Online Appendix of
"Shopping for Lower Sales Tax Rates"

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A. Additional Data

A.1 Nielsen Retail Scanner (Retail Prices)

With the Nielsen Retail Scanner Panel (NRP), price and quantity information is available at the store level for each UPC carried by a covered retailer and span the years 2006-2014. An average (quantity weighted) price is reported, by UPC, for each store every week.[26] NRP covers 125 product groups with more than 3.2 million individual UPCs. Units are consistently standardized and most products are measured in ounces (OZ, 51%), count (CT, 45%) or ml (ML, 2%).

A.2 PromoData (Wholesale Prices)

We use PromoData to measure wholesale prices for grocery and retail goods. Promo obtains its information from one (confidential) major wholesaler in each market.[27] One downside to this approach is that, since no single wholesaler carries every SKU in a given market, information about the universe of goods is not observed. Overall, Promo prices are available for 32 markets after removing redundant markets and combining overlapping markets.[28]

Data on wholesale prices are available from 2006 - 2012. However, during 2012 the data loses a significant amount of coverage. For this reason, we perform robustness tests excluding 2012 data from our sample. PromoData contains all changes in price or deals that are run by the wholesaler. Thus, we take prices as constant between observations, based on the last observed price data. We then are able to collapse prices to a monthly level for each product group. To arrive at consistent unit prices within type of product (eg. product groups), we scale the observed wholesale prices by the number of goods in a 'pack' and by the size of the unit (eg. number of ounces in a candy bar and number of candy bars in a box). To make meaningful unit price comparisons we need to know the units associated with each good. Unfortunately unit information is often not provided

[26] For a given store, coverage over time is stable and relatively complete across all years. Unit prices are calculated as $price/(prmult \times size1\_amt)$.

[27] By only using one wholesaler, Promo relies on the Robinson–Patman Anti-Price Discrimination Act of 1936 that prohibits price discrimination. In particular, it prevents wholesalers from offering special discounts to large chain stores but not to other, smaller retailers.

[28] Leveraging this regional information provides additional variation but introduces more measurement error given less complete coverage in any given market both with respect to corresponding Nielsen product groups in the cross-section and time-series coverage of specific products.

or is inconsistently coded (e.g., CT, PACK, EACH, OZ, O etc.). We use the modal unit within UPC to impute missing values. The intuition is that if a product is recorded as being measured in OZ most of the time units are reported, it is probably measured in OZ.

A.3 Matching Wholesaler and Retailer Data

Given the large number of products in the retailer dataset we aggregate retail unit prices to the product group level before matching with wholesale prices. We assign products in the wholesaler data to Nielsen product groups by matching at the UPC level. The mapping is not one-to-one due to differences in end-digits when shifting to UPCs of different levels of granularity (e.g., some are reported with retailer specific end-digits, etc.). This leads to multiple Nielsen UPCs corresponding to a single Promo UPC for some goods. However, this appears to have little effect when merging Nielsen product groups to their Promo equivalents.

As a consistency check we also match retail and wholesale prices by UPC at a single point in time. The implied markup distribution supports the accuracy of both the raw data and our unit price calculations, with 90% of markups falling between -7% and 135%. We calculate Promo coverage of Nielsen product groups as the percentage of UPCs in each Nielsen product group that can be found in Promo. Overall, we see that about 4% of overall UPCs in Nielsen are also covered directly in the wholesale data for a given market. Aggregating across markets to the national level, this coverage increases somewhat.

The two datasets are merged based on the weekly date. That is, Promo prices are those associated with the week containing the Nielsen week-ending Saturday. For a Nielsen retailer using a 7-day period ending on Saturday the periods correspond closely. However, as mentioned above this is not the case for all retailers. For a retailer using a Thursday to Wednesday week, the Nielsen prices would pre-date the Promo prices by a few days.

Comparing unit prices is not completely straightforward as Promo units are missing for many products. As discussed above, we impute some missing units based on the modal unit reported in Promo for that UPC. When merging, we retain only UPCs for which the imputed Promo unit matches the Nielsen unit. A coarse attempt is made to standardize the more common Promo units before matching. In particular we assume O and Z refers to OZ and $C, CNT, PK, EA, EACH, STK, ROL, RL, PC, \#, CTN$ refer to CT.

