Consider the following thought experiment. A state is observed to impose a tax of 8 cents on a gallon of gasoline. But were it forced to specify the tax as so many cents per quart, it would impose a tax not of 2 cents per quart, but of 3 cents per quart. Or suppose that if the Federal Reserve Bank were required to specify interest rates as so many points per month rather than per year, it would change the federal discount rate from 10 percent a year to 1 percent a month. What would we make of such behavior? The units of measure matter, and therefore the behavior is highly unlikely to reflect the results of maximization.

This paper shows evidence for such irrational behavior in government activity. We find the evidence in a novel way. We do not follow the common approach of examining particular models, testing them, or analyzing them (an approach used in the influential work of Green and Shapiro (1995)). Instead we search for patterns of behavior which are inconsistent with almost any plausible theory of rational behavior.

We look for two related patterns. First, a central tenet of economics is that consumers and firms look behind the veil of money, making decisions on the basis not of nominal prices, but of inflation-adjusted (real) prices. To put it starkly, it should not matter to relative prices whether they were quoted in cents or dollars. We find that inflation, whose effects resemble those of a change in the unit of account, greatly reduces the inflation-adjusted gasoline tax imposed by states. Second, we believe that rational behavior precludes attaching importance to particular numbers or digits. But we find that states avoid setting taxes at the value of ten cents per gallon, while they do not avoid other integer values. This avoidance of the number ten is also found in the behavior of the Federal Reserve Board when it sets interest rates. It is not found in the behavior of private banks when they set the prime interest rate.

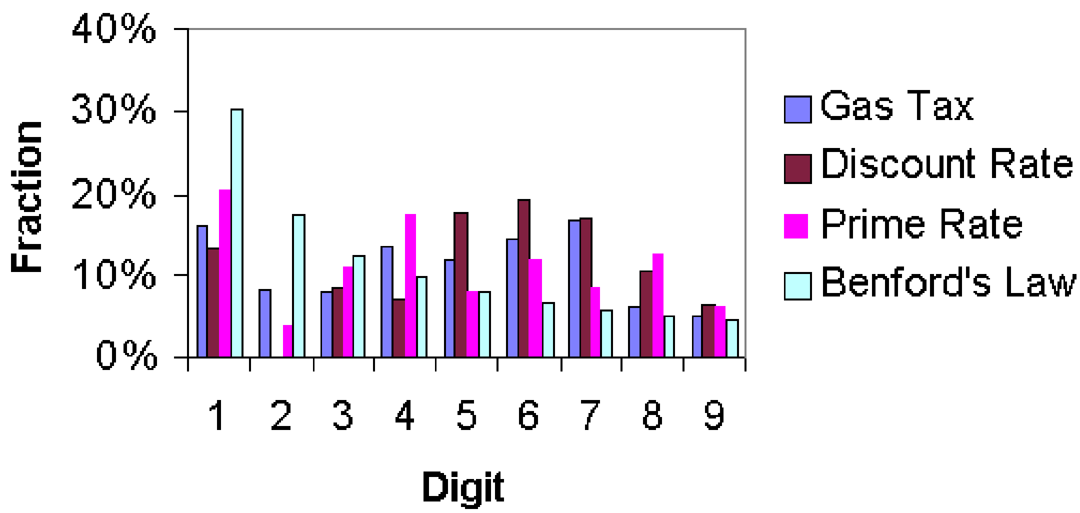
Benford's Law

As a first cut, we examine whether several policies adopted by government satisfy Benford's Law. That law demonstrates that the first significant digits for scale-invariant measurements do not occur with equal frequency. Instead, the probability that the first digit is a "*d*" is $log(1+ (1/d))$; thus the digit 1 tends to occur with a probability of about 30 percent (Benford (1938); for a recent exposition see Hill (1998)). The Dow-Jones Index and the Standard and Poor Index well fit the distribution described by Benford's Law. So do populations of the 3,000 counties in the United States. Indeed, violation of Benford's Law has been used to detect tax fraud (Hill 1998).

