data, I estimate that ETC is associated with a 2.2 percent increase in tolls each year (not shown).

evidence in column 1, this suggests that the increase in tolls associated with ETC comes about primarily through more frequent toll increases of similar magnitude.

I then expand the baseline specification in (17) to include indicator variables for whether it is an election year, and the interactions of these indicators with the change in salience, as proposed in the estimating equation (15) from Section 2.2. This allows me to examine whether there is a political business cycle in toll setting and whether this political business cycle varies under manual toll collection and ETC. Specifically, I estimate:

$$y_{it} = \gamma_t + \beta_1 ETCAdopt_{it} + \beta_2 ETC_{it} + \beta_3 \mathbf{1}(ElecYear)_{st} + \beta_4 \mathbf{1}(ElecYear)_{st} * ETCAdopt_{it} + \beta_5 \mathbf{1}(ElecYear)_{st} * ETC_{it} + \varepsilon_{it} \quad (20)$$

Columns (3) and (4) report results when $\mathbf{1}(ElecYear)_{st}$ is an indicator for whether there is any state election (for either the governor or the legislature) in state s and year t , about half of the facility-years in the data are an election year, but the timing of the electoral calendar variables across states. Columns (5) and (6) report results when $\mathbf{1}(ElecYear)_{st}$ is two separate indicators for whether the governor (and therefore almost always the legislature as well) is up for election and for whether only the legislature is up for election; each of these indicator variables is turned on in roughly one-quarter of state years.

In all four specifications, the coefficients on all of the election year indicators are negative and statistically significant; this demonstrates the political business cycle under manual toll collection. Given the average annual 2 percent increase in tolls, the coefficient on the election year dummies of about -0.016 in columns (3) and (5) indicates that toll increases are about 75 percent lower during election years than non election years under manual toll collection.

The interaction term between the election year indicator variables and ETC is always positive; it is statistically significant for legislature only election years (columns 5 and 6) and statistically significant (or only marginally insignificant) for any election year (columns 3 and 4). This suggests that under ETC, toll setting behavior is less sensitive to the political election calendar (particularly legislature elections) than under manual toll collection. Indeed, there is no evidence that toll increases are lower in election years relative to non election years under electronic toll collection; the sum of the coefficients on the election

year indicator variable and its interaction with ETC (i.e. $\beta_3 + \beta_5$) is almost always positive (and never significantly negative).²⁴

7. Alternative explanations

In this section, I briefly consider a range of alternative explanations for the increase in tolls associated with ETC other than the decline in the salience of the toll. I note at the outset that a general point in favor of the salience-based explanation is the finding that toll setting becomes less sensitive to the local election calendar under ETC; this is consistent with a decline in salience reducing the political costs of raising tolls, but would not be predicted by any of the alternative explanations I discuss.

7.1 ETC lowers the operating cost of toll collection

ETC is associated with substantial reductions in the annual costs of operating and maintaining toll facilities; the ETC cost savings come primarily from reductions in the labor costs associated with manual toll collection (Pietrzyk and Mierzejewski 1993, Hau 1992, Levinson 2002).²⁵ However, for increases in the efficiency of tax collection to increase the equilibrium tax rate requires an improvement in the *marginal* efficiency of tax collection (Becker and Mulligan, 2003). By contrast, ETC improves the *fixed* component of the efficiency cost of taxation – since the administrative cost savings are independent of the toll rate – which should therefore not prompt an increase in the rate of existing taxes.²⁶

A decline in the fixed administrative costs of tax collection could, however, encourage the introduction of new taxes, such as the introduction of tolls on roads that had not been previously been tolled or the construction of new (tolled) roads where no road existed before. Any such effects of ETC,

²⁴ The “main effect” of ETC, while positive, is no longer statistically significant in columns 3 and 5; toll increases are not statistically significantly larger in non election years under ETC than under manual toll collection. However, toll increases are statistically significantly larger in election years under ETC than under manual toll collection; the sum of the coefficients on ETC and the interaction of ETC and election year (i.e. $\beta_2 + \beta_5$ in equation 20) is statistically significant in column 3 and statistically significant for the legislative election year variable in column 5 (not shown).

²⁵ Toll collection costs under manual toll collection can be quite high. A 1995 study of turnpikes in Massachusetts and New Jersey estimated that toll collection costs under manual toll collection were about 6 percent of toll revenue (Friedman and Waldfogel, 1995); a 2006 study found that on portions of the Massachusetts Turnpike where there is relatively little traffic, toll collection costs were over one third of toll revenue (Kriss, 2006).