A.4 State Ballot Propositions

To study tax salience, we focus on sales tax changes triggered by state-level ballot propositions. Using Ballotpedia.com we identify all state ballot propositions that involve changes in state sales taxes from 2004-2015. These data include propositions in Arizona, Arkansas, California, Colorado, Georgia, Maine, Massachusetts, Michigan, Minnesota, Missouri, South Dakota, and Washington, with some states having multiple ballots regarding sales taxes.

In total, we observe 20 propositions with potential effects ranging from a decline in sales taxes of 3.25ppt to an increase in sales taxes of 1ppt. 10 of the 20 propositions were successful, 9 were unsuccessful, and one was partially successful (took effect in a subset of state counties). 9 of the 20 propositions took place in November with the remaining propositions spread across February, May, June, and August.

B. Derivation of the Shopping Model

B.1 Supporting Calculations

B.1.1 Within-Period Value Function, $U(C_{t_n}, \Delta t_n)$

Define $f(\Delta t;\alpha) = \frac{e^{\alpha\Delta t}-1}{\alpha}$ with $f' = e^{\alpha\Delta t}$, $f^{(n)} = \alpha^{n-1}e^{\alpha\Delta t}$, $f(0) = 0$, $\lim_{\alpha\to 0} f(\Delta t;\alpha) = \Delta t$ and a second-order approximation around $\Delta t = 0$ is $f(\Delta t;\alpha) \approx (1 + \frac{\alpha}{2}\Delta t)\Delta t$. The Lagrangian of (3) is $\int_{x=0}^{\Delta t_n} \left[e^{-\rho t}u(C(t_n + x)) - \lambda e^{\delta x}C(t_n + x)\right]dx + \lambda S_{t_n}$. Defining $F(C, C', t) = e^{-\rho t}u(C(t_n + t)) - \lambda e^{\delta t}C(t_n + t)$, the general form of the Euler condition of this problem is $F_C = \frac{dF_{C'}}{dt} = F_{C'C}C' + F_{C'C'} + F_{C't}C''$. Since $F_{C'} = 0$, this reduces to $F_C = 0$, which implies $e^{\delta x}\lambda = e^{-\rho x}u'(C(t_n + x)) = e^{-\rho x}C(t_n + x)^{-1/\sigma}$. Hence $C(t_n + x) = \lambda^{-\sigma}e^{\gamma x}$ and $C_{t_n} = C(t_n) = \lambda^{-\sigma}$, where $\gamma = -(\delta + \rho)\sigma$,

$$C(t_n + x) = C_{t_n}e^{\gamma x}.$$

Plugging into the constraint yields $S_{t_n} = \int_0^{\Delta t_n} e^{\delta x}C(t_n+x)dx = \lambda^{-\sigma}\int_{x=0}^{\Delta t_n} e^{(\delta+\gamma)x}dx = \lambda^{-\sigma}f(\Delta t_n;\phi)$, with $\phi = \delta + \gamma = \delta - \sigma(\delta + \rho)$, so that

$$S_{t_n} = C_{t_n} \cdot f(\Delta t_n;\phi).$$

Plugging into the objective function and integrating yields[29]

$$\begin{aligned} U(C_{t_n}, \Delta t_n) &= \int_{x=0}^{\Delta t_n} e^{-\rho x}u(C(t_n + x))dx = u(C_{t_n})\int_{x=0}^{\Delta t_n} e^{-\rho x}e^{\frac{\sigma-1}{\sigma}\gamma x}dx \\ &= u(C_{t_n})\int_{x=0}^{\Delta t_n} e^{\phi x}dx \\ &= u(C_{t_n}) \cdot f(\Delta t_n;\phi). \end{aligned}$$

B.1.2 Inventories, S_{t_n}, s_{i,t_n}

Between shopping transactions, inventory evolves according to the first-order ordinary differential equation $\dot{s}_i(x) = -\delta s_i(x) - c_i(x)$, with boundary conditions $s_i(t_n) = s_{i,t_n}$ and $s_i(t_{n+1}^-) = 0$. The solution for $x \in [t_n, t_{n+1})$ is

$$s_i(t_n + x) = e^{-\delta x}\left[s_{i,t_n} - \int_{z=0}^{x} e^{\delta z}c_i(t_n + z)dz\right] \tag{14}$$

[29] Also note that $U(C_{t_n}, \Delta t_n) = U(S_{t_n}, \Delta t_n) = u(S_{t_n}) \cdot f(\Delta t_n;\phi)^{1/\sigma}$.

