E-ZTax: Tax Salience and Tax Rates

Amy Finkelstein
MIT and NBER

December 2007

Abstract: This paper tests the hypothesis that the salience of a tax system affects equilibrium tax rates. I analyze how toll rates change after toll facilities adopt electronic toll collection, under which tolls are automatically deducted as the car drives through the toll plaza, eliminating the need to hand over cash. A survey I conducted indicates that drivers are much less aware of toll rates when they pay electronically. I find that, in steady state, toll rates are 20 to 40 percent higher than they would have been without electronic toll collection. Two additional findings support the hypothesis that electronic toll collection increases the toll rate by decreasing its salience: following adoption of electronic toll collection, the short run elasticity of driving with respect to the toll declines (in absolute value), and toll setting behavior becomes less sensitive to the local election calendar. I consider a variety of alternative explanations for these results and conclude that these are unlikely to be able to explain the findings.

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

JEL Classification Codes: H11, H71, R48

I am grateful to Daron Acemoglu, Gene Amromin, Pol Antras, David Autor, Raj Chetty, Peter Diamond, Liran Einav, Hanming Fang, Naomi Feldman, Mike Golosov, Austan Goolsbee, Jerry Hausman, Larry Katz, Erzo Luttmer, Brigitte Madrian, Sean Nicholson, Ben Olken, Jim Poterba, Nancy Rose, Stephen Ryan, Monica Singhal, Heidi Williams, Clifford Winston, two anonymous referees, and seminar participants at Cornell, MIT, Berkeley, Stanford GSB, Yale, and the NBER Public Economics Meeting for helpful comments, to James Wang and especially Julia Galef for outstanding research assistance, to Tatyana Deryugina, Julia Galef, Stephanie Hurder and Erin Strumpf for help conducting the survey of toll awareness, and to the innumerable employees of toll operating authorities around the country who generously took the time to provide data and to answer my many questions

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, 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 for examining 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 two additional pieces of evidence that support the hypothesis that ETC increases the equilibrium toll rate by decreasing its salience. First, I find that the short run elasticity of driving with respect to the actual toll declines (in absolute value) with the adoption of electronic toll collection. Second, I show that under manual toll collection, toll increases are significantly lower during state government election years, but that under ETC toll setting behavior becomes less sensitive to the local election calendar. This suggests that, consistent with a salience-based explanation for the increase in tolls under ETC, ETC reduces the political costs of raising tolls.

I consider a wide range of alternative explanations for the rise in tolls under ETC. Crucially, none would predict the finding that ETC would reduce the political cost of raising tolls. Perhaps the most a priori compelling alternative explanation is that ETC reduces the compliance (i.e. time) costs to drivers of paying tolls, which can increase drivers' willingness to pay the monetary toll costs. In practice, however, the objective function of the toll operating authority that I estimate based on its toll setting behavior under manual toll collection suggests that their response to the reduction in compliance costs associated with ETC would be about two orders of magnitude smaller than the estimated 20 to 40 percent increase in the monetary toll. Consistent with this analysis, two distinct experiments in the data show no detectable increase in toll rates associated with reductions in compliance costs.

I also present evidence that other aspects of ETC are unlikely to be able to explain my findings. For example, I show that the rise in tolls associated with ETC is difficult to explain by the capital outlay required to install ETC. The evidence also suggests that the timing of ETC adoption is not spuriously correlated with increased toll rates.

The analysis in this paper is perhaps most similar in spirit to Becker and Mulligan (2003), who formalize the closely related theoretical idea that a more efficient tax system can raise the equilibrium size of government. Consistent with this theory, they present cross-country evidence that countries with more efficient tax systems have larger government sectors, and within-country evidence that exogenous increases in government spending needs decrease discretionary spending while exogenous increases in government revenue increase government spending.[1]

The rest of the paper proceeds as follows. Section 2 provides a conceptual framework for the likely effects of a decline in tax salience. Section 3 presents evidence that tolls are less salient when paid by ETC than by cash. Section 4 describes the data . Section 5 presents the main empirical results. Section 6 uses the framework in Section 2 to infer the objective function of the toll authorities and shows that the magnitude of the toll increase associated with ETC is consistent with the estimated objective function. Section 7 considers a range of other alternative explanations for the empirical findings. The last section concludes.

2. Effect of Tax Salience on Tax Rates: Conceptual Framework

In a fully salient tax system, individuals are aware of actual taxes as they make economic decisions. In a less salient tax system, some individuals do not directly observe the actual tax when making economic decisions, and instead form a perception of the tax. A natural way to model a decrease in the salience of the tax system is as an increase in the fraction of such individuals in the population. Thus, for example, an increase in the proportion of tolls paid electronically might correspond to a decrease in the salience of the tax system.

In this section, I consider the theoretical effect of a decline in tax salience on the equilibrium tax rate. I begin in Section 2.1 by assuming that a reduction in tax salience reduces the behavioral responsiveness to a tax. Under a wide class of political economy models, the qualitative comparative static prediction is

[1] As another empirical test of the relation between tax efficiency and the size of government, Dusek (2003) examines the introduction of state income tax withholding. He finds that withholding is associated with a mechanical increase in revenue due to less tax evasion, but not with any change in statutory income tax rates. However, his analysis also suggests that the decision to adopt state income tax withholding may be correlated with increased demand for bigger government, making the results hard to interpret. In Section 7.2 below I discuss several pieces of evidence that suggest that the adoption of ETC is not correlated with increased demand for revenue.

that the equilibrium tax rate will increase in response to a decline in behavioral responsiveness to a tax. However the magnitude of the tax increase will vary with the specific model of political behavior.

In Section 2.2 I consider cases in which a decline in tax salience may have different effects from a decline in behavioral responsiveness. When individuals have systematic misperceptions of taxes –as in the public choice tradition of "fiscal illusion" – the sign of the effect of tax salience will depend on whether tax perceptions are biased upward or downward from reality – and therefore whether behavioral responsiveness to the tax increases or decreases. It may also vary depending on the size of the tax relative to the individual's overall budget. This analysis suggests that the effect of tax salience in other tax systems – such as income taxes or commodity taxes – may differ in sign, as well as magnitude, from the effects estimated here.

2.1 Tax setting under different models of government behavior

The equilibrium of many different models of government behavior can be characterized by a reduced form model in which the government chooses the vector of taxes (on a single good) across different groups to maximize a weighted social welfare function of individual indirect utilities and government revenue (Persson and Tabellini, 2000). In this formulation, the chosen vector of tax rates $\vec{\tau}^*$ is the solution to:

$$\max_{\vec{\tau}} \sum_j \nu_j W_j(\tau_j) + (1 - \sum_j \upsilon_j) R(\vec{\tau}) \qquad (1)$$

where the W_j 's are the indirect utility functions of individual (or group) j, $\nu_j \in [0,1]$ is the relative weight the government places on individual (or group) j, and R represents government revenue. Different political economy models are characterized by different weights (ν_j 's). For example, a government that implements the preferences of the median voter with probabilistic voting (as in Lindbeck and Weibull 1987) can be characterized as maximizing (1), with the ν_j 's determined by group j's probability of being the swing (i.e. median) voter. In the lobbying model of Grossman and Helpman (1994), the government maximizes (1) placing more weight on groups that are organized (i.e. make contributions). A Leviathan government (as in Buchanan 1967) chooses taxes to maximize net revenue (R) subject to the feasibility constraint of staying in office; the ν_j's depend on the importance of group *j* for satisfying this constraint. In the limit, a Leviathan government facing no political constraints would behave like a net revenue (i.e profit) maximizing monopolist who maximizes (1) given $\Sigma_j \nu_j = 0$.

This objective function yields a standard inverse elasticity rule for the tax on group *j* (τ_j^*) :

$$\frac{\tau_j^*}{p+\tau_j^*} = \frac{1}{\varepsilon_j}\left(\frac{1-\left(\sum_j \upsilon_j\right)-\lambda_j \upsilon_j}{1-\left(\sum_j \upsilon_j\right)}\right) \qquad (2)$$

where *p* is the producer price of the good (assumed constant with respect to the tax), ε_j is the absolute value of the elasticity of demand for group *j*, and λ_j is the marginal utility of income of group *j*. The tax rate on group *j* (τ_j^*) is decreasing in group *j's* demand elasticity, marginal utility of income, and social welfare weight (ν_j).

Equation (2) yields the standard prediction from optimal tax models that if taxpayers become less elastic in their responsiveness to a particular tax, the government will raise the rate of this tax. It also shows that while this qualitative comparative static obtains under a wide range of political economy models, the magnitude of the tax increase will depend on the particular political economy model (i.e. the social welfare weights ν_j's); the higher the social welfare weight for group *j*, the less the government will raise taxes on this group in response to a decline in their elasticity. In Section 6 I present suggestive evidence of the weights used by toll authorities and compare the predicted tax increase from equation (2) to the estimated tax increase.

2.2 The effect of tax salience on tax rates

The effect of a decline in tax salience on tax rates may differ from the effect of a decline in behavioral responsiveness to the tax if individuals have systematically biased perceptions about taxes. Recent empirical evidence on individuals' responses to non-linear income tax schedules is consistent with such biases (Liebman and Zeckhauser 2004, Feldman and Katuscak 2005). Moreover, a decline in the salience of the tax system can increase the extent of tax misperception. In the particular context I examine, I present evidence that toll misperception is greater under electronic than under manual toll collection (see Section 3).[2] In a similar vein, Chetty et al. (2007) show that a decline in the salience of the sales tax increases misperception of this tax.

If the government lacks the ability to commit to future policy, what matters for the effect of tax salience on tax rates is how tax salience affects perceptions – or misperceptions – of tax *changes*. If individuals under-estimate (or in the extreme do not even observe) tax increases when the tax is less salient, their behavioral response of consumption of the taxed good to the tax increase decreases relative to the fully salient case. For goods such as tolls that are a small part of an individual's overall budget (so that we can ignore any distortionary effects on consumption of other goods via the misperceived budget constraint), this decline in the behavioral response reduces the distortionary effect of the tax increase. Therefore the tax will be increased. By contrast, if individuals over-estimate the tax increase when the tax is not salient, the tax would be expected to decrease with a decline in tax salience, since now the behavioral responsiveness to tax changes increases rather than decreases with a decline in tax salience.

This suggests a testable empirical prediction which I investigate below: if a decline in tax salience is associated with an increase in the tax rate, it should also be associated with a decline (in absolute value) in the elasticity of demand with respect to the tax change. However, it is important to note that this is a prediction about the short run elasticity of demand with respect to the actual tax *change*. The normative implications of any increase in taxes associated with a decline in tax salience depend on the long-run elasticity of demand with respect to the actual tax *level*, which in turn depends on how individuals' expectations of the tax evolve over time (and whether they therefore under, over, or correctly estimate the

[2] The cost of observing the toll need not be large to generate misperception in equilibrium as the benefits from correctly observing the (small) toll are themselves not large.

tax level). A government lacking commitment power, however, will not take these long run expectations into account in setting tax rates, and may therefore engage in sub-optimal behavior.

Finally, the discussion has ignored the budgetary consequences of a misperceived tax and the resultant distortionary effects on other goods. When spending on the taxed good is small relative to the individual's overall budget – as it is in the case of tolls – this may be a reasonable abstraction; utility is effectively quasi-linear in non-toll goods, and therefore the budgetary consequences of any part of the tax increase that is not perceived functions as a lump sum (non distortionary) tax. However, as emphasized by Chetty et al. (2007), for taxes on goods that are a larger share of the individual's budget – such as income taxes – tax misperception may also have distortionary effects on the consumption of the other good, via the effect on the budget constraint. This introduces another source of ambiguity in the expected sign of the effect of reduced tax salience on the tax rate. For example, the sign of the effect of increased under-estimation of the tax change on tax rates will depend on whether the decreased distortionary behavior on the taxed good dominates any increased distortion of consumption of the other goods.

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. This section provides evidence from two separate surveys that individuals are substantially less aware of tolls that they pay electronically than those that they pay 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"). One third of drivers in the Massachusetts Survey and three-quarters of drivers in the NYNJ Survey paid the toll electronically. More details on the MA Survey can be found in Appendix A; more details on the NYNJ Survey can be found in Holguin-Veras et al., 2005.

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 1 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"; [3] by contrast, only 2 percent of drivers who paid with cash had to be prompted to offer a guess about the toll they had paid. 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.[4]

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. In the MA Survey, the average conditional estimation error was +$1.33 for ETC drivers, compared to +$0.16 for cash drivers; the median conditional errors for ETC and cash drivers were +$0.75 and +$0.25, respectively (not shown). In the NYNJ survey, the average estimation error among those who mis-estimated the toll was + $0.40 for ETC drivers, compared to –$0.10 for cash drivers.[5]

---

[3] Indeed, many of the ETC drivers literally responded "I don't know, I used EZ-Pass [or Fast Lane]."
[4] 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 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.
[5] 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

Both surveys thus suggest markedly lower knowledge of tolls among people who paid electronically compared to those who paid with cash. These findings are 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 to the analysis 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 than cash drivers persists in two very different populations. Second, it is possible that cross-sectional differences in awareness of tolls between ETC drivers and cash drivers may reflect other differences in these drivers than merely their payment method. Reassuringly, a comparison of the results in columns 3 and in column 4 of Table 1 show that none of the differences in toll awareness in the MA Survey are sensitive (in either magnitude of statistically significance) to adding controls for demographic characteristics of drivers, including their age, gender, education, median household income of zip code, and the value of the car they drive. Finally, both surveys ask about toll levels while, as discussed in Section 2, for a government that lacks commitment ability, what matters for the tax setting response is individuals' perceptions of tax *changes* not of tax *levels*.[6] 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 cash drivers are also more likely to be cognizant of small changes in the toll than ETC drivers. Relatedly, even though both surveys find that ETC drivers tend to over-estimate tolls, the primary finding is that ETC drivers are much less aware of tolls than cash drivers (indeed, often reluctant to form an estimate of the toll); this suggests that they are likely to be less (rather than more) responsive in their driving behavior to toll changes. Consistent with this interpretation of the survey evidence, Section 5.2 presents evidence

---

percent of drivers 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.