But the governmental policies we shall examine violate Benford's law. Figure 1 shows the distribution of the most significant digits for state gasoline taxes (on the left) and the federal discount rate (second to the left). As a partial control, we also checked the distribution of prime interest rates, which though set by banks is subject to political pressure. The rightmost column above each digit lists the distribution predicted under Benford's Law. Visual inspection suggests that Benford's Law is grossly violated. Chi-square tests confirm that the distribution predicted by Benford's Law is violated at better than the 1 percent significance level for each of the three variables.

What causes these violations? As stated above, one cause would be violation of scale invariance. We do not observe switches in taxes from gallons to quarts. But inflation is a change in the unit of measurement, and thus allows for direct tests of scale invariance. The next section accordingly examines the effects of inflation on real gasoline taxes, finding that inflation reduces the real gasoline tax. We also find that government policy is biased against imposing a tax, or setting an interest rate, of exactly ten percent. In Figure 1 we note a shortage of 1 as the first significant digit. The federal discount rates tabulated ranged from three percent to fourteen percent a year. So a shortage of 1 as the first significant digit is equivalent to an aversion to charging interest rates of ten percent or above. Similarly, gasoline taxes lie overwhelmingly in the rage of two cents per gallon to nineteen cents a gallon: the shortage of taxes with 1 as the most significant digit thus means an aversion to double-digit taxes. All this is more fully described below.

Figure 1:
Distribution of First Digit



State Gasoline Taxes

Consider first the effect of inflation on taxes. Good data are available on state gasoline taxes, both cross sectionally and over time. Moreover, thanks to the paper by Berry and Berry (1992), we have a good idea of what induces changes in taxes. We follow the Berry and Berry model with only two changes: our dependent variable is the real change in the gas tax rather than their binary variable indicating whether a state adopted a tax; we include an explanatory variable (RealErosion) which measures by how much inflation would reduce the inflation-adjusted tax on gasoline if the legislature had taken no action. We list all variables in Appendix A. Table 1 reports our results using weighted Non-linear Least Squares estimation where the dependent variable (GasTaxChange) is the real change in the tax. The explanatory variable of interest is RealErosion. It is tautologically true that in the economy as a whole the coefficient on RealErosion is 0.

Table 1. Dependent Variable: GasTaxChange Estimation: Non-linear Least Squares

Variable	Coefficient	t-statistic
Constant	0.000287	0.14
RealErosion	-0.537	-7.74
Income	0.0148	0.65
Urban	-0.000389	-1.61
FiscalHealth	-0.0160	-4.44
ElectYear	-0.00516	-6.61
NotElection	-0.000693	-0.99
Neighbor	0.000833	2.31
Unified	0.000185	-0.32
R-Squared	0.939	
F-statistic	2360	
Number of observations	1242	

The key finding for our purposes is the coefficient on the inflation variable, RealErosion. It is negative and statistically significant: inflation causes the real gasoline tax to decline.

Inflation should be neutral if policy were fully rational. Moreover, the behavior differs from what we observe in the economy as a whole. Note also that we are not merely stating that government may be slow, delaying a tax increase following an erosion of the tax by inflation. For in the private sector as well some firms may delay increasing prices. But while some firms may not increase prices, others, when they finally do increase prices, may increase prices by more than inflation. So if we examined a random sample of firms we would find that they increase prices at the inflation rate. We see that state governments behave differently.