Hicksian demand $c_i(t)$ is a function of the relative price at the transaction date t_n, $p_{i,t_n}/P_{t_n}$ such that $c_i(t_n+z) = b_i\big(\frac{p_{i,t_n}}{P_{t_n}}\big)^{-\eta} C(t_n+z) = b_i\big(\frac{p_{i,t_n}}{P_{t_n}}\big)^{-\eta} C_{t_n} e^{\gamma z}$. We can use individual inventories $s_i(t_n)$ to define inventories of the composite consumption good

$$
\begin{aligned}
S(t_n+x) \equiv \frac{\sum_i p_{i,t_n} s_i(t_n+x)}{P_{t_n}} &= e^{-\delta x}\Big[S_{t_n} - \int_{z=0}^{x} e^{\delta z} \underbrace{\frac{\sum_i b_i\Big(\frac{p_{i,t_n}}{P_{t_n}}\Big)^{-\eta} p_{i,t_n}}{P_{t_n}}}_{=1} C(t_n+z)dz\Big] \\
&= e^{-\delta x}\Big[S_{t_n} - C_{t_n}\int_{z=0}^{x} e^{(\delta+\gamma)z}dz\Big] \\
&= e^{-\delta x}\Big[S_{t_n} - C_{t_n} f(x;\phi)\Big].
\end{aligned}
$$

The condition $s_i(t_n+\Delta t_n) = s_i(t_{n+1}^-) = 0$ implies $S(t_n+\Delta t_n) = S(t_{n+1}^-) = 0$ and

$$S_{t_n} = C_{t_n} f(\Delta t_n;\phi).$$

Similarly, using $s_i(t_{n+1}^-) = 0 = e^{-\delta\Delta t_n}\Big[s_{i,t_n} - \int_{z=0}^{\Delta t_n} e^{\delta z} c_i(t_n+z)dz\Big]$, beginning-of-period inventories for the individual goods are

$$
\begin{aligned}
s_{i,t_n} &= \int_{z=0}^{\Delta t_n} e^{\delta z} c_i(t_n+z)dz \\
&= b_i\big(\frac{p_{i,t_n}}{P_{t_n}}\big)^{-\eta} C_{t_n}\int_{z=0}^{\Delta t_n} e^{(\delta+\gamma)z}dz = b_i\big(\frac{p_{i,t_n}}{P_{t_n}}\big)^{-\eta} C_{t_n} f(\Delta t_n;\phi) \\
&= b_i\left(\frac{p_{i,t_n}}{P_{t_n}}\right)^{-\eta} S_{t_n}
\end{aligned}
$$

and the expenditure share of good i is

$$B_{i,t_n} = \frac{p_{i,t_n} s_{i,t_n}}{P_{t_n} S_{t_n}} = b_i\left(\frac{p_{i,t_n}}{P_{t_n}}\right)^{1-\eta}.$$

B.1.3 Tax Elasticity of the Price Index

The effective cost-of-living price index is $P(\tau) = [b_\tau(1+\tau)^{1-\eta}\tilde{p}_\tau^{1-\eta} + b_e\tilde{p}_e^{1-\eta}]^{1/(1-\eta)}$, where $\tilde{p}_i$ is the pre-tax price so that $p_\tau = (1+\tau)\tilde{p}_\tau$ and $p_e = \tilde{p}_e$. Hence

$$
\begin{aligned}
\frac{d\ln P(\tau)}{d\ln(1+\tau)} &= \frac{1+\tau}{P}\frac{dP}{d(1+\tau)} \\
&= \frac{1+\tau}{P}\frac{1}{1-\eta}P^{\eta}(1-\eta)(1+\tau)^{-\eta} b_\tau \tilde{p}_\tau^{1-\eta} \\
&= b_\tau\left(\frac{(1+\tau)\tilde{p}_\tau}{P}\right)^{1-\eta} = b_\tau\left(\frac{p_\tau}{P}\right)^{1-\eta}.
\end{aligned}
$$