[6]Unfortunately, it was not possible to design a survey to solicit information on knowledge of the latest toll change as the latest toll change occurred on the Mass Pike will vary depending on the particular entrance and exit taken.

that the elasticity of driving with respect to the toll declines in absolute value as the fraction of drivers using ETC increases.

4. Data and Descriptive Statistics

This section provides some brief background on the data. More details can be found in Appendix B.

4.1 Sample construction

The target sample was all 183 publicly-owned toll facilities in the U.S. that were charging tolls in 1985, which predates the introduction of ETC in the U.S.[7] By contacting each toll authority, I was able to collect data for 123 facilities. On average, the data contain 50 years of toll rates per facility.

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. The 123 facilities are run by 49 different operating authorities in 24 different state-like entities (22 states and 2 joint ventures, one between NY and NJ and one between NJ and PA).

4.2 Key variables

4.2.1 ETC Adoption and Diffusion. 87 of the 123 facilities adopted ETC by 2005. Figure 1 shows a histogram of the adoption dates, which range from 1987 through 2005, with a median of 1999. Almost all the variation in whether and when ETC is adopted is between rather than within operating authorities; 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 2 shows that relationship between facility characteristics and ETC adoption. ETC is more common and earlier on roads than bridges and tunnels. ETC adoption rates are highest in the Northeast (70 percent) and lowest in the West (30 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). Indeed, I find that a one standard deviation increase in the average

[7] A toll "facility" is a particular road, bridge, or tunnel; a complete list of facilities is given in Appendix B.

wage of a state or local public employee in the state (as measured in the 1990 census) is associated with statistically significant 10 percentage point increase in the probability a facility has adopted ETC by 2005 (not shown). Whether ETC is adopted does not appear related to the age of the facility; however, conditional on adoption, older facilities tend to adopt 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 as the fraction of toll transactions or revenue collected by ETC) for about two-thirds of facility-years with ETC. Figure 2 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. 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 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, I obtained 34 years of such data per facility.

5. The impact of ETC

Section 5.1 shows that ETC is associated with an increase in tolls. The next two sub-sections present evidence in support of the hypothesized mechanism, namely that ETC increases the equilibrium toll rate by decreasing its salience. Section 5.2 shows that the short run elasticity of driving with respect to the actual toll declines (in absolute value) with the adoption of electronic toll collection. Section 5.3 shows that toll setting behavior becomes less sensitive to the local election calendar under ETC; this suggests that ETC reduces the political cost of raising tolls.

5.1 The Impact of ETC on toll rates

5.1.1. Basic results

The basic estimating equation to examine the effect of ETC on toll rates is:

$$\mathrm{y}_{\mathrm{it}} = \gamma_t + \beta_1 ETCAdopt_{it} + \beta_2 ETC_{it} + \varepsilon_{it} \qquad (3)$$

In the baseline specification, the dependent variable is the change in the log of the minimum toll (Δlog(min toll)$_{it}$).[8] 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}. $ETCAdopt_{it}$ is an indicator variable for whether facility *i* adopted ETC in year *t*; its coefficient measures any level shift in the minimum toll associated with ETC; this might include, for example, the effect of any ETC discounts. 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} measures the average annual growth in a facility's toll once it has ETC. Finally, ε_{it} is a random disturbance term capturing all omitted influences.[9] I estimate equation (3) allowing for an arbitrary variance-covariance matrix within each "state"; the results are not sensitive to clustering on the

[8] I choose a logs rather than levels specification 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. However, I show below that the results are robust to the alternative levels specification.

[9] Equation (3) is specified in first differences. An alternative would be to estimate this equation in levels and to include facility fixed effects. I adopt the first differences specification because in the fixed effects version the residuals are highly serially correlated (with an AR1 coefficient of 0.92). By contrast, the residuals from equation (3) are much less serially correlated (AR1 coefficient of -0.045), making first differences the preferred specification (Wooldridge 2002, p.274-81).

operating authority or facility instead. I give equal weight in the regression to each of the 49 operating authorities; in practice, the results are not sensitive to weighting each facility or each state equally instead.

The first column of Table 3 shows the results from estimating equation (3). 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.

The toll change in the first year of ETC is given by the sum of the coefficients on $ETCAdopt_{it}$ 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 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 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 $ETCAdopt_{it}$ 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 (column 1) – indicates that the estimated growth in tolls after ETC is installed does not merely reflect a 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).[10]

---

[10] Although it might at first appear puzzling that the 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

5.1.2. 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. If ETC increases tolls by reducing their salience, we would expect the effect to be increasing in the ETC penetration rate. On average, ETC penetration increases by 5 percentage points per year. However, the diffusion rate is not constant over time (see Figure 2) 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:

$$\Delta \log(\text{min toll})_{\text{it}} = \gamma_t + \sum_{k=-9}^{k=9} \beta_k \mathbf{1}(ETCYear_{(k,k+1)})) + \varepsilon_{it} \qquad \text{(4a)}$$

and

$$\Delta ETC\_Penetration_{\text{it}} = \gamma_t + \sum_{k=1}^{k=9} \beta_k \mathbf{1}(ETCYear_{(k,k+1)})) + \varepsilon_{it} \qquad \text{(4b)}$$

where $\Delta ETC\_Penetration_{it}$ 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 $\mathbf{1}(ETCYear_{(k,k+1)})$. These are indicator variables for whether it is k or k+1 years since ETC was adopted on the facility. For example, $\mathbf{1}(ETCYear_{(1,2)})$ is an indicator variable for whether ETC was adopted this year or last year (i.e. ETC Year is 1 or 2). In equation (4a), all of the indicator variables represent a two year interval, except for the first (respectively, last) indicator 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 (4b) I include only the post-ETC dummies that are in equation (4a).

Figure 3a 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 (4a) and the dark dashed line shows the corresponding time

---

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.

pattern of ETC diffusion implied by the estimates of equation (4b).[11] 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.[12] Figure 3b therefore shows the results from re-estimating equations (4a) and (4b) 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.[13]

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 (3):

$$\Delta \log(\text{min toll})_{\text{it}} = \gamma_t + \beta_1 ETCAdopt_{it} + \beta_2 \Delta ETC\_Penetration_{it} + \varepsilon_{it} \qquad (5)$$

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. [14] A practical estimation problem is that changes in the ETC discount will affect both the diffusion of ETC and the minimum toll. I therefore

---

[11] 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 $2^*\beta_{-4}$.
[12] For the same reason, I do not extend the dummies in equations (4a) or (4b) for more years after ETC is adopted.
[13] 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 9 below I investigate the issue of potential pre period trends in more detail, using a more parsimonious specification to increase statistical precision.
[14] 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 2).

estimate equation (5) on the sub-sample of facilities that never offer an ETC discount, and for which this problem therefore does not arise. Column 4 of Table 3 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 (5) 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 3. The results from the baseline specification (Table 3, column 1) suggest that after 14 years, by which point ETC has diffused to its steady state level (see Figure 2), ETC is associated with an increase in the toll rate of 17 percent, or about one-fifth (~ exp($\beta_{ETCAdopt}$ + 14*β_{ETC})). The IV estimates in 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 (~ exp($\beta_{ETCAdopt}$ + 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.

5.1.3 Robustness

The identifying assumption behind all of the estimates in Table 3 is that absent the introduction of ETC on facility *i* in year *t*, toll rates would not have changed differentially for that facility. The correlation of various observable characteristics with whether or when a facility adopts ETC (see Table 2) raises concerns about this assumption. I therefore estimate the effect of ETC separately on samples stratified by these characteristics. Table 4 shows the results. Column 1 replicates the baseline specification (Table 3, column 1). Columns 2 through 7 show the effects separately by 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. To more directly control for differences across facilities in the underlying rate of toll growth, column 8 shows that the results are robust to the addition of facility fixed effects to equation (3), which is equivalent to allowing for facility-specific linear trends in toll rates. In Section 7.2, I also show that there is no substantive or statistically significant change in the pattern of changes of toll rates, traffic or revenue prior to ETC adoption.

The remaining columns of Table 4 show robustness along several additional dimensions. Column 9 shows that the results are unaffected by restricting the sample to years 1985 and later. Column 10 shows that the results are robust to specifying the dependent variable as the change in the level rather than the log of the minimum toll. Indeed, given the average annual change in the minimum toll of \$0.032, the coefficient on ETC_{it} of 0.057 (s.e. = 0.018), implies that after installing ETC, the facility's toll rate rises by about 175 percent more per year than it did prior to ETC; this is larger than the baseline estimate of a 75 percent increase in the rate of toll increase (column 1).[15]

[15] An advantage of this specification relative to the log specification is that observations are not censored when the toll rate is set to zero. By construction all facilities are charging a toll at the start of the sample; however, 15 of the 123 facilities subsequently reduce the toll to zero. In the specification in column 10 I include the year the toll is set to zero in the analysis; I do not include the subsequent years of zero tolls since it is not clear whether such a facility is any longer "at risk" for a toll increase. In the baseline specification, however, the year the toll is set to zero is also excluded due to the log dependent variable. To investigate whether this in practice creates problems for the

Finally, in column 11 I investigate whether the impact of ETC varies across operating authorities based on the amount of information provided to ETC users about their monthly charges. 7 operating authorities (representing 21 facilities) automatically send a statement of charges to ETC users, while 19 authorities (representing 54 facilities) do not send statements unless drivers actively request them, and in some cases further require that drivers pay to receive their statement.[16] I re-estimate equation (3) including an indicator variable for whether the authority sends statements automatically, and the interaction of this "automatic" variable with ETC_{it} and $ETCAdopt_{it}$. The results do not suggest any differential effect of ETC across "automatic" and "non automatic" facilities. Likewise, among the facilities that require active requests, I find no differential effect of ETC based on whether drivers must pay for the statement (not shown). These findings are consistent with the literature on "payment decoupling" discussed earlier; receipt of a monthly statement, decoupled from the purchase behavior, is not expected to have much of an effect on awareness of prices, or, correspondingly, on demand. I now turn to a direct examination of the impact of ETC on demand for driving.

5.2 The Impact of ETC on the elasticity of driving with respect to a toll change

As discussed in Section 2, if ETC diffusion raises tolls by lowering their salience, it should also be associated with a decline (in absolute value) in the short run elasticity of demand with respect to the actual toll change. To investigate this, I estimate:

$$\begin{aligned} \Delta \log(traffic)_{it} = \gamma_t &+ \beta_1 \Delta \log(\text{minimum toll}_{it}) + \beta_2 \Delta \log(\text{minimum toll}_{it}) * \text{Never\_ETC}_i \\ &+ \beta_3 \Delta \log(\text{minimum toll}_{it}) * \text{ETC\_Penetration}_{it} \\ &+ \beta_4 \text{Never\_ETC}_i + \beta_5 \text{ETC\_Penetration}_{it} + \varepsilon_{it} \end{aligned} \quad (6)$$

Equation (6) examines the relationship between the annual percent change in a facility's traffic (Δlog(traffic)$_{it}$) and the annual percent change in its toll (Δlog(minimum toll)$_{it}$). It allows this relationship

---

estimation, I re-estimated equation (3) by OLS using as the dependent variable an indicator variable for whether the toll rate on facility *i* in year *t* became zero from a non-zero rate. This occurs in 0.3 percent of the sample. I estimate a negative, and marginally statistically significant coefficient on both ETC variables (not shown). Not surprisingly, facilities are less likely to set tolls to zero after installing ETC, suggesting that, if anything, the censoring of zero toll observations biases downward the estimated effect of ETC on toll rates.

[16] These data are from information on operating authority websites in June 2007. Information was available for all but 5 of the 31 operating authorities (all but 12 of the 87 facilities) with ETC. The main results concerning the effect of ETC on toll increases are indistinguishable if these 12 facilities are excluded from the sample (not shown).

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 other wise), and by the ETC penetration rate on the facility in that year ($ETC\_Penetration_{it}$). Once again, γ_t represents a full set of year fixed effects; these control for any secular changes in traffic over time. The key coefficient of interest in β_3; this indicates how the elasticity changes on a facility as ETC use diffuses. Once again, I allow for an arbitrary variance-covariance matrix within each "state" and give equal weight in the regression to each operating authority.

When estimating equation (6), I limit the sample to the 60 percent of facilities that never offer an ETC discount.[17] As discussed, this allows me to include the ETC penetration rate directly on the right hand side, without worrying about the potential effect of the ETC discount on both this key regressor and the dependent variable. In addition, in this sample there is only one toll rate, which avoids the measurement error that ETC discounts would otherwise introduce in the right hand side toll variable.

Estimation of equation (6) 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 the next sub-section 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 (6) on their lag 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

[17] The analysis is also limited to the approximately two-thirds of facilities for which I obtained traffic data. The estimated impact of ETC on toll rates in this sub-sample is very similar in magnitude to the estimates in the full sample, although no longer statistically significant at conventional levels (not shown).

timing of the toll change is random with respect to short-run traffic changes, although it may reflect longer run demand changes.

It is important to note that the prediction (discussed in Section 2) that the short run elasticity of demand with respect to a tax change will decline (in absolute value) with a decline in tax salience is a partial equilibrium prediction; the government is expected to respond to this decline in elasticity by raising taxes, and indeed the evidence in section 5.1 suggests that this indeed occurs. In equilibrium, therefore, the elasticity need not decline. However, as long as toll authorities do not immediately and fully adjust the toll in response to the change in elasticity associated with ETC – an assumption required for econometric identification of equation (6) as just discussed –we expect to find a decline (in absolute) value in the elasticity associated with ETC.

Table 5 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, 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.

Column 3 shows the results from estimating the complete equation (6). 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 (6) 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

$\Delta \log(\text{minimum toll}_{it}) * \text{ETC\_Year}_{it}$ 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.

The last two columns 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).

5.3 The impact of ETC on the politics of toll setting

Consistent with the hypothesis that reduced salience is responsible for the association between ETC and higher tolls, this section shows that ETC lowers the political cost of raising tolls. The political costs of raising tolls is evident under manual toll collection for which, I find, toll increases are significantly lower during election years for the state's governor or legislature. As toll authorities are typically appointed by the state governor or legislature, it makes sense that the political concerns of these state elected officials affect the toll setting behavior of the toll authorities. However, I find that toll setting is significantly less sensitive to the election cycle under ETC.