²⁶ Note moreover that if operating authorities set tolls to meet an exogenous revenue requirement, the reduction in administrative costs would lower (rather than raise) the equilibrium toll needed to raise a fixed amount of (net) revenue.

however, would not show up in my analysis, which limits the sample to facilities with pre-existing tolls. Lower fixed administrative costs of toll collection could also encourage the installation of more toll collection points on an existing toll facility; however, I find no evidence that ETC had such an effect.²⁷

7.2 ETC installation requires capital outlay

Although ETC lowers the costs of operating and maintaining toll facilities, installation of ETC requires a capital outlay. It seems unlikely that this capital outlay would require an increase in tolls. Operating authorities can borrow to cover these capital costs, and the capital costs are recouped within a few years by the savings in operating and maintenance costs, and by revenue from the sale or lease of the transponders and interest on prepayments and deposits (Pietrzyk and Mierzejewski 1993, Hau 1992). Of course, it is possible that operating authorities might use the installation costs of ETC as an excuse to raise tolls, even though ETC is self-financing. Any such excuse might be used for a one-time increase in tolls when ETC comes in; it seems less natural that this excuse could be used for subsequent increases in tolls as ETC use diffuses among drivers.

7.3 Changes in menu costs associated with ETC

It is possible that ETC lowers the administrative (menu) cost of toll changes. There could be literal menu cost savings if signs listing the toll rate no longer have to be changed under ETC. Alternatively, ETC might allow for smaller increases of non “round” amounts; unlike manual tolls, this would not impose on drivers that they carry small coins. In practice, however, ETC tolls are not less “round” than manual tolls, except when they are specified as a fixed percent discount off of the manual toll. In addition, the increase in tolls associated with ETC persists for the sub-sample of facilities that do not offer discounts; for these facilities, there can be no menu cost savings as changing the electronic toll requires changing the manual toll, and all facilities continue to have at least some manual payers. Finally, even if

²⁷ I re-estimate equation (17) using as a dependent variable a binary measure for whether there is an increase in the number of toll transactions someone driving a one-way, full-length trip on the facility would have to make. I perform this analysis for the full sample of facilities, and separately for both roads and for the bridges and tunnels (not shown).

ETC did reduce menu costs, this should suggest that ETC would be associated with more frequent toll adjustments but it is not clear why this would produce a higher equilibrium toll rate.

7.4 ETC lowers personal compliance costs of toll payment

ETC reduces the drivers' compliance costs of paying tolls (Levinson 2002, Hau 1992). Friedman and Waldfogel (1995) estimate that under manual toll collection, these compliance costs – which consist of time spent queuing and paying tolls at the toll plaza – are, on average, about 15 percent of toll revenue. Reductions in compliance costs of paying tolls may directly increase drivers' willingness to pay the (monetary) toll, and hence provide an alternative explanation for the observed increase in toll rates.

In practice, however, two independent pieces of empirical evidence suggest that toll authorities do not increase tolls in response to reductions in compliance costs; this is consistent with the finding in Section 5 that they set tolls substantially below the revenue-maximizing rate (i.e. that they implicitly place a relatively large weight on consumer surplus). The first piece of suggestive evidence comes from variation across roads in the number of times an individual must make a toll transaction, and hence variation in the compliance costs savings from ETC. For example, in 1985 an individual made 11 toll transactions while driving the length of the Garden State Parkway, compared to only two on the New Jersey Turnpike. If tolls are increased under ETC in response to the reductions in compliance costs, we would expect greater toll increases on roads with a greater number of toll transactions. In fact, I find weak evidence of the opposite. The second piece of suggestive evidence comes from what happens to toll rates when a bridge or tunnel switches from collecting tolls at both ends of the facility to collecting tolls at only one end; at various times over the course of my sample about half of the bridges and tunnels (40 out of 79) made this switch, which reduced compliance costs on their facility in half. I find little evidence of a substantively or statistically significant increase in tolls on a facility following this reduction in compliance costs.²⁸

7.5 ETC raises the optimal congestion-correcting toll

²⁸ The results of both of these two analyses are presented in more detail in the online Appendix (Section C) and in the working paper version of this paper (Finkelstein, 2007).

Could the increase in tolls under ETC come entirely from the increase in the optimal congestion externality-reducing toll that results from the reduced consumer responsiveness to toll? This would suggest that the effect of ETC on toll rates is a salience effect but one that comes entirely from a reduction in salience at the time of consumption (driving). This seems unlikely given the evidence in Section 6.2 that ETC affects the political costs of raising tolls; this suggests that at least some of the toll increase associated with ETC is likely to be due to a decline in voting salience. In addition, as an (admittedly quite) crude test of whether the increase in tolls under ETC is driven by an increase in congestion under ETC, I experimented with controlling for traffic (a proxy for congestion) on the right hand side of equation (17). I find that the impact of ETC on the change in tolls is not sensitive to including traffic as a control, suggesting that even conditional on the level of traffic, tolls still rise under ETC (not shown).