Consider next the levels of nominal gasoline taxes set by the states. The tax can depend on many factors: the fiscal needs of the state, the electoral cycle, and so on. We shall not ask here if the tax is set optimally given the values of these factors. We rather ask a simpler question. Do states avoid imposing a tax of ten cents? We can think of no rational explanation (other than signaling) for doing so. Rather, any shortage of taxes at ten cents would appear to reflect a mystical aversion to "double-digit" taxes. Of course, the private sector also shows aversion to integer values, with retailers often pricing items at $9.99 rather than $10.00. But the evidence suggests that consumers are not fooled into believing that a price of $9.99 is significantly lower than a price of $10.00. Rather, it appears that non-integer pricing is used to signal that the product is on sale. Given that the firm can also alter the quality or size of the product as it changes the price, such signaling can be truthful, and the effects on consumption can be insignificant. When a state sets a tax, however, it controls only the tax, not the product taxed. So integer effects are likely more serious in taxation that in retail pricing.

If voters irrationally oppose a tax increase to ten cents, how might a state legislature react? Suppose that the rationally-based tax is only a bit above ten cents, say 10.25 cents. Then the legislature may leave the tax below ten cents. Alternatively, if the rationally-based tax is considerably above ten cents, say 10.5 cents or 11 cents, then the legislature may find the political costs of raising the tax to double digits outweighed by the costs of keeping the tax below ten cents. It will then raise the tax to the 10.5 cents or the 11 cents called for. In either case, we would observe a dearth of the ten-cents tax. To test for this, Table 2 below lists the frequency of taxes.

For example, in 72 cases the tax lay in the interval of 9.5 cents to 10.5 cents inclusive. Of these, the number of observations with a tax of exactly 10 cents was 30 (41.67 percent of the taxes in the interval between 9.5 and 10.5). Perusal of the table shows that 10 cents was far less likely to be chosen within an interval than any other integer within an interval. The next closest integer to this is 14, in which 58.14 percent were at the integer level. A Chi-square test shows that the proportion of integer values within a range differs for ten cents compared to all other ranges at better than the one percent significance level. States avoid a tax of ten cents far more than they avoid any other integer value.

Discount Rate

Are these results peculiar to gasoline taxes? To check, we also looked at policy in an unrelated area: the discount rate set by the Federal Reserve Board. The results in Table 3 give the number of weeks that the discount rate was in the given intervals.

The results are not as dramatic as for the gasoline taxes, and not statistically significant at the ten percent level. But we nevertheless see a shortage of discount rates at ten percentage points within its interval: 24 percent of the observations, compared to 34 percent among all observations. While other integer levels show similar results, the 10 percent interest rate is still avoided.

Table 2: Distribution of Gasoline Taxes

Range (cents)	Number of observations		Fraction at integer
2.5-3.5	289		
3		274	94.81%
3.5-4.5	491		
4		462	94.09%
4.5-5.5	446		
5		404	90.58%
5.5-6.5	538		
6		408	75.84%
6.5-7.5	708		
7		529	74.72%
7.5-8.5	289		
8		179	61.94%
8.5-9.5	208		
9		154	74.04%
9.5-10.5	72		
10		30	41.67%
10.5-11.5	95		
11		66	69.47%
11.5-12.5	37		
12		30	81.08%
12.5-13.5	65		
13		54	83.08%
13.5-14+.5	43		
14		25	58.14%
14.5-15.5	66		
15		45	68.18%
15.5-16.5	55		
16		48	87.27%
16.5-17.5	42		
17		31	73.81%
17.5-18.5	71		
18		47	66.20%
18.5-19.5	38		
19		23	60.53%
19.5-10.5	50		
20		46	92.00%
Total	3603	2855	79.24%

Table 3: Distribution of Federal Discount Rates

Range	Number of observations		Fraction at integer
3.5-4.5	89		
4		0	0.00%
4.5-5.5	296		
5		31	10.47%
5.5-6.5	380		
6		155	40.79%
6.5-7.5	274		
7		110	40.15%
7.5-8.5	217		
8		54	24.88%
8.5-9.5	153		
9		33	21.57%
9.5-10.5	66		
10		16	24.24%
10.5-11.5	27		
11		14	51.85%
11.5-12.5	56		
12		52	92.86%
12.5-13.5	43		
13		38	88.37%
Total	1601	503	31.42%

Prime Interest Rate

Do we find the same avoidance of ten in the private sector? To examine that, we look at an interest rate set by the private sectorthe prime interest rate. Table 4 shows the daily frequencies of rates over the period 1950-1995.