Table 6 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 Δ 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 (3) (see Table 3, column 1). Column 2 shows the results from estimating equation (3) with the binary dependent variable; 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 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.

The next two columns extend the baseline specification to present evidence of a "political business cycle" (Nordhaus, 1975) in toll setting. Specifically, I estimate:

$$y_{it} = \gamma_t + \beta_1 ETCAdopt_{it} + \beta_2 ETC_{it} + \beta_3 \mathbf{1}(ElecYear)_{st} + \varepsilon_{it} \qquad (7)$$

In columns (3) and (4), $\mathbf{1}(ElecYear)_{st}$ is an indicator variable for whether there is any election – either of the governor or legislature – in state *s* and year *t*.[18] About half of the facility-years in the data are an election year, but the timing of the electoral calendar varies across states. The results indicate that the average percent increase in the toll (column 3) and the probability of any toll increase (column 4) are both statistically significantly lower in election years. Given the average annual 2 percent increase in tolls, the coefficient on $\mathbf{1}(ElecYear)_{st}$ of -0.015 (s.e. = 0.006) in column 3 indicates that toll increases are about 75 percent lower during election years than non election years. The results in column 4 indicate that the probability of a toll increase is about one-third lower during an election year. In columns (5) and (6) $\mathbf{1}(ElecYear)_{st}$ is instead two separate indicator variables for whether the governor (and therefore almost always the legislature as well) is up for election (roughly one-quarter of states years) and whether only the legislature is up for election (roughly one-quarter of state years). The results indicate that toll increases are significantly lower in both types of election years.

The last four columns examine differences in this political business cycle under manual and electronic toll collection. Specifically, I estimate:

$$\begin{aligned} y_{it} = \gamma_t &+ \beta_1 ETCAdopt_{it} + \beta_2 ETC_{it} + \beta_3 \mathbf{1}(ElecYear)_{st} \\ &+ \beta_4 \mathbf{1}(ElecYear)_{st} * ETCAdopt_{it} + \beta_5 \mathbf{1}(ElecYear)_{st} * ETC_{it} + \varepsilon_{it} \end{aligned} \qquad (8)$$

Columns (7) and (8) report results when $\mathbf{1}(ElecYear)_{st}$ is an indicator for whether there is any election; columns (9) and (10) report results when $\mathbf{1}(ElecYear)_{st}$ is two separate indicators for whether the governor is up for election and whether only the legislature is up for election. In all of the specifications, the coefficient on the election year indicators is negative and statistically significant; this demonstrates the political business cycle under manual toll collection. The interaction term between the election year

[18] For the two composite "states" (NYNJ and NJPA) I consider it an election year if it is an election in either state. I am grateful to Jim Alt, Jim Snyder and Carl Klarner for providing the data on state electoral cycles. Following Klarner, the state legislature is considered up for election if more than 10 percent of one house is up for election.

indicator variable and ETC however, is always positive; it is statistically significant for legislature only election years (columns 9 and 10) and statistically significant (or only marginally insignificant) for any election year (columns 7 and 8). 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).[19]

6. Understanding the response of toll authorities to ETC

As discussed in Section 2, the magnitude of the tax increase associated with a decline in tax salience will depend on the implicit social welfare weights in the tax setting authority's objective function. I can infer these weights from the toll authorities' toll setting behavior prior to ETC.

The general government objective function in (1) maximizes a weighted sum of government revenue and the indirect utility of different individuals. In the specific case of a government owned enterprise such as a toll authority, this objective function can be motivated by the assumption that the enterprise's manager(s) want to maintain employment, which requires the satisfaction of its citizens. Citizens are shareholders in the enterprise, and therefore benefit from profit maximizing prices. However, some or all also consume the publicly produced good; this puts downward pressure on the profit maximizing price, with the extent of the downward pressure depending on the relative weight the government places on these consumers' well being (Peltzman, 1971, Baron and Myerson 1982, Timmins 2002).

If we limit the analysis to one group of consumers (ignoring for example the ability to charge different tolls to regular and intermittent commuters), and assume utility is quasi-linear in the toll (a

[19] The "main effect" of ETC, while positive, is no longer statistically significant in columns 7 and 9; while toll increases are larger in non election years under ETC than under manual toll collection, this difference is not statistically significant. 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. $\beta_2 + \beta_5$) is statistically significant in column 7 and statistically significant for the legislative election year variable in column 9 (not shown).

reasonable assumption given its small budget share), the first order condition for setting taxes (equation 2) simplifies to:

$$\frac{\tau^*}{p+\tau^*} = \frac{1}{\varepsilon}\left(\frac{1-2\upsilon}{1-\upsilon}\right) \qquad (9)$$

As in equation (2) p is the producer price of the good, ε is the absolute value of the elasticity of demand, and $\upsilon \in [0,1]$ now simply denotes the weight that the government owned enterprise places on consumer utility relative to profits; the government as a pure profit maximizer corresponds to $\upsilon = 0$.

Under the assumption of zero marginal cost of toll collection (i.e. p = 0), equation (9) allows us to infer the relative weight on consumer surplus from the estimated equilibrium elasticity of demand. In particular, given the estimate elasticity of -0.049 under manual toll collection (Table 5, column 1) equation (9) implies a relative weight on consumer surplus of 0.49. This suggests that the toll authority's objective function comes very close to a net social surplus maximizer (i.e. ν = ½).

Given these weights, and my estimate of the change in elasticity associated with ETC, I can compute the expected change in the toll associated with ETC and compare it to the estimated toll change under ETC. This serves as a useful reality check on these (independent) estimates. I find they are quite similar.

The results from Table 5 column 3 indicate a short run elasticity of driving with respect to the toll change of -0.061 under manual toll collection and -0.007 at the average ETC penetration rate in my sample of 0.4 (= -0.061 + 0.4 * 0.134).[20] Under ETC, therefore, the elasticity declines to 11 percent of its previous level.[21] With a relative weight on consumer utility of 0.49, the first order condition for the toll authority's toll setting (equation 9) implies that his decline in elasticity should be associated with an increase in the toll rate of about 35 percent. This predicted increase is quite similar to the 36 to 38 percent

[20] Evaluating the elasticity under the steady state penetration rate of 0.6 results in a positive (although statistically insignificant) elasticity of 0.019, which creates conceptual problems for this exercise.
[21] This calculation assumes a constant elasticity of demand, at least within the range of the estimated toll increase associated with ETC. It also ignores any direct effect that ETC may have on the underlying demand for driving, an issue I investigate in more detail in Section 7.1.

increase in tolls estimated in the sample of facilities with no ETC discounts (see Table 3), which is the sample from which the change in elasticity was computed.

7. Alternative Explanations

I consider a range of alternative explanations for the increase in tolls associated with ETC other than the decline in salience of the toll. In particular, I consider the lower compliance costs of paying tolls under ETC (Section 7.1), the potential endogeneity of ETC adoption (Section 7.2), the lower operating costs of toll collection under ETC (Section 7.3), the capital outlays required for ETC installation (Section 7.4), and the potential decrease in menu costs under ETC (Section 7.5). One 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 for the rise in tolls under ETC.

7.1 ETC lowers personal compliance costs of toll payment

ETC reduces the 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 about 15 percent of toll revenue. As a result, the increase in the *total* toll (i.e. monetary toll + monetized time cost) associated with ETC is less than the estimated 20 – 40 percent increase in the monetary toll associated with ETC. Under the generous assumption that ETC reduces compliance costs to zero, in steady state (i.e. with 60 percent ETC penetration) ETC would be associated with a 10 to 27 percent increase in the *total* toll; for drivers who adopt ETC and experience the lower compliance costs, the increase in the total toll would be 4 to 22 percent. Of course, there is substantial heterogeneity across motorists in their value of time (e.g. Small et al. 2005) and drivers who adopt ETC may have a disproportionately higher value of time, as they tend to have relatively high income (Amromin et al., 2005 and Pietrzyk and Mierzejewsli 1993). A driver who adopts ETC and whose time cost is two to three times the average would see a reduction in the total toll.

Reductions in compliance costs may be part of the way that ETC reduces the visibility of tolls; indeed, as noted in the Introduction, reductions in the compliance costs of paying taxes – such as federal income tax withholding – are often opposed on the grounds that they make taxes less visible, and therefore encourage an increase in these taxes. However, reductions in compliance costs of paying tolls may also directly affect demand for driving and hence the equilibrium toll rate.[22]

7.1.1 Expected magnitude of toll increase associated with reduction in compliance costs

To investigate whether the decline in compliance costs can explain the estimated increase in tolls under ETC, I do a back of the envelope calculation of the expected increase in the toll associated with the ETC-induced reduction in compliance costs. I find that it is several orders of magnitude lower than the toll increase I estimate. This suggests that compliance costs reductions are unlikely to be the primary driver of the increase in tolls associated with ETC.

For this calculation, I assume that the monetary toll and compliance costs are perfect substitutes – so that the demand for driving is a function only of the total toll – and use a local linear approximation to the demand curve for driving. Under these assumptions, a toll authority which sets tolls according to the first order condition (9) with (as estimated) a relative weight on consumer utility of 0.49 would be expected to raise the toll by $0.04 for every $1 reduction in compliance costs. Even if ETC completely eliminated the 15 cents of compliance costs for all drivers, the average toll authority would be expected to raise tolls by only 0.6 percent, which is considerably smaller than the estimated 20 to 40 percent increase in the monetary toll associated with ETC. Intuitively, because the toll authority places a high weight on consumer utility (relative to profits) in setting tolls, it is optimal to allow much of the "rents" from reduced compliance costs to accrue to the consumer, rather than to extract it via higher prices, as the profit maximizing monopolist would do.

7.1.2 Do toll authorities raise tolls substantially in response to reduced compliance costs?

Consistent with the results of this back of the envelope calculation suggesting that toll authorities would not raise tolls substantially in response to reductions in compliance costs, I present two

[22] Relatedly, it is possible that the increase in demand for driving associated with ETC raises congestion and hence raises the optimal congestion tax. As a crude test of this I examined whether the analysis of the impact of ETC on the change in toll rates in equation (3) was sensitive to including the change in traffic as a control variable, and found that it was not.

independent, suggestive pieces of empirical evidence that there is no detectable increase in tolls in response to reductions in compliance costs. Each test has limitations, which I discuss in more detail below. Nonetheless, it is reassuring that the results suggest that compliance cost reductions are unlikely to be associated with large toll increases.

The first piece of 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, there is weak evidence of the opposite.

Table 7 shows the results. Column 1 shows that the baseline result of an increase in tolls associated with ETC persists when I re-estimate equation (3) on the sub-sample of facilities that are roads. In columns 2 through 4 I enrich equation (3) to include interactions of both $ETCAdopt_{it}$ and ETC_{it} with a variable that measures the compliance costs associated with toll collection on the facility in 1985; I also include the main effect for the measure of compliance costs.[23] Columns 2 through 4 show results for three different measures of compliance costs: the number of separate toll transactions involved in a full length trip on the road (column 2), the number of transactions per dollar of toll (column 3), and the number of transactions per mile of toll (column 4). For all three measures, the results suggest that the increase in tolls associated with ETC is in fact *lower* on roads with higher compliance costs; the coefficient on ETC_{it} *ComplianceCost is always negatively and, sometimes, statistically significant. This is not consistent with the prediction of the compliance cost story that the increase in tolls associated with ETC should be higher on roads where compliance costs are a greater share of the total toll.

[23] I define this variable in 1985, since the number of transactions is potentially affected by whether a facility has ETC. In practice, as discussed in Section 7.3, there is no evidence of an effect of ETC on the number of toll transactions. Not surprisingly, therefore, the analysis in Table 7 is not affected if I allow the number of transactions variable to be time varying (not shown).

Of course, roads with different compliance costs of toll paying may differ for other reasons in their responsiveness to tax salience. For example, roads with greater compliance costs may have higher menu costs of toll changes, introducing an offsetting effect. More generally, authorities that choose different levels of compliance costs may have different political dynamics to begin with. In this regard, it is somewhat reassuring that roads with different compliance cost measures appear otherwise similar on a number of observable dimensions, including the probability and timing of ETC adoption, their location across the county, and their age. While there is some evidence in Table 7 that roads with greater compliance costs had different average toll increases prior to ETC (see the coefficient on the main effect of the compliance cost measure), the sign of this difference varies across the compliance cost measure. The one systematic difference across roads with different compliance costs is that – almost by definition – roads with barrier toll systems (in which toll plazas are set up at various points along the road) have higher compliance costs than roads with ticket toll systems (in which the toll is paid twice, once upon entering the road and once upon exiting the road). In the bottom panel of Table 7, I therefore repeat the analysis limiting the sample to roads to the three-quarters of roads that have barrier toll systems; the results are not affected.

The second piece of suggestive evidence of little responsiveness of tolls to reductions in compliance costs comes from the impact of switching from two-way to one-way tolling. About half of the bridges and tunnels (40 out of 79) switch from collecting tolls at both ends of the facility to collecting tolls at only one end. Figure 4 shows the distribution of these switching dates. This switch from two-way to one-way tolling cuts compliance costs of toll paying in half, a reduction of similar magnitude to the reduction in compliance costs associated with steady state (i.e. 60 percent) ETC penetration. It therefore provides an opportunity to gauge the direct impact of such reductions in compliance costs on toll rates. Of course, it is possible that the change to one-way tolling also affects the salience of tolls; it is not clear, for example, if paying 50 cents twice is more or less salient than paying $1 once. Therefore, a priori, evidence of an impact on tolls is not necessarily a problem for the salience story. However, the fact that I find no compelling evidence of an increase in tolls associated with a switch to one-way tolling mitigates against the hypothesis that the impact of ETC on tolls stems from its effect on reducing compliance costs.

Table 8 shows the results. Column 1 shows the baseline result of the increase in tolls associated with ETC persists when I re-estimate equation (3) on the sub-sample of facilities that are bridges and tunnels. In column 2, I add an additional right hand side indicator variable for whether it is the year in which the facility switched from two-way to one-way tolling ($OneWayAdopt_{it}$).[24] Unlike ETC whose use diffuses over time and whose effects on toll rates is therefore expected to occur incrementally over time, the switch to one-way tolling is instantaneous, and therefore any effect on toll rates might also be expected to be instantaneous. The coefficient on $OneWayAdopt_{it}$ is 0.041 (s.e. = 0.035) which suggests that the change from both-way to one-way tolling is associated with a statistically insignificant 4.1 percent increase in tolls. By contrast, the coefficients on $ETCAdopt_{it}$ and ETC_{it} in column 2 together imply that after ETC has diffused to its steady state level, it is associated with a statistically significant increase in toll rates of 36 percent (~exp($\beta_{ETCAdopt}$ + 14*$\beta_{\Delta ETC}$)). I can reject that the implied steady state effect of ETC is the same as that from the switch to one-way tolling at the 90% confidence level.