8. Conclusion

This paper has examined the hypothesis that a less salient tax system can produce a higher equilibrium tax rate. Belief in this possibility has contributed to opposition to tax reforms that are believed to reduce tax salience, such as Federal income tax withholding or a partial replacement of the income tax with a value-added tax. Yet the sign of the effect of tax salience on tax rates is theoretically ambiguous, and empirical evidence has been lacking.

I examine the relationship between tax salience and tax rates empirically by looking at the impact of electronic toll collection (ETC) on toll rates. Survey evidence indicates that drivers who pay the toll electronically are substantially less aware of toll rates than those who pay with cash, suggesting that ETC reducing tolls' salience. To analyze the impact of this reduction in salience, I assembled a new data set on toll rates over the last half century on 123 toll facilities in the United States. Since different tolls facilities adopted ETC in different years, and some have not yet adopted it, I am able to examine the within-toll facility change in tolls associated with the introduction of electronic toll collection.

I find robust evidence that toll rates increase following the adoption of electronic toll collection. The estimates suggest that after ETC use among drivers has diffused to its steady state level, toll rates are 20 to 40 percent higher than they would have been under manual toll collection. I provide evidence of two

potential mechanisms by which reduced salience may contribute to increased toll rates: under ETC driving behavior becomes less elastic (in absolute value) with respect to the toll, and toll setting becomes less sensitive to the local election calendar. This decline in the political costs of raising tolls associated with ETC would not be predicted by alternative explanations for the increase in tolls associated with ETC. I also present additional evidence that is not consistent with specific alternative explanations.

As previously discussed, the normative implications of these findings are ambiguous. Evidence on what is done with the extra revenue from the higher tolls – in particular, whether it is used for purposes that may be valued by users of the facility such infrastructure investment or reductions in other highways fees, or whether it primarily serves to increase rents for the governing authority through increased employment or salaries of bureaucrats – could help shed some light on the normative implications of the higher tolls under ETC. Unfortunately, the available data are not sufficient for analysis of this issue.

The results also leave open the question of how tax salience affects tax rates in other contexts, such as federal income tax withholding or the replacement of a sales tax with a value added tax. As previously discussed, the sign of the effect of tax salience on tax rates may well differ for taxes that are a larger share of expenditures than tolls. The magnitude of any effect of tax salience is also likely to differ across different political institutions. The results in this paper suggest that the salience of the tax instrument is an important element to consider in both theoretical and empirical investigations of the political economy of tax setting. Relatedly, they suggest that the empirical impact of tax salience in these other specific settings is an interesting and important direction for further work.

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Table I: Survey Evidence on Driver Awareness of Tolls, by Payment Method

	MA Survey				NYNJ Survey		
	ETC Drivers (1)	Cash Drivers (2)	No Covariates (3)	Covariate Adjusted (4)	ETC Drivers (5)	Cash Drivers (6)	Difference between ETC and Cash Drivers (No covariates) (7)
Fraction report “don’t know”	0.618 (0.490)	0.021 (0.142)	0.597*** (0.060)	0.579*** (0.060)	0.381 (0.486)	0.200 (0.400)	0.18*** (0.05)
Fraction who incorrectly estimate toll	0.851 (0.359)	0.308 (0.463)	0.543*** (0.058)	0.512*** (0.067)	0.826 (0.379)	0.395 (0.489)	0.43*** (0.06)
Mean error, conditional on misreporting	\$1.334 (1.850)	\$0.162 (0.828)	1.172*** (0.275)	1.01*** (0.303)	\$0.40	-\$0.10	\$0.50
N	68	146			271	91	

Note: In columns 1, 2, 5, and 6, standard deviations are (in parentheses); in columns 3, 4, and 7 robust standard errors are (in parentheses) and ***, **, * denote statistical significance at the 1%, 5% and 10% levels respectively. “Error” in the third row is computed as Estimated Toll – Actual Toll Paid. In the MA Survey an estimate of the toll paid was eventually elicited from all but one of the respondents; however, in the NJNY Survey, an estimate of the toll paid was only elicited for those who did not respond “do not know” or “refused”. Thus for the MA Survey, the sample in rows 2 and 3 includes all but one of the respondents in row 1, but for the NYNJ Survey, the sample in rows 2 and 3 includes only those respondents who did not report “don’t know” in row 1. For the NYNJ survey, the cash toll was \$6.00, while the ETC toll was \$5.00 on peak and \$4.00 off peak. For the MA survey, the toll depended on the entrance and exit taken; the average toll paid was about \$1.15; less than 10 percent of drivers in the MA survey sample drove on a portion of the Turnpike in which there are ETC discounts; the results are not affected by omitting these drivers from the analysis. In column 4, covariates consist of age, age squared, median household income of zip code, dealer retail price for the driver’s car (based on information from www.edmunds.com as of October 2007), and indicator variables for gender, whether the driver regularly pays a toll on a commute to work, and highest level of education reached (high school degree or less, college degree, or post-college degree, where college degree” includes associates degree, which were 10% of the college degree sample)). Only published summary statistics (as opposed to the underlying micro data) are available for the NYNJ survey, so that the covariate-adjusted difference in means cannot be computed. In addition, the sample sizes by cell for NYNJ survey had to be approximated based on information in the text on the total sample size (362) and the fraction of drivers that pay by ETC (74.8%). As a result, the standard errors for the NYNJ Survey are also approximated; approximated numbers are shown in *italics*. I calculated standard deviations for the binary response variables in the NYNJ Survey, but there was not sufficient information available to calculate the standard deviation for the mean error (or the standard error of the difference in mean error).