The taxable expenditure share is

$$B_\tau = \frac{p_\tau s_\tau}{PS} = \frac{p_\tau}{PS} b_\tau \left(\frac{p_\tau}{P}\right)^{-\eta} S = b_\tau \left(\frac{p_\tau}{P}\right)^{1-\eta}.$$

Hence,

$$\frac{d\ln P(\tau)}{d\ln(1+\tau)} = B_\tau.$$

B.2 Model Solution

B.2.1 Transaction Interval, Δt_n

Define $C = C_{\Delta t}$ with consumption flow $C_{\Delta t} = \int_{x=0}^{\Delta t} C(t_n + x)dx = C_{t_n} f(\gamma)$ so that $S = C\frac{f(\phi)}{f(\gamma)}$ and

$$\begin{aligned} U &= u(C) \cdot f(\gamma)^{\frac{1}{\sigma}-1} \cdot f(\phi) = u\big(C/f(\gamma)\big) \cdot f(\phi) = u(S) \cdot f(\phi)^{\frac{1}{\sigma}} \\ K &= \kappa + PC \cdot \frac{f(\phi)}{f(\gamma)} = \kappa + PS. \end{aligned}$$

The partial derivatives of U and K with respect to C are

$$\begin{aligned} \partial_C K' &= P\frac{f(\phi)}{f(\gamma)} = \frac{PS}{C} \\ \partial_C U' &= u'(C) \cdot f(\gamma)^{\frac{1}{\sigma}-1} f(\phi) = U \cdot \frac{u'(C)}{u(C)} \end{aligned}$$

such that (6) becomes

$$V' = \frac{\partial_C U'}{\partial_C K'} = \frac{(1-\frac{1}{\sigma})U}{PS}.$$

The partial derivatives of U and K with respect to Δt are

$$\partial_{\Delta t} K' = PC\big[-f(\gamma)^{-2} f(\phi) e^{\gamma\Delta t} + f(\gamma)^{-1} e^{\phi\Delta t}\big] = PS\big[\frac{e^{\phi\Delta t}}{f(\phi)} - \frac{e^{\gamma\Delta t}}{f(\gamma)}\big]$$

and

$$\begin{aligned} \partial_{\Delta t} U' &= u(C)\big[(\frac{1}{\sigma} - 1) f(\gamma)^{\frac{1}{\sigma}-2} f(\phi) e^{\gamma\Delta t} + f(\gamma)^{\frac{1}{\sigma}-1} e^{\phi\Delta t}\big] \\ &= u(C) f(\gamma)^{\frac{1}{\sigma}-1} f(\phi) \big[\frac{e^{\phi\Delta t}}{f(\phi)} - (1 - \frac{1}{\sigma})\frac{e^{\gamma\Delta t}}{f(\gamma)}\big] \\ &= U\big[\frac{e^{\phi\Delta t}}{f(\phi)} - \frac{e^{\gamma\Delta t}}{f(\gamma)} + \frac{1}{\sigma}\frac{e^{\gamma\Delta t}}{f(\gamma)}\big] = U\big[\frac{\partial_{\Delta t} K}{PS} + \frac{1}{\sigma}\frac{e^{\gamma\Delta t}}{f(\gamma)}\big]. \end{aligned}$$

Necessary condition for Δt_n Necessary condition (8) can also be written as

$$\partial_{\Delta t} U'_{t_n} - e^{-\rho \Delta t_n} \rho V_{t_{n+1}} = \big[\partial_{\Delta t} K'_{t_n} - e^{-r\Delta t_n} r w_{t_{n+1}}\big] e^{(r-\rho)\Delta t_n} V'_{t_{n+1}}.$$

The right-hand side is

$$\begin{aligned} e^{(r-\rho)\Delta t_n} V'(w_{t_{n+1}})\big[\partial_{\Delta t} K'_{t_n} - r(w_{t_n} - K_{t_n})\big] &= e^{(r-\rho)\Delta t_n} V'(w_{t_{n+1}})\big[\partial_{\Delta t} K'_{t_n} - e^{-r\Delta t_n} r w_{t_{n+1}}\big] \\ &= (1-\frac{1}{\sigma}) U_{t_n}\big[\frac{\partial_{\Delta t_n} K'_{t_n}}{P_{t_n} S_{t_n}} - \frac{e^{-r\Delta t_n} r w_{t_{n+1}}}{P_{t_n} S_{t_n}}\big] \\ &= (1-\frac{1}{\sigma}) U_{t_n}\big[\frac{e^{\phi \Delta t_n}}{f(\phi)} - \frac{e^{\gamma \Delta t_n}}{f(\gamma)} - \frac{e^{-r\Delta t_n} r w_{t_{n+1}}}{P_{t_n} S_{t_n}}\big] \end{aligned}$$