To allow for possible lags in the effect of a change to one-way tolling – and to make the specification of the effect of this change identical to that used to gauge the effects of ETC – in column 3 I add an indicator variable for whether the facility switched to one way tolling that year or a previous year ($OneWay_{it}$).The coefficient on $OneWay_{it}$ is statistically insignificant while the (corresponding) coefficient on ETC_{it} is unaffected in magnitude or statistical significance; I do not, however, have enough power to reject that the coefficients on ETC_{it} and $OneWay_{it}$ are statistically distinguishable.

Of course, it is possible that the effect of reduced compliance costs on one bridge is very different from the effect of a system-wide adoption of ETC which reduces compliance costs on many facilities simultaneously. To investigate this, I limited the sample of ETC adopters to facilities that adopted in 1993

[24] Recall that the tolls on bridges and tunnels are defined as the tolls on a round trip, so that there is no mechanical effect on tolls from changing from two-way to one-way tolling.

or earlier (the first 15% of adopters) and for whom network benefits are likely to be smaller (since by definition there are fewer other facilities on which the technology can be used). The point estimate on ETC_{it} remains the same as in the baseline specification in column 1 of Table 3 (0.015), although the standard error increases to 0.007. This provides some suggestive evidence that the toll response to ETC is not increasing in the size of the ETC network, as would be expected if reductions in compliance costs were the primary cause of the rise in tolls associated with ETC.[25]

7.2 Endogeneity of the timing of ETC adoption

The paper analyzes the endogenous choice of tax rates while assuming that 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. This section investigates the validity of this identifying assumption.

A priori, there are reasons why the timing of ETC adoption might be spuriously correlated with toll increases. For example, facilities may respond to increased congestion by both adopting ETC and raising tolls as complementary congestion-reducing strategies. This suggests we should observe increases in congestion on a facility (or a proxy for it such as traffic) 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

[25] Another potential difference between the two reforms is that drivers using ETC continue to see other cash-paying drivers waiting on line and are therefore reminded of their time savings, whereas with the switch to one-way tolling, drivers may quickly forget how much time they are saving. However, since willingness to pay presumably depends on the level, rather than the change, in compliance cost (at least in standard models), it is not clear that this should make a difference for toll setting behavior.

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 9 shows the results. I re-estimate equation (3) 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, $ETCAdopt_{it}$ 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 (4a) 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 3a and 3b). One reason why the various endogeneity concerns may not in practice be a problem is that, as noted above, 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.

Several other results in Table 9 warrant mention. The finding that revenue increases by about 3 percent per year under ETC is consistent with the estimated increase in tolls under ETC and the finding that demand for driving is very inelastic with respect to the toll.[26] There is also some suggestive evidence that traffic declines under ETC, although these estimates are not statistically significant and are substantively quite small. This decline in traffic is consistent with the survey evidence in Section 3 of over-estimation of toll levels by ETC users. As discussed in Section 2, however, toll setting by a toll authority lacking commitment ability will be based on perceptions of toll changes, rather than toll levels.

7.2.1 ETC and Infrastructure projects

[26] 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).

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.[27] 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 3) with these two additional variables included as covariates.

The results are shown in Table 10. Column 1 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 2 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.[28]

Moreover, the results suggest that infrastructure projects are not, in fact, associated with toll increases. The coefficient on $INFRAAdopt_{it}$ in column 2 suggests that the start of an infrastructure project is associated with a statistically insignificant one-time increase in tolls of 1.7%. There is no evidence that

[27] 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.

[28] In results not shown I also find that the effect of ETC on toll increases is not sensitive to additional controls for whether the infrastructure project is a "major" infrastructure project. I identified about 40 percent of the projects as "major" based on the description provided and information about costs when available.

having an ongoing infrastructure project is associated with continued increases in tolls; the coefficient on $INFRA_{it}$ is -0.003 (s.e. = 0.007).[29]

7.3 ETC lowers the operating cost of toll collection

ETC is associated with substantial reductions in the annual costs of operating and maintaining toll facilities (Pietrzyk and Mierzejewski 1993, Hau 1992, Levinson 2002) which, under manual toll collection, are about 6 percent of toll revenue (Friedman and Waldfogel, 1995). The cost savings arise primarily from reductions in the labor costs associated with toll collection. 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.[30]

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, 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.[31]

7.4 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, since 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

---

[29] Both the point estimates and standard errors on these infrastructure variables are unaffected if equation (3) is estimated without the ETC variables (not shown).

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

[31] I re-estimate equation (3) 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.

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.

7.5 Changes in menu costs associated with ETC

Finally, 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 not 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 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.

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. Consistent with the hypothesis that ETC increases toll rates because it reduces the salience of the tax system, I also find that the short run elasticity of driving with respect to the actual toll change declines (in absolute value) under ETC. Further, I find that under ETC, toll setting becomes less sensitive to the local election calendar than it was under manual toll collection. This suggests that ETC reduces the political costs of raising tolls, which is consistent with the salience-based explanation for the increase in tolls under ETC. Moreover, this decline in the "political business cycle" of toll setting 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.

The normative implications of these findings are ambiguous. As previously discussed, the finding that, under ETC, demand becomes less elastic with respect to toll changes does not necessarily imply that the optimal toll rate is higher; the optimal toll depends on the long run elasticity of demand with respect to the actual tax level which in turn depends on how individuals who do not directly observe toll changes set these long run expectations. A government that lacks commitment power or does not behave as a benign social planner could have an incentive to adopt a less salient tax system even if it reduces social welfare. 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 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 discussed, the sign of the effect of tax salience on tax rates is theoretically ambiguous, and 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 impact of tax salience in these other specific settings is an interesting and important direction for further work.

References

Amromin, Gene, Carrie Jankowski, and Richard Porter. 2005. "Transforming Payment Choices by Doubling Fees on the Illinois Tollway." Unpublished mimeo.

Baron, David and Roger Myerson. 1982. "Regulating a Monopolist with Unknown Costs." *Econometrica* 50: 911 – 930.

Becker, Gary and Casey Mulligan. 2003. "Deadweight costs and the size of government." *Journal of Law and Economics,* XLVI: 293 – 340.

Brennan, Geoffrey and James Buchanan. 1980. "The power to tax: Analytical foundations of a fiscal constitution." Cambridge University Press, Cambridge.

Buchanan , James and Richard E. Wagner. 1977. *Democracy in Deficit.* NY: Academic Press.

Buchanan, James. 1967. "Public Finance in Democratic Process."

Chetty, Raj, Kory Kroft and Adam Looney. 2007 "Salience and taxation: Theory and evidence." NBER Working Paper 13330.

Dollery, Brian and Andrew Worthington. 1996 "The empirical analysis of fiscal illusion", *Journal of Economic Surveys*, 10, pp. 261–298.

Dusek, Libor. 2003. "Do Governments Grow When they Become More Efficient? Evidence from Tax Withholding." Unpublished PhD Dissertation, University of Chicago.

Feldman, Naomi and Peter Katuscak. 2005. "Should the Average Tax Rate by Marginalized?" Mimeo. http://econ.bgu.ac.il/facultym/nfeldman/WPapers/Should_the_Average_Tax_Rate_Be_Marginalized.pdf

Friedman, David and Joel Waldfogel. 1995. "The Administrative and Compliance Cost of Manual Highway Toll Collection: Evidence from Massachusetts and New Jersey." *National Tax Journal*, June.

Friedman, Milton and Rose Friedman. 1998. "Two Lucky People." University of Chicago Press.

Grossman, Gene and Elhanan Helpman. 1994. "Protection for Sale." *American Economic Review* 84 (4): 833-850.

Hau. Timothy. 1992. "Congestion Charging Mechanisms for Roads: An Evaluation of Current Practice" World Bank Research Paper 1071. Washington: The World Bank, December.

Holguin-Veras, Jose, Ozbay Kaan, and de Cerrano, Allison. 2005. "Evaluation Study of the Port Authority of New York and New Jersey's Time of Day Pricing Initiative." http://www.rpi.edu/~holguj2/PA/PANYNJ%20Final%20Report.pdf.

Kearney, Melissa. 2005. "The Economic Winners and Losers of Legalized Gambling". *National Tax Journal.* June.

Levinson, David. 2002. "Financing Transportation Networks."

Liebman, Jeffrey and Richard Zeckhauser. 2004. “Schmeduling”. Unpublished mimeo. Available at http://www.ksg.harvard.edu/jeffreyliebman/schmeduling.pdf

Lindbeck, A. and Weibull, J. 1987. “Balanced-budget redistribution as the outcome of political competition.” *Public Choice* 52 (3): 273-297.

Nordhaus, William. 1975. “The Political Business Cycle.” *The Review of Economic Studies* 42 (2): 169 – 190.

Oates, Wallace. 1988. “On the nature and measurement of fiscal illusion: a survey.” In Geoffrey Brennan et al (eds) “Taxation and Fiscal Federalism: Essays in Honour of Russell Mathews”, pp. 65–82. Sydney: Australian National University Press.

Peltzman, Sam. 1971. “Pricing in Public and Private Enterprises: Electric Utilities in the United States.” *Journal of Law and Economics* 14(1): 109-147.

Persson, Torsten and Guido Tabellini. 2000. Political Economics – Explaining Economic Policy. MIT Press. Cambridge, MA.

Pietrzyk, Michael and Edward Mierzejewski. 1993. “Electronic Toll and Traffic Management Systems.” Washington DC, National Academy Press.

Slemrod, Joel. 1996. “Which is the Simplest Tax System of Them All?” in Hank Aaron and William Gale (eds.) “The Economics of Fundamental Tax Reform” The Brookings Institution, pp. 355 – 391.

Small, Kenneth, Clifford Winston, and Jia Yan. 2005. “Uncovering the Distribution of Motorists’ Preferences for Travel Time and Reliability.” *Econometrica* 73 (4): 1367 – 1283.

Soman, Dilip. 2001. “Effects of Payment Mechanism on Spending Behavior: The Role of Rehearsal and Immediacy of Payments.” *Journal of Consumer Research* 27: 460 – 474.

Thaler, Richard. H. 1999. “Mental Accounting Matters.” *Journal of Behavioral Decision Making* 12(3): 183 – 206.

The President’s Advisory Panel on Federal Tax Reform. 2005. “Simple, Fair, and Pro-Growth: Proposals to Fix America’s Tax System.” U.S. Government Printing Office, Washington D.C.

Timmins, Christopher. 2002. “Measuring the dynamic efficiency costs of regulators’ preferences: Municipal water utilities in the arid west.” *Econometrica* 70(2): 603 – 629.

U.S. Census Bureau. 1985. “Annual Survey of State and Local Government Finances and Census of Governments.”

U.S. Department of Transportation, various years. “Highway Statistics, YEAR.”

Wooldridge, Jeffrey. 2002. “Econometric Analysis of Cross Section and Panel Data.” MIT Press. Cambridge: MA.

Appendix A: Survey of Toll Awareness

I conducted a survey in May 2007 of toll awareness of 214 individuals who were attending a large, open-air antiques show in Brimfield Massachusetts.[32] The venue was chosen to ensure easy access to a large number of people who were likely to have driven on a toll road (in this case, I-90, otherwise known as the Mass Pike) to reach the venue.[33]

Individuals at the antique show were approached and asked if they had driven on the Mass Pike that day to get to the antiques show. If they answered yes, they were asked if they would take 1 to 2 minutes to answer some survey questions for MIT researchers. They were informed that the survey was entirely voluntary and they did not have to answer any questions that they did not want to answer. Only the driver was surveyed and other passengers were asked not to participate in helping to answer the questions. The survey questionnaire is shown at the end of this appendix.

The survey was designed to collect information on drivers' awareness of the toll that they had paid during their drive. Specifically drivers were asked "What is your best guess of how much you paid in tolls today on the Mass Pike on your drive here?" The survey also collected data on the entrance and exit that they had taken (so that the actual toll paid could be computed and compared to their estimated toll).[34] Finally, I collected basic demographic information on the respondents. The survey instrument is shown at the end of Appendix A.

One-third of drivers reported paying using ETC. This is broadly consistent with data from the Massachusetts Turnpike Authority indicating that, in 2005, 55 percent of tolls on the Mass Pike were paid for using ETC. Note that the survey data is weighted by drivers while the Authority's data is weighed by transactions. It is likely that the transaction-weighted number from my sample would look quite similar to the Authority's estimate, as individuals in my sample who reported paying with ETC were over twice as likely to report that they "regularly drive through a toll plaza on a commute to work."

Appendix Table A reports the demographic characteristics of the sample overall, and separately for ETC and cash drivers. About two-thirds of survey respondents were from Massachusetts; another 23 percent are roughly evenly drawn from CT, NH, NY and RI (not shown). On average the sample population is slightly richer than the general population. For example, for the Massachusetts respondents (about two-thirds of the sample), average median household income of their zip code was $60,157 compared to $54,143 for Massachusetts residents overall in the 2000 Census (not shown).

Reassuringly, where comparisons are feasible, the statistics on drivers who use ETC relative to those who use cash are similar to those found in other studies. Consistent with other survey evidence (Amromin et al., 2005, Pietrzyk and Mierzejewsli 1993), Appendix Table A shows that individuals who drive frequently on toll facilities are more likely to adopt ETC, and that drivers who adopt ETC are of higher socio-economic status (as measured by zip code-level income, educational attainment, or the value of their car) than those who do not. The two types of drivers are quite similar in terms of age and gender, as well as in terms of the average cash toll for the trip taken on the day of the survey.

The differences in demographic characteristics between ETC and cash drivers raises the concern that these drivers may differ in their awareness of tolls for other reasons than their method of toll payment. It

[32] Brimfield, in Western Massachusetts, is easily reached from Exit 8 or 9 on I-90. It hosts what it bills as the "largest outdoor antiques show in the world" three times a year; it estimates over 130,000 visitors per show.