Table II: Which facilities adopt ETC?

	Number of facilities	Probability adopt ETC by 2005	Average adoption date conditional on adoption
All	123	0.71	1998.2
By facility type			
Roads	44	0.70	1996.4
Bridges or Tunnels	79	0.71	1999.2
By region of country			
Northeast	58	0.78	1998.7
Midwest	10	0.60	1996.7
South	41	0.68	1997
West	14	0.57	2000.9

Table III: The elasticity of traffic with respect to tolls

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \log \text{min. toll}_{it}$	-0.049 (0.015) [0.004]	-0.058 (0.018) [0.008]	-0.061 (0.019) [0.009]	-0.057 (0.017) [0.006]	-0.062 (0.039) [0.145]	-0.060 (0.037) [0.135]
$\Delta \log \text{min. toll}_{it} *$ ETC_Penetration _{it}			0.134 (0.038) [0.005]		0.141 (0.076) [0.091]	
$\Delta \log \text{min. toll}_{it} *$ ETC_Year _{it}				0.006 (0.001) [0.002]		0.006 (0.003) [0.062]
$\Delta \log \text{min. toll}_{it} *$ Never_ETC _i			-0.071 (0.136) [0.611]	-0.073 (0.131) [0.588]	-0.009 (0.209) [0.966]	-0.006 (0.205) [0.976]
Mean dep. Var	0.049	0.042	0.043	0.042	0.040	0.039
# of states	21	12	12	12	12	12
# op authors	32	16	16	16	16	16
# of facilities	76	33	33	33	33	33
N	2,200	727	671	727	292	305
Sample restriction(s)		No ETC discounts	No ETC discounts	No ETC discounts	No ETC discounts	No ETC discounts
					+2/-2 sample	+2/-2 sample

Note: Table reports results from estimating variants of equation (16) by OLS. The dependent variable is the change in log traffic. In addition to the covariates reported in the table, all regressions include year fixed effects and a main effect for any variables that are interacted with $\Delta \log(\text{min. toll})$. The bottom row indicates any sample restrictions. “No ETC discounts” limits facilities to those that never off an ETC discount. “+2/-2 sample” limits sample to facility-years in which there is a toll change or the 2 years before or after a facility’s toll change. Never_ETC_i is an indicator variable for whether facility *i* never has ETC. ETC_Penetration_{it} is the share of tolls paid by ETC on facility *i* in year *t*; it is zero in years in which the facility does not have ETC. ETC_Year_{it} is the number of years the facility has had ETC; it is zero in any year in which the facility does not have ETC, 1 the year the facility adopts ETC, 2 the second year the facility has ETC, and so forth. Each operating authority receives equal weight. Standard errors (in parentheses) are clustered by state. P-values are reported [in square brackets].

Table IV: Impact of ETC on Toll Rates.

	Δ Log Min. Toll	Δ Log Manual Toll	Δ Log Toll	Δ Log Toll	Δ log Min. Toll	Δ log Min. Toll
	(1)	(2)	(3)	(4)	(5)	(6)
ETC _{it}	0.015 (0.006) [0.018]	0.020 (0.006) [0.004]	0.024 (0.012) [0.061]			
Δ ETC_ Penetration _{it}				0.623 (0.285) [0.044]	0.557 (0.262) [0.045]	0.501 (0.261) [0.067]
ETCA _{it}	-0.051 (0.035) [0.158]	0.016 (0.032) [0.622]	-0.033 (0.019) [0.097]	-0.051 [0.035] [0.166]	-0.105 (0.109) [0.348]	-0.097 (0.108) [0.380]
Mean dep. var	0.020	0.022	0.017	0.017	0.020	0.020
# of states	24	24	17	17	24	24
# op. author	49	49	31	31	49	49
# facilities	123	123	70	70	123	123
N	5,079	5,079	2,875	2,751	4,815	4,815
Estimation	OLS	OLS	OLS	OLS	IV	IV
Sample restriction			No ETC discount	No ETC discount		