Here we see no avoidance of the number 10. Indeed, an interest rate of 10 percent is relatively more common within its interval than among all observations. Private banks do not appear to fear the number ten the way government does.

Table 4: Distribution of Prime Interest Rates

Range	Number of observations		Fraction at integer
2.5-3.5	2065		
3		1000	48.43%
3.5-4.5	3349		
4		688	20.54%
4.5-5.5	3432		
5		540	15.73%
5.5-6.5	2493		
6		1140	45.73%
6.5-7.5	1840		
7		381	20.71%
7.5-8.5	2588		
8		465	17.97%
8.5-9.5	1984		
9		445	22.43%
9.5-10.5	1675		
10		560	33.43%
10.5-11.5	1377		
11		391	28.40%
11.5-12.5	806		
12		84	10.42%
12.5-13.5	293		
13		120	40.96%
13.5-14.5	127		
14		24	18.90%
14.5-15.5	165		
15		23	13.94%
15.5-16.5	303		
16		16	5.28%
16.5-17.5	253		
17		35	13.83%
17.5-18.5	95		
18		32	33.68%
18.5-19.5	116		
19		35	30.17%
19.5-20.5	239		
20		92	99
Total	23200	6071	26.17%

Conclusion

To test for rationality in policy, we do not begin with a model that may or may not describe reality or rationality. We instead looked for behavior that is inconsistent with any reasonable definition of rational behavior. We saw that gasoline taxes, the federal discount rate, and the prime interest rate all showed an aversion to values that begin with the digit 1, and violated the distributions given by Benford's law. We examined the causes more deeply by first investigating the level of tax set on a gallon of gasoline by the 50 U.S. states. A rational approach to the nominal level of tax would demonstrate a rise in taxes commensurate with inflation. We do not find that. Our next test was to examine the frequencies of different taxes, where we found a strong bias against a tax of exactly ten cents. A bias in the same direction, though not as strong, was found in the discount rate set by the Federal Reserve Board. In contrast, the prime interest rates set by private banks had no similar avoidance of the integer ten. As we move from the least political actionthe interest rate set by banks, to the more politicalthe discount rate set by the independent Federal Reserve Board, to the most political action studied--taxes set by the legislature, we see an increase in the aversion to the number ten. That pattern does not strike us as showing a common rationality in decisions.

Appendix 1: Variables

CPI	Consumer price index
ElectYear	Equals one in the year of a gubernatorial election and zero otherwise
FiscalHealth	An indicator of state government fiscal health, equal to the ratio of revenue minus total state spending to total state spending
GasTax	Nominal tax on a gallon of gas, in cents
GasTaxChange	Real change in gasoline tax
GasTaxL1	GasTax from previous year
Income	State *per capita* income (in $1000) divided by the implicit price deflator for personal consumption expenditures
Inflation	Percentage increase in the Consumer Price Index (CPI) year to year
Neighbor	Number of tax increases by neighboring states very early in the year of measurement, or in the year prior to the year of measurement
NotElection	Equals one if the year of the observation is neither an election year nor the year after an election; it equals zero otherwise
RealErosion	GasTaxL1*Inflation/CPI
Unified	Equals one if a government is "unified" (i.e., the governor and both legislative houses are controlled by the same party) and zero otherwise
Urban	Urban population divided by total state population

The data for the following variables are from Berry and Berry (1994): Electyear, Notelection, Fiscalhealth, Historical Control, Lotto, Income, Unified. CPI, and Inflation variables are from *Statistical Abstract of the United States* (various years). We calculated Neighbor by counting the proportion of immediately neighboring states that raised gasoline taxes that year. Inflation-adjusted values are obtained by dividing the nominal value by the consumer price index (with 1982-84=100).

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