[33] Pilot attempts at other venues in Massachusetts, such as a mall near I-90, pointed to the difficulty in using other venues, as most had traveled only a short distance, for which there were many alternative non-toll roads.

[34] About 9 percent of both drivers who paid with cash and those who paid electronically drove on a portion of the Mass Pike in which the toll is lower if paid electronically. For these drivers, the actual toll paid based on their payment method was used in calculating the error in toll estimation. None of the results of the survey are affected either qualitatively or quantitatively by omitting this sub-sample of individuals for whom the toll varied by method of payment (not shown). The toll schedules for passenger cars on the Mass Pike can be found here: http://www.masspike.com/pdf/tolls/toll_class1.pdf (cash schedule) and here http://www.masspike.com/pdf/tolls/toll_class1FL.pdf (ETC schedule).

is not a priori obvious in what direction these differences might bias awareness of tolls. On the one hand, ETC drivers may be more likely to be aware of tolls as they drive more often on toll roads, and are higher educated. On the other hand, ETC drivers are wealthier and may therefore be less likely to pay attention to small costs such as tolls. Reassuringly, a comparison of the results in columns 3 and 4 of Table 1 indicate that none of the differences in toll awareness are at all sensitive (in either magnitude of statistically significance) to adding controls for the covariates shown in the bottom half of the table.

MIT TRANSPORTATION STUDY

1.	What is your best guess of how much you paid in tolls today on the Mass Pike on your drive here?	$ ___ . ___
	TICK HERE IF FIRST RESPONSE WAS some version of "I don't know" and respondent had to be prompted to give an answer.*	___
2.	Where did you get on the Mass Pike today? **SHOW LIST OF ENTRANCES. RECORD ENTRANCE NUMBER.**	___
3.	Where did you get off the Mass Pike today? **SHOW LIST OF EXITS. RECORD EXIT NUMBER.**	___
4.	Did you pay cash for the toll today or did you use Fast-Lane / EZ-Pass?	1 Cash 2 Fast lane / EZ Pass 9 Don't know
5.	Do you regularly drive through a toll plaza on a commute to work?	1 Yes 2 No 6 Don't work / not applicable
6.	What is your zip code?	___
7.	What is the make, model and year of the car you drove here today?	
7a.	Make:	___
7b.	Model:	___
7c.	Year:	___
8.	What is the highest grade of school you completed, or the highest degree you received?	1. Grade: ___ 2. High school 3. College 4. Post-college
9.	How old are you?	___
10.	**SURVEYOR NOTE GENDER.**	1 Male 2 Female

* Surveyors were instructed to allow a pause for individuals to volunteer a guess on their own, and to only mark the respondent as saying "I don't know" if the respondent did not volunteer any guess, but stopped at this point and had to be urged (prompted) to please make their best guess. In the end, all but one of the surveyed individuals made a guess.

Appendix B: Construction of toll data set

B.1 Sample

The target sample is all publicly owned toll facilities in the United States (excluding ferries) that were charging a toll in 1985. I chose the year 1985 to ensure at least 20 years of toll rate history on each facility, as well as data on all roads prior to the first facility's adoption of ETC in the United States (which occurred in 1987).

I identified the target sample as the universe of toll facilities from the 1985 and 1986 volumes of "Highway Statistics" published by the U.S. Department of Transportation. In a few instances, I added facilities to the data that did not appear independently in the "Highway Statistics" volumes but that were disaggregated for us by the operating authority when we contacted them (such as the "Bee Line East Expressway" which is part of the "Florida Turnpike System" in "Highway Statistics").

To construct the necessary data, I contacted each toll operating authority and requested toll rate histories for each of their toll facilities from 1950 or its opening (whichever was later) through 2005. I also requested the date (if any) that ETC was adopted, annual traffic and revenue data, and the annual fraction of traffic and revenue accounted for by ETC. The data collection effort took place mainly in the first six months of 2006. I consider the data usable if it contains the date of ETC adoption and toll rate histories back to at least 1985.

The target sample consists of 183 toll facilities run by 88 operating authorities in 31 states. Of these, I was able to collect the requisite data for 123 facilities run by 49 operating authorities in 22 states. For the acquired facilities, opening dates range from 1924 to 1985, with a median opening date of 1955. All of the facilities in the sample started charging tolls on the opening date. About sixty percent of the facilities are bridges or tunnels; the remainder consists of roads.

Appendix Table B1 provides some summary statistics on the 123 facilities in the sample. Specifically, it lists for each state and operating authority, the facilities for which I collected data, the date the facility started charging tolls, the date my toll data start (if later than the toll start date), the date (if any) at which the facility adopted Electronic Toll Collection (ETC), and whether the facility ever offered a discounted toll rate to ETC users. For purposes of the analysis, I defined two additional "states" ("New Jersey – Pennsylvania and New York – New Jersey") to reflect the fact that certain operating authorities – specifically, the Port Authority of New York and New Jersey, the Delaware River Joint Toll Bridge Commission, and the Delaware River Port Authority – are under the purview of two states (NY and NJ, and NJ and PA, respectively). The sample for analysis therefore consists of 24 state-like entities, as reflected in Table B1.

Appendix Table B2 provides a list of the 60 facilities in the target sample for which we were unable to find data. Not surprisingly, a factor that is strongly predictive of a lack of success in getting toll data is that the facility is no longer charging a toll toward the end of our sample period. Only half of the facilities that we were unable to collect data for were still charging tolls in 2003, compared to over 90 percent of the facilities for which I was able to collect data. Of the 9 states in which I was unable to collect data on any target facilities, 4 (CT, IA, MN, and WA) were no longer charging tolls in 2003**.** For facilities that were no longer charging tolls by the end of out sample period, I was usually unable to find any contact information, particularly if the operating authority that managed that facility no longer had any toll charging facilities. (Indeed, 8 out of the 13 facilities that were not charging a toll in 2003 that I was able to collect data for were managed by operating authorities that still had other facilities charging tolls). For the vast majority of facilities for which I am missing data that were still charging tolls at the end of our sample period, I contacted the relevant operating authority repeatedly but was unable to obtain the necessary data; in a very few of these cases, I was unable to find the relevant contact information.[35] Another noticeable pattern in success in data collection is that we are missing data on all 12 target facilities in TX (even though all but 1 of the 10 operating authorities were still running facilities charging tolls by the end of the sample period). The TX operating authorities either did not respond to inquiries or did not provide sufficient data (despite multiple requests) to be included in the analysis.

The missing facilities raise questions about the validity of analyzing the impact of ETC on only a sub-sample of toll facilities. To the extent that the missing data is related to systematic geographic characteristics – such as the lack of any data on TX – we may wish to interpret the results as applicable only in certain states. A potentially more major concern is the selection on the dependent variable. As noted, facilities that are no longer charging tolls are much less likely to be in the sample. However, this likely biases my analysis against finding an effect of ETC on toll increases as facilities that are no longer charging tolls (and are therefore not experiencing any toll increases by definition) are much less likely to have adopted ETC. Indeed, only 1 of the 15 facilities in the acquired sample that had stopped charging a toll by 2005 had ever adopted ETC.

B.2 Variable definitions

ETC Penetration: I define the ETC Penetration rate as the fraction of toll transactions or the fraction of toll revenue collected by ETC. The definition of ETC penetration varies across (but not within) facilities depending on whether I could obtain more years of data for the fraction of toll transactions or the fraction of toll revenue paid for by ETC. These measures may differ because of ETC discounts. Where I observe both, the correlation is 0.90. Since all of the analysis is within-facility, this slight variation in definition across facilities should not pose any problems.

For over 95 percent of facilities, ETC penetration is defined based on all toll revenue (or transactions); in a few cases it refers to just passenger car revenue (or transactions). For about two-thirds of facilities ETC penetration was reported separately for each facility. For the others, it was reported for the entire operating authority; for these, I impute to each facility-year the operating authority - year average. Since, as discussed, adoption of ETC is almost always simultaneous on facilities within an operating authority, this should be a reasonable approximation.

Tolls: Tolls are defined as the nominal toll rate for passenger cars; high frequency discounts (i.e. commuter discounts) are not coded. None of the facilities offer time-of-day varying prices. I collected data on both the "manual" (i.e. cash) toll rate and the discounted electronic toll rate, if offered. I define the toll on bridges, tunnels, or causeways as the round-trip cost on that facility; I use the round-trip rate because 40 of the 79 bridges and tunnels changed from collecting a toll on both ends of the bridge to only collecting it on one end during the sample period. I define the toll rate on a road as the cost of a full length trip on this road. Where the road has several potential branches (such as the PA turnpike), I code a full length trip as the length on the mainline; where a road forks at one end (such as the New Jersey Turnpike), I code the full length trip as the longer fork. One potential concern with this definition is that it may fail to capture some toll changes on a road. Specifically, toll changes will be missed if they occur on uncoded branches (such as branches of the PA turnpike other than the mainline), on exit or entrance ramps along the road, or on non full-length routes within a ticket system (such as the New Jersey turnpike). In practice, I determined that this is unlikely to have any effect on my analysis. I constructed an indicator variable "any toll increase" that is coded if the road has a toll change on the coded toll *or* an unrecorded toll change for any of the reasons just discussed. I find that the analysis of the impact of ETC on the probability of a toll increase yields literally the same point estimates and standard errors when this

[35] These were: the White County Bridge Commission, the Indiana Transportation Finance Authority, the Bellevue Bridge Commission, and the Roma International Toll Bridge.

variable is used instead of the standard binary variable for a coded toll increase; this is not surprising, given that the correlation between "any toll increase" and the standard binary variable for a recorded toll increase is 0.98 on roads.

In 2005, the average (manual) toll was $5.41 for a full length trip on a road (implying an average per-mile toll of $0.063)[36] and $3.03 for a round-trip on a bridge or tunnel.

As noted in the text, 15 of the 123 toll facilities that are charging a toll in 1985 subsequently set the toll to zero. These facilities (and the date that the toll is set to zero) are as follows: Astoria-Pt. Ellice Bridge (1993), Bluegrass Parkway (1991), Coronado Bridge (2002), Cumberland Bridge (2003), Daniel Boone Parkway (2003), Jackson Purchase Parkway (1992), Mt. Hope Bridge (1998), Murray Road Toll Bridge (2000), Navarre Bridge (2004), Norfolk-Virginia Beach Toll Road (1995), Pennyrile Parkway (1992), Rock Island Centennial Bridge (2003), Torras Causeway (2004), Vincent Thomas Bridge (2001), and Western Kentucky Parkway (1986). All of these facilities keep the toll at zero through 2005. However, it does not appear that a toll set to zero is always an absorbing state. Two facilities that set tolls to zero prior to 1985 subsequently reintroduced positive tolls: Antioch Bridge (reintroduced a toll in 1978) and Carquinez Bridge (reintroduced a toll in 1957). I treat all facility-years with zero tolls as censored in the analysis. As noted in the text, this may bias the estimated effect of ETC downward, as facilities are less likely to set tolls to zero when they have ETC; indeed of the 15 facilities that set their tolls to zero, only the Navarre Bridge adopted ETC and subsequently set the toll rate to zero.

Traffic and revenue: I considered data on toll revenue or toll traffic usable if I was able to get at least 10 years of facility-level data. For a facility with usable data, on average I collected 34 years of data. For over 95 percent of facilities, the data pertain to all toll revenue or toll traffic; in a few cases they pertain only to passenger cars. Traffic and revenue data are all reported at the facility level, except for the three facilities in the New Hampshire Department of Transportation and for the three facilities in the Illinois State Toll Highway Authority for which they are reported at the level of the operating authority. For these, I assign the operating authority value to each facility within it.

Over the sample, traffic on a facility grew on average by 4.9 percent per year and (nominal) facility revenue by 7.7 percent.

---

[36] Mileage data for a full length trip were taken from U.S. Department of Transportation (2003) or information from the operating authority's web site.

Figure 1: Distribution of ETC Start Dates

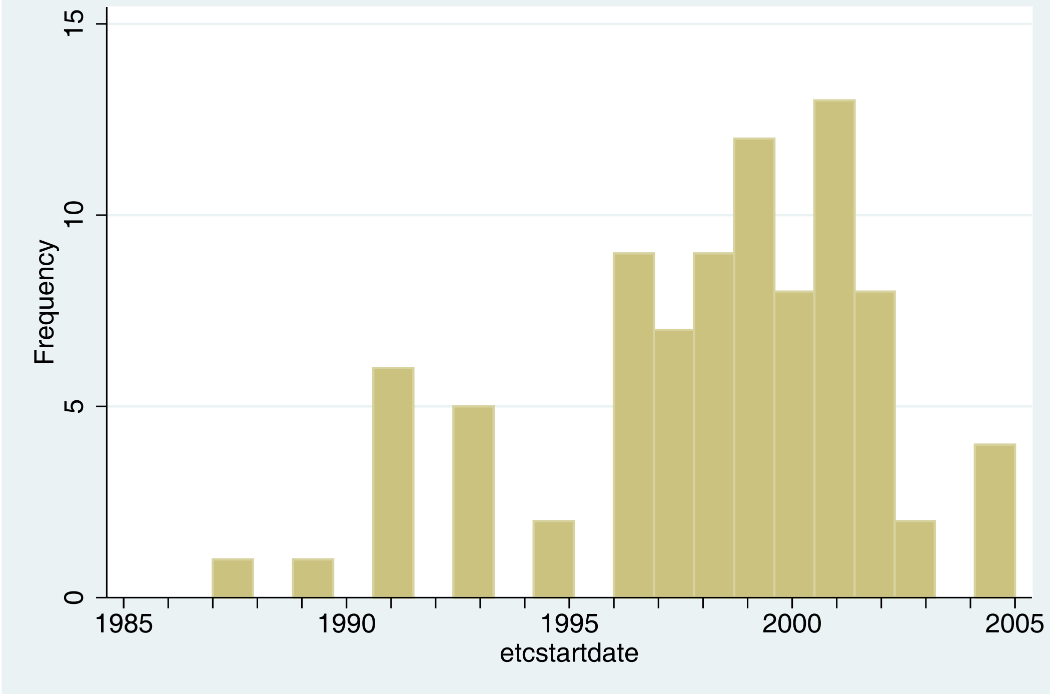
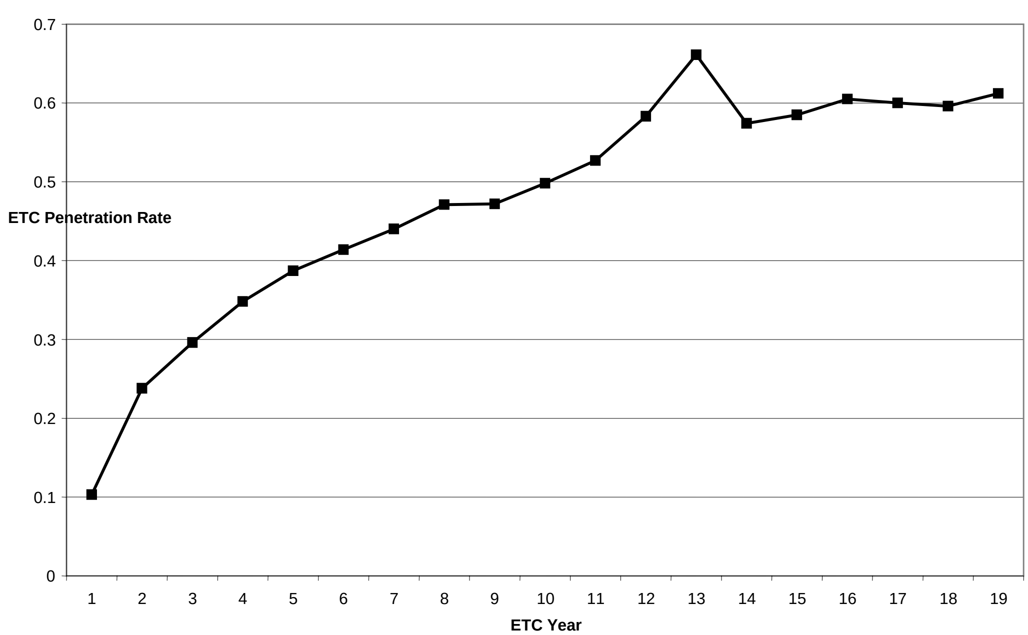