Note: Table reports results of estimating equation (17) (columns 1 – 3) and equation (19) (columns 4 – 6). Column headings define the dependent variable; the bottom two rows provide additional information on the estimation technique and sample restriction. ETC_{it} is an indicator variable for whether facility *i* adopted ETC in year *t*. ETC_{it} is an indicator variable for whether the facility has ETC; it is 1 in the year that ETC is adopted and in all subsequent years. Δ ETC_Penetration_{it} measures the change in the proportion of tolls on the facility paid by ETC; it is zero if the facility does not have ETC. In column (5), the instrument for Δ ETC_Penetration_{it} is ETC_{it}. In column (6), the instrument for Δ ETC_Penetration_{it} is a cubic polynomial in the number of years the facility has had ETC. In addition to the covariates shown in the table, all regressions include year fixed effects. Each operating authority receives equal weight. Standard errors (in parentheses) are clustered by state. P-values are reported [in square brackets]. “No ETC discounts” limits facilities to those that never off an ETC discount. Declines in sample size in column 4 (compared to column 3) and in column 5 or 6 (compared to column 1) reflects missing data on ETC penetration rates (see Section 4).

Table V: Impact of ETC on Toll Rates: Robustness Analysis

	Baseline	Northeast & Midwest	South & West	Roads	Bridges & Tunnels	Open after 1960	Open 1960 or before	Facility Fixed effects	Facilities with Infrastructure data	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ETC _{it}	0.015 (0.006) [0.018]	0.016 (0.010) [0.141]	0.014 (0.005) [0.030]	0.015 (0.008) [0.067]	0.028 (0.010) [0.015]	0.021 (0.010) [0.065]	0.013 (0.007) [0.079]	0.013 (0.007) [0.072]	-0.055 (0.035) [0.125]	-0.055 (0.035) [0.124]
ETCA _{adopt, it}	-0.051 (0.035) [0.158]	-0.048 (0.054) [0.399]	-0.044 (0.027) [0.137]	-0.023 (0.063) [0.719]	-0.086 (0.017) [0.000]	0.051 (0.079) [0.534]	-0.084 (0.025) [0.003]	-0.053 (0.036) [0.147]	0.014 (0.007) [0.048]	0.014 (0.007) [0.048]
INFRA _{ADOPT, it}										0.017 (0.014) [0.221]
INFRA _{it}										-0.003 (0.007) [0.659]
Mean dep. var	0.020	0.022	0.017	0.021	0.020	0.019	0.021	0.020	0.021	0.021
# of states	24	14	10	18	16	13	21	24	23	23
# op authors	49	28	21	24	31	20	39	49	46	46
# of facilities	123	68	55	44	79	43	77	123	115	115
N	5079	3008	2071	1,692	3,387	1,389	3,690	5,079	4,712	4,712

Note: Table reports results from estimating variants of equation (17) by OLS. The dependent variable is the change in the log minimum toll. All regressions include year fixed effects (not shown). Each operating authority receives equal weight. Standard errors (in parentheses) are clustered by state. P-values are reported [in square brackets]. ETC_{adopt, it} is an indicator variable for whether facility *i* adopted ETC in year *t*. ETC_{it} is an indicator variable for whether the facility has ETC; it is 1 in the year that ETC is adopted and in all subsequent years. Columns 2 and 3 limit the sample to, respectively, facilities in the Northeast and Midwest, and facilities in the South and West. Columns 4 and 5 limit the sample to, respectively, roads, and bridges or tunnels. Columns 6 and 7 limit the sample to, respectively, facilities that opened after 1960 and facilities that opened in 1960 or earlier. Column 8 adds facility fixed effects to the right hand side of equation (17). In columns 9 and 10 sample is limited to the 115 facilities for which infrastructure data are available. INFRA_{adopt, it} is an indicator variable for whether facility *i* started a new infrastructure project in year *t*. INFRA_{it} is an indicator variable for whether facility *i* has an infrastructure project in progress in year *t*; it is 1 in the year that the project is started and in all subsequent years that the project is in progress. All estimates give equal weight to each operating authority. Standard errors in (parentheses) are clustered by state, and p-values are shown in [square brackets].

Table VI: Changes in traffic, revenue and tolls prior to ETC adoption.

	Dep Var: $\Delta \log(\text{traffic})$		Dep Var: $\Delta \log(\text{revenue})$		Dep Var: $\Delta \log(\text{minimum toll})$	
	(1)	(2)	(3)	(4)	(5)	(6)
1-2 years before ETCA _{adopted_{it}}	-0.000 (0.007) [0.955]		-0.009 (0.016) [0.599]		0.004 (0.013) [0.777]	
1-5 years before ETCA _{adopted_{it}}		0.013 (0.010) [0.198]		0.006 (0.012) [0.601]		0.009 (0.007) [0.242]
ETCA _{adopt_{it}}	-0.000 (0.010) [0.996]	0.000 (0.010) [0.978]	0.002 (0.025) [0.922]	0.002 (0.025) [0.930]	-0.051 (0.035) [0.158]	-0.051 (0.035) [0.162]
ETC _{it}	-0.006 (0.010) [0.551]	-0.001 (0.010) [0.959]	0.028 (0.015) [0.090]	0.031 (0.015) [0.058]	0.016 (0.006) [0.018]	0.017 (0.006) [0.008]
Mean dep. Var		0.049		0.077		0.020
# of states		21		13		24
# op authors		32		19		49
# of facilities		76		45		123
N		2,200		1,411		5,079