and the left-hand side is

$$\begin{aligned} \partial_{\Delta t} U'_{t_n} - e^{-\rho\Delta t_n} \rho V(w_{t_{n+1}}) &= U_{t_n}\big[\frac{\partial_{\Delta t} K'_{t_n}}{P_{t_n} S_{t_n}} + \frac{1}{\sigma}\frac{e^{\gamma\Delta t_n}}{f(\gamma)}\big] - e^{-\rho\Delta t_n}\rho V(w_{t_{n+1}}) \\ &= U_{t_n}\big[\frac{e^{\phi\Delta t_n}}{f(\phi)} - (1-\frac{1}{\sigma})\frac{e^{\gamma\Delta t_n}}{f(\gamma)}\big] - e^{-\rho\Delta t_n}\rho V(w_{t_{n+1}}). \end{aligned}$$

Hence, necessary condition (8), which implicitly defines Δt_n, can be rewritten as

$$\frac{\rho e^{-\rho\Delta t_n} V(w_{t_{n+1}})}{U(S_{t_n}, \Delta t_n)} - \big(1 - \frac{1}{\sigma}\big)\frac{r e^{-r\Delta t_n} w_{t_{n+1}}}{P_{t_n} S_{t_n}} = \frac{1}{\sigma}\frac{e^{\phi\Delta t_n}}{f(\Delta t_n; \phi)} \tag{15}$$

or substituting out inventories,

$$\frac{\rho e^{-\rho\Delta t_n} V(w_{t_{n+1}})}{u(C_{t_n})} - \big(1 - \frac{1}{\sigma}\big)\frac{r e^{-r\Delta t_n} w_{t_{n+1}}}{P_{t_n} C_{t_n}} = \frac{1}{\sigma} e^{\phi\Delta t_n}.$$

B.2.2 Final Stationary State (starting at t_{ss})

In the stationary state with $r = \rho$, (4) implies

$$V_{t_{ss}} = (1 - e^{-\rho\Delta t_{ss}})^{-1} U_{t_{ss}} \tag{16}$$

$$w_{t_{ss}} = (1 - e^{-r\Delta t_{ss}})^{-1} K_{t_{ss}} = (1 - e^{-r\Delta t_{ss}})^{-1}(\kappa + P_{t_{ss}} S_{t_{ss}}) \tag{17}$$

Plugging the stationary-state value function and wealth into (15) and evaluating at the stationary state $\rho = r$, noting that $e^{-r\Delta t} r(1 - e^{-r\Delta t})^{-1} = f(\Delta t; r)^{-1}$, yields (9),

$$(1-\sigma)\frac{\kappa}{P_{t_{ss}} S_{t_{ss}}} = e^{\phi\Delta t_{ss}}\frac{f(\Delta t_{ss}; r)}{f(\Delta t_{ss}; \phi)} - 1$$

or in terms of consumption,

$$(1-\sigma)\frac{\kappa}{P_{t_{ss}} C_{t_{ss}}} = e^{\phi\Delta t_{ss}} f(\Delta t_{ss}; r) - f(\Delta t_{ss}; \phi). \tag{18}$$

Furthermore, by plugging (17) into (9), we can express the optimal shopping cycle in the stationary state instead as a function of the total level of wealth in stationary state, $w_{t_{ss}}$,[30]

$$(1-\sigma)\Big[\frac{\kappa}{(1-e^{-r\Delta t_{ss}})w_{t_{ss}}-\kappa}\Big] = e^{\phi\Delta t_{ss}}\frac{f(\Delta t_{ss};r)}{f(\Delta t_{ss};\phi)} - 1. \tag{19}$$