Figure 2: Within-Facility ETC Diffusion



Note: Figure 2 reports the coefficients on indicator variables for the number of years a facility has had ETC from the following regression: $\text{ETC\_Penetration}_{it} = \alpha_i + \sum_{k=1}^{19} \beta_k \mathbf{1}(ETCyear = k)$ 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.

Figure 3: Time Pattern of Toll Changes and ETC Diffusion

Figure 3A: Full Sample

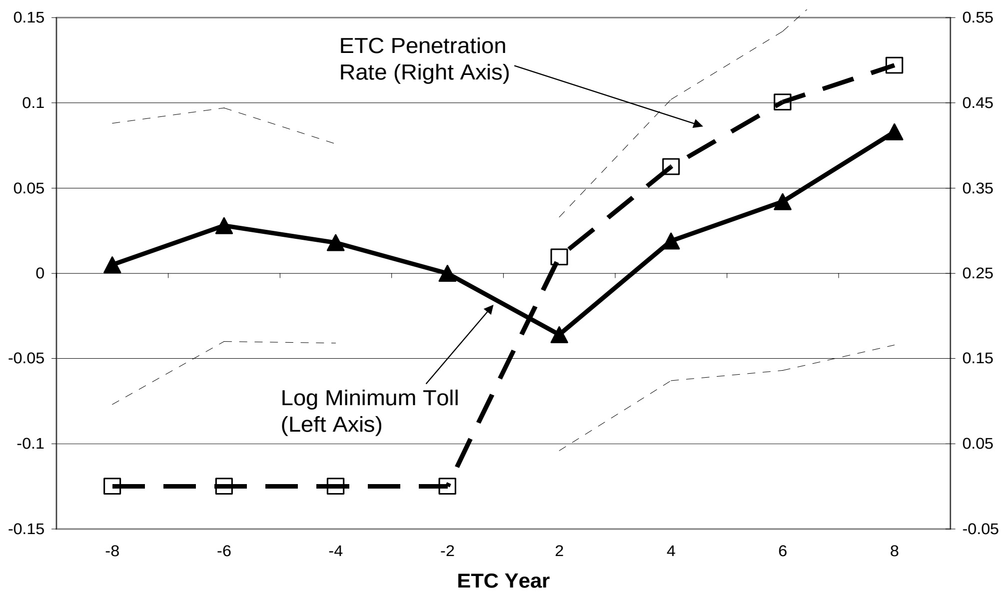
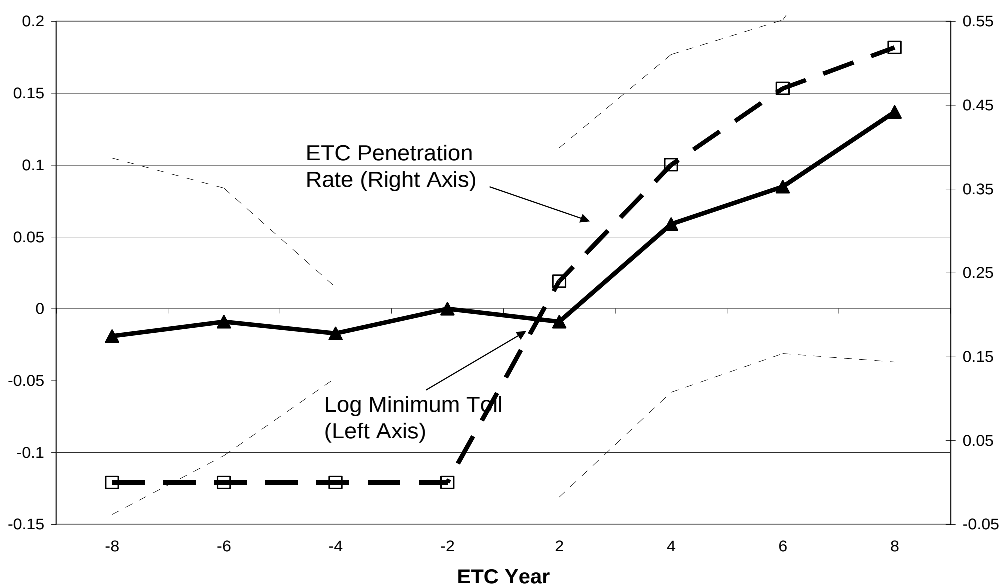


Figure 3B: Balanced Panel



Note: The solid black line shows the pattern of log minimum toll implied by the estimates from equation (4a); 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 (4b). ETC Year represents the number of years since (or before) ETC adoption. The omitted category (ETC Year -2 for equation 4a and all years prior to ETC adoption for equation 4b) 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 3B the sample of ETC-adopting facilities is limited to those who adopted in 1998 or earlier. In Figure 3B, 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 3A 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 3B, the analogous confidence intervals are: (0.197, 0.283), (0.333, 0.425), (0.389, 0.550), and (0.419, 0.617).

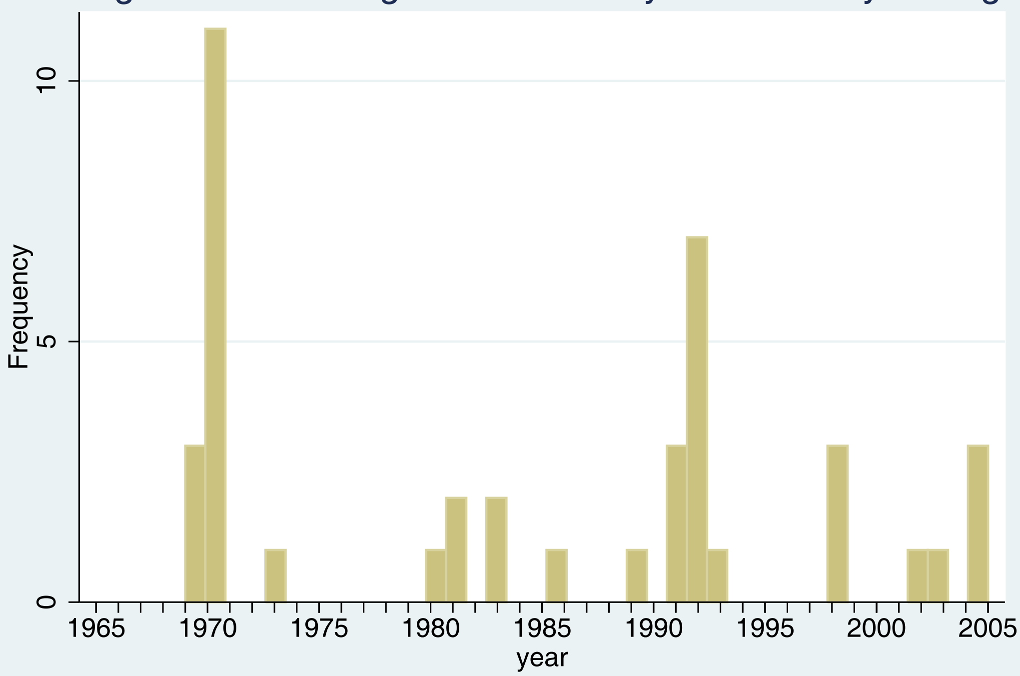


Figure 4: Switching from Two−Way to One−Way Tolling

Table 1: Survey Evidence on Driver Awareness of Tolls, by Payment Method

	MA Survey				NYNJ Survey		
			Difference between ETC and Cash Drivers				
	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. The MA Survey is a 2007 in-person survey of 214 individuals who had driven that day on the Massachusetts Turnpike to an antiques show in Western Massachusetts; more details on the Massachusetts survey can be found in Appendix A. The NYNJ Survey is a 2004 telephone survey 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; more details on the NJNY survey can be found in Holguin-Veras et al. (2005), especially pages 116 – 126 and pp. 383 – 394. 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 2: Which facilities adopt ETC?

	Probability adopt ETC by 2005	Average adoption date conditional on adoption
Facility type		
Roads	0.76	1996.5
Bridges or Tunnels	0.52	2000
Region of Country		
Northeast	0.70	1999.1
Midwest	0.58	1998.5
South	0.65	1996.4
West	0.30	2000.4

Note: Based on ETC adoption dates from 88 facilities. See text for more details.

Table 3: Impact of ETC on Toll Rates.

	Δ Log Min. Toll (1)	Δ Log Manual Toll (2)	Δ Log Toll (3)	Δ Log Toll (4)	Δ log Min. Toll (5)	Δ log Min. Toll (6)
ETC_{it}	0.015	0.020	0.024			
	(0.006)	(0.006)	(0.012)			
	[0.018]	[0.004]	[0.061]			
ΔETC_ Penetration$_{it}$				0.623	0.557	0.501
				(0.285)	(0.262)	(0.261)
				[0.044]	[0.045]	[0.067]
$ETCAdopt_{it}$	-0.051	0.016	-0.033	-0.051	-0.105	-0.097
	(0.035)	(0.032)	(0.019)	[0.035]	(0.109)	(0.108)
	[0.158]	[0.622]	[0.097]	[0.166]	[0.348]	[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 (3) (columns 1 – 3) and equation (5) (columns 4 – 6). Column headings define the dependent variable; the bottom two rows provide additional information on the estimation technique and sample restriction. $ETCAdopt_{it}$ 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. ΔETC_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 ΔETC_Penetration$_{it}$ is ETC_{it}. In column (6), the instrument for ΔETC_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 4: Impact of ETC on Toll Rates: Robustness Analysis

	Baseline (1)	Northeast & Midwest (2)	South & West (3)	Roads (4)	Bridges & Tunnels (5)	Open after 1960 (6)	Open 1960 or before (7)	Facility Fixed effects (8)	1985ff (9)	Dep var: Δ min toll (10)	Statement receipt (11)
ETC_{it}	0.015	0.016	0.014	0.015	0.028	0.021	0.013	0.013	0.015	0.057	0.016
	(0.006)	(0.010)	(0.005)	(0.008)	(0.010)	(0.010)	(0.007)	(0.007)	(0.006)	(0.018)	(0.007)
	[0.018]	[0.141]	[0.030]	[0.067]	[0.015]	[0.065]	[0.079]	[0.072]	[0.018]	[0.004]	[0.046]
$ETCAdopt_{it}$	-0.051	-0.048	-0.044	-0.023	-0.086	0.051	-0.084	-0.053	-0.051	-0.091	-0.034
	(0.035)	(0.054)	(0.027)	(0.063)	(0.017)	(0.079)	(0.025)	(0.036)	(0.035)	(0.066)	(0.055)
	[0.158]	[0.399]	[0.137]	[0.719]	[0.000]	[0.534]	[0.003]	[0.147]	[0.158]	[0.181]	[0.539]
ETC_{it}* $Automatic_i$											-0.004
											(0.013)
											[0.752]
$ETCAdopt_{it}$* $Automatic_i$											-0.022
											(0.053)
											[0.677]
Mean dep. var	0.020	0.022	0.017	0.021	0.020	0.019	0.021	0.020	0.027	0.032	0.020
# of states	24	14	10	18	16	13	21	24	24	24	22
# op authors	49	28	21	24	31	20	39	49	49	49	44
# of facilities	123	68	55	44	79	43	77	123	123	123	111
N	5079	3008	2071	1,692	3,387	1,389	3,690	5,079	2,450	5094	4463

Note: Table reports results from estimating variants of equation (3) by OLS. The dependent variable is the change in the log minimum toll except in column 10 where it is the change in the 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]. $ETCAdopt_{it}$ 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 (3). Column 9 limits the sample to years 1985 and later. In column 10 the dependent variable is the change in the minimum toll. In column 11, equation (3) is augmented to include an indicator variable ("automatic") for whether the facility automatically sends statements of charges to ETC users (coefficient not shown) and the interaction of both $ETCAdopt_{it}$ and ETC_{it} with "automatic"; the decline in sample size reflects the fact that this information was unobtainable for 12 facilities