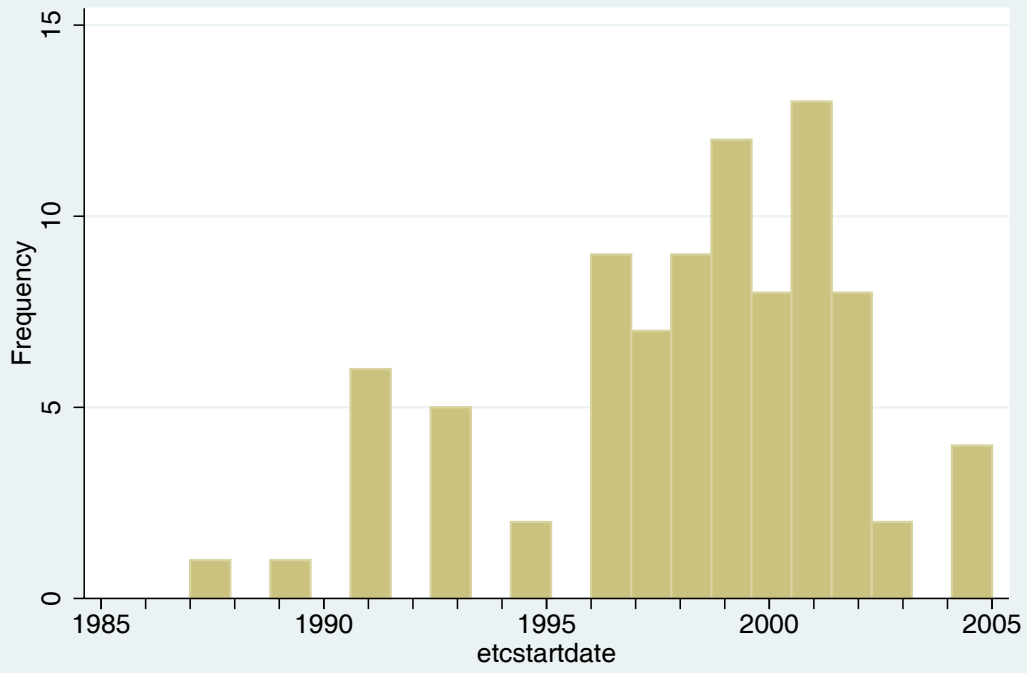
Note: Table reports results from estimating variants of equation (17) by OLS. Dependent variables are defined in the column headings. In addition to the covariates shown in the table, all regressions include year fixed effects. Each operating authority receives equal weight. Standard errors (in parentheses) are clustered by state. P-values are reported [in square brackets]. “1-2 years before ETC_{adopted_{it}}” is an indicator variable for whether it is one to two years before the facility adopts ETC. “1-5 years before ETC_{adopted_{it}}” is an indicator variable for whether it is one to five years before the facility adopts ETC. ETC_{adopt_{it}} is an indicator variable for whether facility *i* adopted ETC in year *t*. ETC_{it} is an indicator variable for whether the facility has ETC; it is 1 in the year that ETC is adopted and in all subsequent years.