Approximate steady-state trip interval ("square-root formula") Define the right-hand side of (18)

$$F(\Delta t) = e^{\phi\Delta t} f(\Delta t; r) - f(\Delta t;\phi).$$

Taking a second-order Taylor expansion of F around $\Delta t = 0$

$$F(\Delta t) \approx F(0) + F'(0)\Delta t + F''(0)\frac{(\Delta t)^2}{2},$$

noting that

$$\begin{aligned} F(0) &= 0 \\ F'(\Delta t) &= \phi e^{\phi\Delta t} f(\Delta t;\phi) + e^{(\phi+\delta)\Delta t} - e^{\phi\Delta t} && \Rightarrow F'(0) = 0 \\ F''(\Delta t) &= \phi^2 e^{\phi\Delta t} f(\Delta t;\phi) + (2\phi + r)e^{(\phi+r)\Delta t} - \phi e^{\phi\Delta t} && \Rightarrow F''(0) = (1-\sigma)(\delta + r) \end{aligned}$$

yields

$$F(\Delta t) \approx (1-\sigma)(\delta + r)\frac{(\Delta t)^2}{2}.$$

If $\sigma = 0$ (which we cannot reject based on our estimates of the long-run spending response), then consumption is constant, in particular $C_{t_n} = C$, and does not depend on Δt. Hence the left-hand side of (18) is not affected by the Taylor expansion around $\Delta t = 0$. Therefore, substituting the approximation of the right-hand side into (18) yields the approximate square root formula in the text,

$$\Delta t_{ss} \approx \sqrt{\frac{\kappa}{\frac{\delta+r}{2}P_{t_{ss}}C_{t_{ss}}}}.$$

B.2.3 Interim Shopping Period (starting at t_{ss-1})

A. Change of the iterim-period interval (Δt_{ss-1}) Using (15) we have

$$\frac{1}{\sigma}\frac{e^{\phi\Delta t_{ss-1}}}{f(\Delta t_{ss-1};\phi)} = \frac{\rho e^{-\rho\Delta t_{ss-1}}V(w_{t_{ss}})}{U(C_{t_n},\Delta t_n)} - \big(1-\frac{1}{\sigma}\big)\frac{re^{-r\Delta t_{ss-1}}w_{t_{ss}}}{P_{t_{ss-1}}S_{t_{ss-1}}}$$

[30] Note that if $\sigma = 1$ (i.e., income effect equals substitution effect) then Δt_{ss} is not defined by (9) since the LHS=RHS=0 independent of Δt_{ss}, but instead is pinned down by the steady-state budget constraint.

$$= \frac{\rho e^{-\rho\Delta t_{ss-1}}(1-e^{-\rho\Delta t_{ss}})^{-1}U_{t_{ss}}}{U_{t_{ss-1}}} - (1-\frac{1}{\sigma})\frac{re^{-r\Delta t_{ss-1}}(1-e^{-r\Delta t_{ss}})^{-1}(\kappa+P_{t_{ss}}S_{t_{ss}})}{P_{t_{ss-1}}S_{t_{ss-1}}}$$
$$= re^{-r\Delta t_{ss-1}}(1-e^{-r\Delta t_{ss}})^{-1}\Big[\frac{U_{t_{ss}}}{U_{t_{ss-1}}} - \big(1-\frac{1}{\sigma}\big)\big(\frac{P_{t_{ss}}S_{t_{ss}}}{P_{t_{ss-1}}S_{t_{ss-1}}} + \frac{\kappa}{P_{t_{ss-1}}S_{t_{ss-1}}}\big)\Big].$$

Using (7) we find an expression for $U_{t_{ss}}/U_{t_{ss-1}}$,

$$\frac{U_{t_{ss}}}{U_{t_{ss-1}}} = \frac{u(S_{t_{ss}})f(\Delta t_{ss};\phi)^{1/\sigma}}{u(S_{t_{ss-1}})f(\Delta t_{ss-1};\phi)^{1/\sigma}} = \left(\frac{S_{t_{ss}}}{S_{t_{ss-1}}}\right)^{1-1/\sigma}\left(\frac{f(\Delta t_{ss};\phi)}{f(\Delta t_{ss-1};\phi)}\right)^{1/\sigma}$$
$$= e^{(\sigma-1)(r-\rho)\Delta t_{ss-1}}\Big(\frac{P_{t_{ss}}}{P_{t_{ss-1}}}\Big)^{1-\sigma}\frac{f(\Delta t_{ss};\phi)}{f(\Delta t_{ss-1};\phi)}$$