Table 5: The elasticity of traffic with respect to tolls

	(1)	(2)	(3)	(4)	(5)	(6)
Δ log min. toll $_{it}$	-0.049	-0.058	-0.061	-0.057	-0.062	-0.060
	(0.015)	(0.018)	(0.019)	(0.017)	(0.039)	(0.037)
	[0.004]	[0.008]	[0.009]	[0.006]	[0.145]	[0.135]
Δ log min. toll $_{it}$ * ETC_Penetration$_{it}$			0.134		0.141	
			(0.038)		(0.076)	
			[0.005]		[0.091]	
Δ log min. toll $_{it}$ * ETC_Year$_{it}$				0.006		0.006
				(0.001)		(0.003)
				[0.002]		[0.062]
Δ log min. toll $_{it}$ * Never_ETC$_i$			-0.071	-0.073	-0.009	-0.006
			(0.136)	(0.131)	(0.209)	(0.205)
			[0.611]	[0.588]	[0.966]	[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 (6) 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 Δlog(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 6: 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)	Δ Log Min. Toll (7)	Min Toll Raised? (8)	Δ Log Min. Toll (9)	Min Toll Raised? (10)
ETC_{it}	0.015	0.073	0.016	0.074	0.016	0.074	0.006	0.044	0.006	0.044
	(0.006)	(0.024)	(0.006)	(0.024)	(0.006)	(0.024)	(0.009)	(0.022)	(0.009)	(0.022)
	[0.018]	[0.006]	[0.017]	[0.006]	[0.016]	[0.005]	[0.507]	[0.042]	[0.494]	[0.042]
AnyElec $Year_{st}$			-0.015	-0.026			-0.016	-0.029		
			(0.006)	(0.011)			(0.004)	(0.010)		
			[0.017]	[0.023]			[0.000]	[0.003]		
GovElec $Year_{st}$					-0.017	-0.036			-0.016	-0.036
					(0.006)	(0.013)			(0.005)	(0.012)
					[0.011]	[0.010]			[0.001]	[0.002]
LegOnly $ElecYear_{st}$					-0.013	-0.014			-0.015	-0.021
					(0.007)	(0.013)			(0.005)	(0.012)
					[0.064]	[0.263]			[0.005]	[0.085]
AnyElec $Year_{st}$ $*ETC_{it}$							0.017	0.055		
							(0.012)	(0.027)		
							[0.140]	[0.041]		
GovElec $Year_{st}$ $*ETC_{it}$									0.004	0.016
									(0.014)	(0.033)
									[0.791]	[0.617]
LegOnly $ElecYear_{st}$ $*ETC_{it}$									0.030	0.094
									(0.014)	(0.033)
									[0.038]	[0.005]

Note: Columns 1 and 2 report estimates of equation (3); columns 3 – 6 report estimates of equation (7); columns 7 – 10 report estimates of equation (8). Dependent variable (shown in column heading) is Δlog 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).

Table 7: The impact of ETC-induced reductions in compliance costs on toll rates

Measure of compliance costs	(1)	Number of transactions (2)	Number of trans-actions per $ toll (3)	Number of transactions per mile (4)
Panel A: All roads				
ETC_{it}	0.015	0.023	0.024	0.029
	[0.008]	(0.011)	(0.011)	(0.013)
	(0.067]	[0.043]	[0.048]	[0.046]
ETC_{it} *(Measure of compliance costs)		-0.004	-0.008	-0.132
		(0.002)	(0.004)	[0.047]
		[0.122]	[0.057]	[0.013]
$ETCAdopt_{it}$	-0.023	-0.047	0.016	0.009
	(0.063)	(0.083)	(0.044)	(0.078)
	[0.719]	[0.575]	[0.716]	[0.905]
$ETCAdopt_{it}$ *(Measure of compliance costs)		0.010	-0.024	-0.360
		(0.010)	(0.025)	(0.153)
		[0.323]	[0.340]	[0.033]
Measure of compliance costs		-0.002	-0.001	0.053
		(0.001)	(0.003)	(0.029)
		[0.017]	[0.806]	[0.086]
Panel B: Barrier toll roads				
ETC_{it}	0.015	0.024	0.025	0.034
	(0.007)	(0.011)	(0.012)	(0.019)
	[0.740]	[0.040]	[0.050]	[0.096]
ETC_{it} *(Measure of compliance costs)		-0.004	-0.009	-0.151
		(0.003)	(0.005)	(0.071)
		[0.158]	[0.085]	[0.057]
$ETCAdopt_{it}$	-0.027	-0.058	0.033	0.013
	(0.081)	(0.104)	(0.067)	(0.130)
	[0.740]	[0.586]	[0.633]	[0.921]
$ETCAdopt_{it}$ *(Measure of compliance costs)		0.012	-0.030	-0.397
		(0.011)	(0.024)	(0.345)
		[0.312]	[0.232]	[0.275]
Measure of compliance costs		-0.002	-0.0002	0.072
		(0.001)	(0.003)	(0.026)
		[0.036]	[0.938]	[0.018)

Note: Table reports results from estimating variants of equation (3) by OLS. Dependent variable is the change in the log minimum toll rate. In addition to the covariates shown in the table, all regressions include year fixed effects. $ETCAdopt_{it}$ 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. The "Measure of compliance costs" variable is defined as of 1985 according to the definition in the column headings. In column 2 it is the number of separate toll transactions on a full length trip on the road. In column 3 it is the number of separate toll transactions divided by the monetary toll for a full length trip. In column 4 it is the number of separate toll transactions divided by the mileage for a full length trip. Data on the number of toll transactions come from toll operating authority websites, which include not only current information but histories of additions or removals of toll plazas. Mileage data are from U.S. Department of Transportation (2003) or information from the operating authority's web site. Each operating authority receives equal weight. Standard errors (in parentheses) are clustered by state. P-values are reported [in square brackets]. In Panel A, the sample is limited to all roads (N = 1,692; number of facilities = 44; number of operating authorities = 24; number of states = 18; mean of dependent variable = 0.021). In Panel B the sample is further limited to roads with barrier toll systems (N = 1,254; number of facilities = 34; number of operating authorities = 19; number of states = 14; mean of dependent variable = 0.020).

Table 8: Impact of Changing from Two-Way to One-Way Tolling on Tolls

	(1)	(2)	(3)
ETC_{it}	0.028	0.028	0.025
	(0.010)	(0.010)	(0.011)
	[0.015]	[0.012]	[0.039]
$OneWayAdopt_{it}$		0.041	0.032
		(0.035)	(0.042)
		[0.258]	[0.454]
$OneWay_{it}$			0.010
			(0.009)
			[0.291]
$ETCAdopt_{it}$	-0.086	-0.086	-0.086
	(0.017)	(0.017)	(0.017)
	[0.000]	[0.000]	[0.000]
Mean dep var		0.020	
# states		16	
# op authors		31	
# facilities		79	
N		3387	

Notes: Table reports results from estimating variants of equation (3) by OLS. The dependent variable is always the change in the log minimum toll rate. Sample is limited to bridges and tunnels. In addition to the covariates shown in the table, all regressions include year fixed effects. $ETCAdopt_{it}$ 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. $OneWayAdopt_{it}$ and $OneWay_{it}$ are indicator variables for, respectively, whether the facility switched to one-way tolling in that year and whether the facility switched to one-way tolling that year or in a previous year. Each operating authority receives equal weight. Standard errors (in parentheses) are clustered by state. P-values are reported [in square brackets].

Table 9: Changes in traffic, revenue and tolls prior to ETC adoption.

	Dep Var: $\Delta\log(traffic)$		Dep Var: $\Delta\log(revenue)$		Dep Var: $\Delta\log(\text{minimum toll})$	
	(1)	(2)	(3)	(4)	(5)	(6)
1-2 years before $ETCAdopted_{it}$	-0.000		-0.009		0.004	
	(0.007)		(0.016)		(0.013)	
	[0.955]		[0.599]		[0.777]	
1-5 years before $ETCAdopted_{it}$		0.013		0.006		0.009
		(0.010)		(0.012)		(0.007)
		[0.198]		[0.601]		[0.242]
$ETCAdopt_{it}$	-0.000	0.000	0.002	0.002	-0.051	-0.051
	(0.010)	(0.010)	(0.025)	(0.025)	(0.035)	(0.035)
	[0.996]	[0.978]	[0.922]	[0.930]	[0.158]	[0.162]
ETC_{it}	-0.006	-0.001	0.028	0.031	0.016	0.017
	(0.010)	(0.010)	(0.015)	(0.015)	(0.006)	(0.006)
	[0.551]	[0.959]	[0.090]	[0.058]	[0.018]	[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 (3) 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 $ETCAdopted_{it}$" is an indicator variable for whether it is one to two years before the facility adopts ETC. "1-5 years before $ETCAdopted_{it}$" is an indicator variable for whether it is one to five years before the facility adopts ETC. $ETCAdopt_{it}$ 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 10: ETC and Infrastructure Projects

	(1)	(2)
$ETCAdopt_{it}$	-0.055	-0.055
	(0.035)	(0.035)
	[0.125]	[0.124]
ETC_{it}	0.014	0.014
	(0.007)	(0.007)
	[0.048]	[0.048]
$INFRAAdopt_{it}$		0.017
		(0.014)
		[0.221]
$INFRA_{it}$		-0.003
		(0.007)
		[0.659]
Sample restriction		
Mean dep var.	0.021	0.021
# of states	23	23
# op. authorities	46	46
# of facilities	115	115
N	4,712	4,712

Note: Table shows results of estimating variants of equation (3) by OLS. Dependent variable is the change in the log minimum toll. In addition to the covariates shown in the table, all regressions include year fixed effects. $ETCAdopt_{it}$ 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. $INFRAAdopt_{it}$ 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, and that cluster standard errors in parentheses. Standard errors are shown in (parentheses), and p-values are shown in [square brackets]. Sample is limited to the 115 facilities for which infrastructure data are available.

Appendix Table A: Demographic Caracteristics of MA survey respondents, by payment method

	Entire Sample (1)	ETC Drivers (2)	Cash Drivers ((3)	Difference btwn ETC and Cash Drivers (4)
Average Age	46.7	45.3	47.3	-2.00
	(12.01)	(11.4)	(12.3)	(1.74)
Fraction Male	0.581	0.567	0.587	-0.020
	(0.495)	(0.500)	(0.494)	(0.074)
Fraction "usually pay toll	0.169	0.265	0.124	0.141**
on commute to work"	(0.376)	(0.444)	(0.331)	(0.060)
Average median hh	$ 56,865	$62,199	$54,368	$7,830**
income of zip code	(21,110)	($25,312)	($18,400)	(3,473)
Avg Retail Price of Car	$11,310	$13,357	$10,302	$3,055***
	(6,600)	(7,222)	(6,050)	(1,054)
Fraction Highest Degree Received				
HS Degree or Less	0.201	0.176	0.212	-0.036
	(0.402)	(0.384)	(0.410)	(0.058)
College Degree	0.509	0.441	0.541	-0.100
	(0.501)	(0.500)	(0.500)	(0.073)
Post-College Degree	0.290	0.382	0.247	0.136**
	(0.455)	(0.490)	(0.433)	(0.069)
Average cash toll for drive	$1.14	$1.09	$1.16	-0.070
	($1.05)	($0.905)	($1.11)	(0.143)
Fraction from MA	0.682	0.765	0.644	0.121*
	(0.466)	(0.424)	(0.479	(0.065)
N	214	68	146	

Notes: Standard deviations are in parentheses, except in column 4 where robust standard errors are reported instead. In column 4, ***, **, * denote statistical significance at the 1%, 5% and 10% levels respectively.

Appendix Table B1: Facilities in Sample and the Data Available for them

State	Operating Authority	Facility	Year First Toll	Toll data start date	Traffic Data	Revenue Data	ETC start date	ETC Penetration Data
CA	California Transportation Commission	Antioch Bridge	1926	1950	1993-2004	1993-2004	2001	2002-2005
		Bay Bridge	1936	1950	1993-2004	1993-2004	2001	2002-2005
		Benicia-Martinez Bridge	1962	1962	1993-2004	1993-2004	2001	2002-2005
		Carquinez Bridge	1927	1950	1993-2004	1993-2004	2001	2002-2005
		Coronado Bridge	1969	1969			--	--
		Dumbarton Bridge	1927	1959	1993-2004	1993-2004	2001	2002-2005
		Richmond San Rafael Bridge	1956	1956	1993-2004	1993-2004	2001	2002-2005
		San Mateo Bridge	1929	1959	1993-2004	1993-2004	2001	2002-2005
		Vincent Thomas Bridge	1963	1963			--	--
	City of Oceanside	Murray Road Toll Bridge	1984	1984			--	--
	Golden Gate Bridge and Highway District	Golden Gate Bridge	1937	1950	1974-2004		**2000**	2001-2005
DE	Delaware Transportation Authority	John F. Kennedy Memorial Highway (I-95) -- Delaware	1963	1963	1963-2005	1963-2005	**1998**	1999-2005
	Delaware River and Bay Authority	Delaware Memorial Bridge		1970			2001	2002 - 2005
FL	City of Treasure Island	Treasure Island Causeway		1950	1971-2005	1996-2005	--	--
	Florida Department of Transportation	Bee Line East Expressway	1974	1974	1994-2005		2001	2004 - 2005
		Everglades Parkway (Alligator Alley)	1969	1969	1994-2005		1999	2003 – 2005
		Navarre Bridge	1961	1961	1994-2005		2000	
		Pinellas Bayway System	1962	1962	1994-2005		2000	2003 – 2005
		Selmon Crosstown Expressway	1976	1976	1994-2005		2000	2003 – 2005
		Sunshine Skyway Bridge	1954	1954	1994-2005		**2000**	2003 – 2005
	Lee County	Lee County Toll Bridges -- Sanibel Bridge and Causeway	1963	1963	1965-1978 1980-1998 2000-2005		1987	2001-2005
	Monroe County	Card Sound Toll Bridge	1965	1965		1991-2005	--	--
	Town of Bay Harbor Islands	Broad Causeway	1951	1951	1952-2004	1952-2004	**1989**	2001-2005
GA	Georgia State Tollway Authority	Torras Causeway	1981	1981			--	--
IL	City of Chicago	Calumet Skyway Toll Bridge (Chicago Skyway)	1959	1959	1983-2003	1983-2003	2005	--