Table VII: The impact of ETC on the politics of toll setting

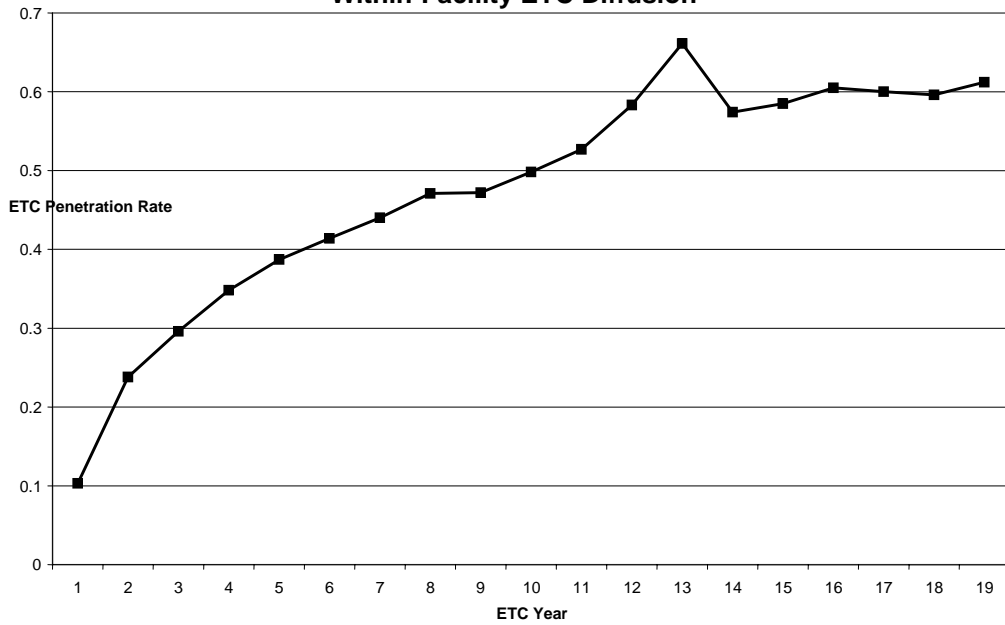
	Δ Log Min Toll (1)	Min Toll Raised? (2)	Δ Log Min. Toll (3)	Min Toll Raised? (4)	Δ Log Min. Toll (5)	Min Toll Raised? (6)
ETC _{it}	0.015 (0.006) [0.018]	0.073 (0.024) [0.006]	0.006 (0.009) [0.507]	0.044 (0.022) [0.042]	0.006 (0.009) [0.494]	0.044 (0.022) [0.042]
AnyElec Year _{st}			-0.016 (0.004) [0.000]	-0.029 (0.010) [0.003]		
GovElec Year _{st}					-0.016 (0.005) [0.001]	-0.036 (0.012) [0.002]
LegOnly ElecYear _{st}					-0.015 (0.005) [0.005]	-0.021 (0.012) [0.085]
AnyElec Year _{st} *ETC _{it}			0.017 (0.012) [0.140]	0.055 (0.027) [0.041]		
GovElec Year _{st} *ETC _{it}					0.004 (0.014) [0.791]	0.016 (0.033) [0.617]
LegOnly ElecYear _{st} *ETC _{it}					0.030 (0.014) [0.038]	0.094 (0.033) [0.005]

Note: Columns 1 and 2 report estimates of equation (17); columns 3 – 6 report estimates of equation (20). Dependent variable (shown in column heading) is Δ log minimum toll (odd columns) or an indicator variable for whether the minimum toll was raised (even columns). In addition to the covariates shown in the table, all regressions include year fixed effects, ETCAdopt_{it}, and interactions between ETCAdopt_{it} and any indicator variables for the election year included in the regression. Each operating authority receives equal weight. Standard errors (in parentheses) are clustered by state. P-values are [in square brackets]. “AnyElecYear_{st}” is an indicator variable for whether state *s*’s governor or legislature is up for election in year *t*. “GovElecYear_{st}” is an indicator variable for whether the governor (and therefore almost always the legislature as well) is up for election. “LegOnlyElecYear_{st}” is an indicator variable for whether only the legislature is up for election. ETC_{it} is an indicator variable for whether the facility has ETC; it is 1 in the year that ETC is adopted and in all subsequent years. Sample size in all columns is 5,079 facility-years, 123 facilities, 49 operating authorities, and 24 “states”. The mean of the dependent variable is 0.020 (odd columns) and 0.077 (even columns).