	City of Rock Island	Rock Island Centennial Bridge	1940	1950	1971, 1973, 1975, 1977, 1979, 1981, 1983, 1985 1987-1995 1999, 2001, 2003, 2005		--	--
	Illinois State Toll Highway Authority	Northwest Tollway	1958	1959			**1993**	1998-2005
		Ronald Reagan Memorial Tollway	1958	1959			**1993**	1998-2005
		Tri-State Tollway	1958	1959			**1993**	1998-2005
IN	Indiana Toll Finance Authority	Indiana Toll Road	1956	1956	1957-2004	1957-2004	--	--
		Wabash Memorial Toll Bridge	1956	1956	1977-1981 1983-2004	1957-2004	--	--
KS	Kansas Turnpike Authority	Kansas Turnpike System	1956	1956	1956-2005	1956-2005	**1995**	1995-2005
KY	The Turnpike Authority of Kentucky	Audubon Parkway	1970	1970		1972-2005	--	--
		Bluegrass Parkway	1965	1965			--	--
		Cumberland Parkway	1973	1973		1974-2004	--	--
		Daniel Boone Parkway	1971	1971		1973-2004	--	--
		Jackson Purchase Parkway	1968	1968			--	--
		Pennyrile Parkway	1969	1969			--	--
		Western Kentucky Parkway	1963	1963			--	--
		William H Natcher Parkway	1972	1972		1974-2005	--	--
MA	Massachusetts Turnpike Authority	Massachusetts Turnpike	1957	1980			**1998**	1998-2005
		Sumner Tunnel	1934	1934	1966-1998		**1998**	1998-2005
MD	Maryland Transportation Authority	Chesapeake Bay Bridge	1952	1952	1969-1992 2000-2005		2001	2002-2005
		Fort McHenry Tunnel	1985	1985	1986-1992 2000-2005		1999	2000-2005
		John F. Kennedy Memorial Highway	1963	1963	1969-1992 2000-2005		2001	2002-2005
		Key Bridge	1977	1977	1978 1980-1992 2000-2005		1999	2001-2005
		Patapsco Tunnel	1957	1957	1969-1978 1980-1992 2001-2005		1999	2000-2005

		Potamac River Bridge	1940	1950	1969-1978 1980-1992 2000-2005		2001	2002-2005
		Susquehanna River Bridge	1940	1950	1969-1978 1980-1992 2000-2005		2002	2002-2005
ME	Maine Turnpike Authority	Maine Turnpike	1947	1950	1980-2000		**1997**	2000, 2002, 2005
MI	Mackinac Bridge Authority	Mackinac Bridge	1957	1957	1957-2005		2001	2001-2005
NH	New Hampshire Department of Public Works and Highways	Blue Star Turnpike	1950	1950	1950-2004	1950-2004	**2005**	2005
		Central Turnpike	1955	1955	1955-2004	1955-2004	**2005**	2005
		Spaulding Turnpike	1956	1956	1956-2004	1956-2004	**2005**	2005
NJ	Burlington County Bridge Commission	Burlington-Bristol Bridge	1929	1950			2003	2004-2005
		Tacony-Palmyra Bridge	1929	1950			2003	2004-2005
	Cape May Bridge Commission	Corsons Inlet Bridge	1948	1950			NA	--
		Grassy Sound Bridge	1940	1950			NA	--
		Middle Thorofare Bridge	1940	1950			NA	--
		Ocean City Longport Bridge	1946	1950			NA	--
		Townsends Inlet Bridge	1941	1950			NA	--
	New Jersey Highway Authority	Garden State Parkway	1954	1954	1955 - 2004		**1999**	2001-2005
	New Jersey Turnpike Authority	New Jersey Turnpike^	1951	1967	1967-2003		**2000**	2001-2005
	New Jersey Expressway Authority	Atlantic City Expressway	1965	1965	1965-2004	1965-2004	**1998**	1998-2004
NJPA	Delaware River Joint Toll Bridge Commission	Easton-Phillipsburg Bridge		1983			**2002**	2003-2005
		Interstate 80 Delaware Water Gap		1983			**2002**	2003-2005
		Milford-Montague Bridge		1983			**2002**	2003-2005
		New Hope-Lambertville Bridge		1983			**2002**	2003-2005
		Portland-Columbia Bridge		1983			**2002**	2003-2005
		Trenton-Morrisville Bridge		1983			**2002**	2003-2005
	Delaware River Port Authority	Ben Franklin Bridge	1926	1950	1993 – 2005		**1999**	2000-2005
		Betsy Ross Bridge	1976	1976	1993-2005		**1999**	2000-2005
		Commodore Barry Bridge	1974	1974	1993-2005		**1999**	2000-2005
		Walt Whitman Bridge	1957	1957	1993-2005		**1999**	2000-2005

NY	Buffalo and Ft. Erie Public Bridge Authority	Peace Bridge	1927	1956	1995-2004	1995-2004	**2002**	2002-2004
	Nassau County Bridge Authority	Atlantic Beach Bridge		1967			--	--
	New York State Bridge Authority	Bear Mountain Bridge	1940	1950			1998	’98, ’02, ’05
		Kingston-Rhinecliff Bridge	1957	1957			1998	’98, ’02, ’05
		Mid-Hudson Bridge	1933	1950			1998	’98, ’02, ’05
		Newburgh-Beacon Bridge	1963	1963			1998	’98, ’02, ’05
		Rip Van Winkle Bridge	1935	1950			1998	’98, ’02, ’05
	New York State Thruway Authority	New York State Thruway^	1954	1954	1970-2004	1970-2004	**1993**	1993-2005
		Tappan Zee Bridge	1955	1955	1956-1961 1963-1964 1969-1970 1972-2004	1956-2004	**1993**	1999-2005
	Niagara Falls Bridge Commission	Lewiston-Queenston Bridge	1962	1969			--	--
		Rainbow Bridge	1941	1969			--	--
		Whirlpool Bridge	1959	1969			--	--
	Ogdensburg Bridge and Port Authority	Ogdensburg-Prescott Bridge	1960	1960			--	--
	Thousand Islands Bridge Authority	Thousand Island Bridges	1938	1950	1950-2005	1950-2005	--	--
	Triborough Bridge and Tunnel Authority	Bronx-Whitestone Bridge	1939	1969	1969-2004	1969-2004	**1996**	1996-2004
		Brooklyn-Battery Tunnel	1950	1969	1969-2004	1969-2004	**1996**	1996-2004
		Cross Bay Veterans Memorial Bridge	1939	1969	1969-2004	1969-2004	**1996**	1996-2004
		Henry Hudson Bridge	1936	1969	1969-2004	1969-2004	**1996**	1996-2004
		Marine Parkway-Gil Hodges Memorial Bridge	1937	1969	1969-2004	1969-2004	**1996**	1996-2004
		Queens Midtown Tunnel	1940	1969	1969-2004	1969-2004	**1996**	1996-2004
		Throgs Neck Bridge	1961	1969	1969-2004	1969-2004	**1996**	1996-2004
		Triborough Bridge	1936	1969	1969-2004	1969-2004	**1996**	1996-2004
		Verrazano Narrows Bridge	1964	1969	1969-2004	1969-2004	**1995**	1995-2004
NYNJ	Port Authority of New York and New Jersey	Bayonne Bridge	1931	1950	1950-2004		**1997**	2005
		George Washington Bridge	1931	1950	1950-2004		**1997**	2005
		Goethals Bridge	1928	1950	1950-2004		**1997**	2005
		Holland Tunnel	1927	1950	1950-2004		**1997**	2005
		Lincoln Tunnel	1937	1950	1950-2004		**1997**	2005

		Outerbridge Crossing	1928	1950	1950-2004		**1997**	2005
OH	Ohio Turnpike Commission	Ohio Turnpike	1955	1955	1961-2004	1961-2004	--	--
OK	Oklahoma Transportation Authority	Cimarron Turnpike	1975	1975	1982-2005	1975-2005	**1991**	1991-2005
		H.E. Bailey Turnpike	1964	1964	1982-2005	1964-2005	**1991**	1991-2005
		Indian Nation Turnpike	1966	1966	1982-2005	1966-2005	**1991**	1991-2005
		Muskogee Turnpike	1969	1969	1982-2005	1969-2005	**1991**	1991-2005
		Turner Turnpike	1953	1953	1982-2005	1982-2005	**1991**	1991-2005
		Will Rogers Turnpike	1957	1957	1982-2005	1957-2005	**1991**	1991-2005
OR	Oregon State Highway Div.	Astoria-Pt. Ellice Bridge	1966	1966			--	--
	Port of Cascade Locks Commission	Cascade Locks Bridge	1926	1950			--	--
	Port of Hood River Commission	Hood River-White Salmon Bridge	1924	1950	1994-2005	1994-2005	--	--
PA	Pennsylvania Turnpike Commission	Pennsylvania Turnpike^	1940	1950	1950-2005		2000	
RI	RI Turnpike & Bridge Authority	Jamestown-Newport Bridge	1969	1969			--	--
		Mt. Hope Bridge	1955	1955			--	--
VA	Richmond Metropolitan Authority	Boulevard Bridge	1969	1969	1972-2004		1999	2000-2005
		Downtown Expressway	1976	1976	1976-2004		**1999**	2000-2005
		Powhite Parkway	1973	1973	1973-2004		**1999**	2000-2005
	VA Department of Highways	Norfolk-Virginia Beach Toll Road	1967	1967			--	--
		Dulles Toll Road	1984	1984	1985-2005		1996	2000-2005
WV	City of Parkersburg	Parkersburg Bridge	1955	1974			--	--
	WV Turnpike Commission	West Virginia Turnpike	1954	1954	1991-2005		2000	

Notes: Blank cells indicate missing data. All toll data go through 2005. "ETC start date" is coded "--" to indicate "not applicable" if facility never instated ETC and is **bolded** if the facility ever offered a discounted rate to ETC users. Toll, Traffic and Revenue data denote the years after 1950 for which we have these data. "ETC Penetration" records years in which a facility has ETC for which we have ETC Penetration data; it is coded "--" to indicate "not applicable" for facilities that did not adopt ETC by 2005. "Year first toll" is missing for the few facilities for which I was not able to obtain this information. ^ denotes that this road has multiple branches; for the purposes of this study, we defined the road as the mainline branch (where relevant) or the longest possible path from the end of one branch to the end of another. Operating Authority names are based on the Operating Authority that controlled the facility in 1985, according to the U.S. Department of Transportation (1985, 1986).

Appendix Table B2: Target facilities lacking requisite data for analysis

State	Operating Authority	Facility	Toll in 2003?
CO	City of Colorado Springs	Pikes Peak Toll Highway	1
CT	Connecticut Department of Transportation	Charter Oak Bridge	0
		Connecticut Turnpike	0
		John Bissell Bridge	0
		Merritt Parkway	0
		Thames River Bridge	0
		Wilbur Cross Parkway	0
		William H. Putnam Bridge	0
FL	City of Clearwater	Clearwater Toll Bridge	0
	Dade County Port Authority	Biscayne Key (Rickenbacker) Causeway	1
		Venetian Causeway	1
	Escambia County	Pensacola Beach Bridge	1
	Florida Department of Transportation	Central Florida Expressway	1
		Florida Turnpike System*	1
		Miami-Dade County Expressways	1
		St. George Island (Bryant Patton) Bridge	0
		Tampa-Hillsborough County (South Crosstown) Expressway	1
	Jacksonville Transportation Authority	Jacksonville Expressway System	0
	Ocean Highway and Port Authority	Buccaneer Trail Road	0
IA	City of Burlington	MacArthur (Burlington) Bridge	0
	City of Keokuk	Keokuk Municipal Bridge	0
	Iowa Department of Transportation	Clinton Toll Bridge	0
		Dubuque Toll Bridge	0
		Muscatine Bridge	0
		Savanna-Sabula Toll Bridge	0
IL	City of Chester	Chester (Mississippi River) Bridge	0
	City of East St. Louis	Martin Luther King (Veterans Memorial) Bridge	0
	City of Venice	McKinley Bridge	0
	White County Bridge Commission	New Harmony Bridge	1
IN	Indiana Toll Finance Authority	Hawesville-Cannelton Bridge	0
	Indiana Transportation Finance Authority	Brandenburg-Maukport Bridge	1
LA	Greater New Orleans Expressway Commission	Greater New Orleans Expressway	1
MA	Massachusetts Port Authority	Maurice J. Tobin (Mystic River) Bridge	1
MI	International Bridge Authority of MI	Sault Sainte Marie Bridge	1
	Michigan Department of Transportation	Blue Water Bridge	1
MN	Village of Baudette	Baudette-Rainy River International Bridge	0
MO	City of Kansas City	Broadway Bridge	0
	Platte County	Platte Purchase Bridge	0
	Wayland Special Road District	St. Francisville Bridge	1
NE	Bellevue Bridge Commission	Bellevue Bridge	1
	Burt County Bridge Commission	Burt County Missouri River (Decatur) Bridge	1
NY	Lake Champlain Bridge Commission	Crown Point Bridge	0

		Rouses Point Bridge	0
TX	Cameron County	Cameron County International Toll Bridge	1
	City of Del Rio	Del Rio International Bridge	1
	City of Eagle Pass	Eagle Pass-Piedras Negras International Bridge	1
	City of El Paso	El Paso International Bridge	0
	City of Laredo	Laredo-Nuevo Laredo International Bridge	1
	City of McAllen	McAllen International Toll Bridge	1
	Galveston County	San Luis Pass-Vacek Bridge	1
	Harris County Toll Road Authority	Harris County Toll Road	1
	Starr County	Roma International Toll Bridge	1
	Texas Turnpike Authority	Dallas North Tollway	1
		Houston Ship Channel Bridge	0
		Mountain Creek Lake Bridge	0
VA	Chesapeake Bay Bridge and Tunnel District	Chesapeake Bay Bridge and Tunnel System	1
	City of Chesapeake	Jordan Bridge	1
	Virginia Department of Highways	Elizabeth River Bridge and Tunnels	0
		Richmond-Petersburg Turnpike	0
WA	Washington Toll Bridge Authority	Maple Street Bridge	0

Note: Last column indicates whether or not facility is still charging toll in 2003; this is based on data from U.S. Department of Transportation (2003, 2004). These were the latest available data as of August 2006. * Denotes that facility provided dates of toll changes, but not actual toll rates.