Figure I: Distribution of ETC Start Dates



**Figure II:
Within-Facility ETC Diffusion**

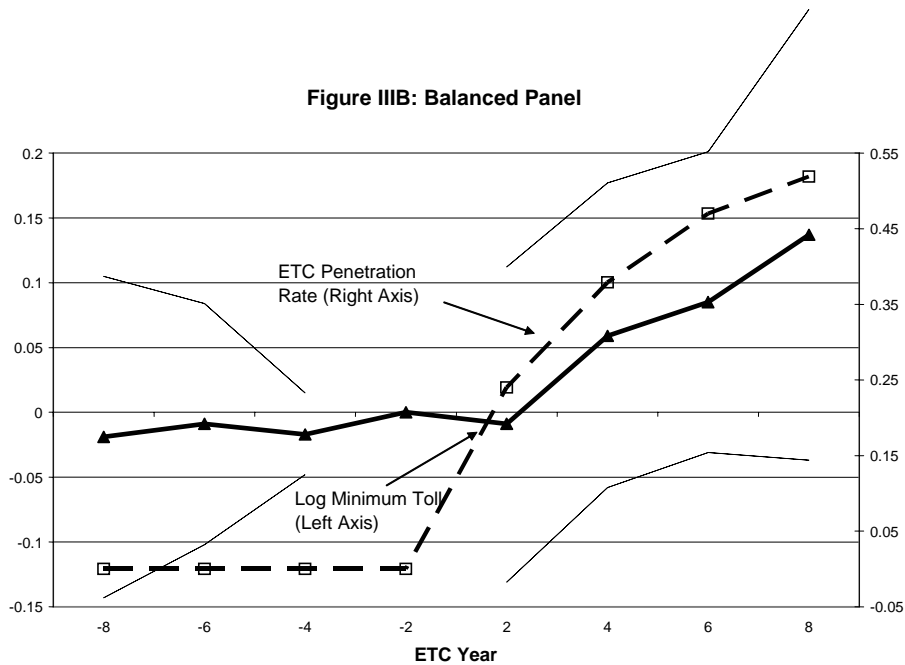
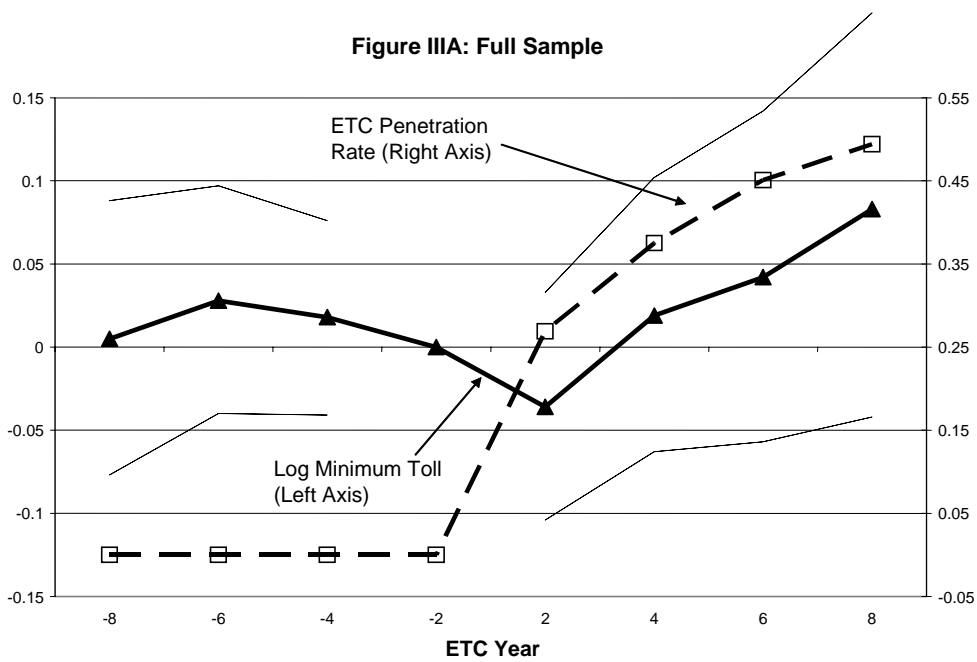


Note: Figure II reports the coefficients on indicator variables for the number of years a facility has had ETC from the

following regression: $ETC_Penetration_{it} = \alpha_i + \sum_{k=1}^{19} \beta_k \mathbf{1}(ETCyear = k)$ where the α_i are facility fixed effects,

$\mathbf{1}(ETCyear=k)$ are indicator variables for whether it is the k^{th} year of ETC, and ETC_Penetration is defined either as percent of toll transactions paid by ETC or percent of revenue paid by ETC, depending on the facility. The regressions is estimated on the sample of facility-years with ETC and data on ETC penetration (N = 467; 84 unique facilities).

Figure III
Time Pattern of Toll Changes and ETC Diffusion



Note: The solid black line shows the pattern of log minimum toll implied by the estimates from equation (18a); the light dashed lines show the corresponding 95 percent confidence interval. The dark dashed line shows the pattern of the ETC penetration rate implied by estimating equation (18b). ETC Year represents the number of years since (or before) ETC adoption. The omitted category (ETC Year -2 for equation 18a and all years prior to ETC adoption for equation 18b) is set to zero. Indicator variables for whether it is 9 or more years after ETC adoption are included in the estimating equation but not graphed; in equation (4a) an indicator variable for whether it is 9 or more years before ETC adoption is also included in the regression but not graphed. In Figure IIIB the sample of ETC-adopting facilities is limited to those who adopted in 1998 or earlier. In Figure IIIB, the upper end of the 95 percent confidence interval for the log minimum toll at 8 years is not shown for scale reasons; it is 0.201 (full sample) and 0.311 (balanced panel). To enhance the readability of the graph, the 95 percent confidence interval on ETC Penetration Rate is not shown. For Figure IIIa the upper and lower 95 percent confidence intervals for ETC Penetration Rate are as follows: (0.16, 0.378) for ETC Year 2, (0.267, 0.484) for ETC Year 4, (0.336, 0.565) for ETC Year 6, and (0.378, 0.610) for ETC Year 8. For Figure IIIB, the analogous confidence intervals are: (0.197, 0.283), (0.333, 0.425), (0.389, 0.550), and (0.419, 0.617).