and

$$\frac{P_{t_{ss}}S_{t_{ss}}}{P_{t_{ss-1}}S_{t_{ss-1}}} + \frac{\kappa}{P_{t_{ss-1}}S_{t_{ss-1}}} = \frac{P_{t_{ss}}S_{t_{ss}}}{P_{t_{ss-1}}S_{t_{ss-1}}}\big(1+\frac{\kappa}{P_{t_{ss}}S_{t_{ss}}}\big)$$
$$= e^{\sigma(r-\rho)\Delta t_{ss-1}}\Big(\frac{P_{t_{ss}}}{P_{t_{ss-1}}}\Big)^{1-\sigma}\frac{f(\Delta t_{ss};\phi)}{f(\Delta t_{ss-1};\phi)}\big(1+\frac{\kappa}{P_{t_{ss}}S_{t_{ss}}}\big).$$

Plugging back in and evaluating at $\rho = r$,

$$\frac{1}{\sigma}\frac{e^{\phi\Delta t_{ss-1}}}{f(\Delta t_{ss-1};\phi)} = e^{-r(\Delta t_{ss-1}-\Delta t_{ss})}f(\Delta t_{ss};r)^{-1}\Big(\frac{P_{t_{ss}}}{P_{t_{ss-1}}}\Big)^{1-\sigma}\frac{f(\Delta t_{ss};\phi)}{f(\Delta t_{ss-1};\phi)}\Big[1-\big(1-\frac{1}{\sigma}\big)\big(1+\frac{\kappa}{P_{t_{ss}}S_{t_{ss}}}\big)\Big]$$
$$= e^{-r(\Delta t_{ss-1}-\Delta t_{ss})}f(\Delta t_{ss};r)^{-1}\Big(\frac{P_{t_{ss}}}{P_{t_{ss-1}}}\Big)^{1-\sigma}\frac{f(\Delta t_{ss};\phi)}{f(\Delta t_{ss-1};\phi)}\frac{1}{\sigma}\big[1+(1-\sigma)\frac{\kappa}{P_{t_{ss}}S_{t_{ss}}}\big].$$

Therefore,

$$(1-\sigma)\frac{\kappa}{P_{t_{ss}}S_{t_{ss}}} = e^{\phi\Delta t_{ss-1}+r(\Delta t_{ss-1}-\Delta t_{ss})}\frac{f(\Delta t_{ss};r)}{f(\Delta t_{ss};\phi)}\Big(\frac{P_{t_{ss}}}{P_{t_{ss-1}}}\Big)^{-(1-\sigma)} - 1.$$

Substituting the left-hand side with (9)

$$\Big(\frac{P_{t_{ss}}}{P_{t_{ss-1}}}\Big)^{(1-\sigma)} = e^{(\phi+r)(\Delta t_{ss-1}-\Delta t_{ss})} = e^{(1-\sigma)(\delta+r)(\Delta t_{ss-1}-\Delta t_{ss})}$$

and taking logs yields

$$\Delta t_{ss-1} - \Delta t_{ss} = \frac{\ln\big(P_{t_{ss}}/P_{t_{ss-1}}\big)}{\delta + r}.$$

Elasticity Hence, we obtain (11) by the following approximation,

$$\frac{\ln\big(P_{t_{ss}}/P_{t_{ss-1}}\big)}{(\delta+r)\Delta t_{ss}} = \frac{\Delta t_{ss-1}-\Delta t_{ss}}{\Delta t_{ss}} \approx -\ln\big(\Delta t_{ss}/\Delta t_{ss-1}\big)$$

such that

$$\varepsilon_{\Delta t_{ss-1}} = \frac{d\ln(\Delta t_{ss}/\Delta t_{ss-1})}{d\ln(1+\tau_{t_{ss}})}\Big|_{\Delta t_{ss}\ cons} = -\frac{1}{(\delta+r)\Delta t_{ss}}\frac{d\ln\left(P_{t_{ss}}/P_{t_{ss-1}}\right)}{d\ln(1+\tau_{t_{ss}})}$$
$$= -\frac{B_\tau}{(\delta+r)\Delta t_{ss}}.$$

B. Change of iterim-period spending ($s_{i,t_{ss-1}}$) Beginning-of-period inventory of good i is

$$s_{i,t_n} = b_i\Big(\frac{p_{i,t_n}}{P_{t_n}}\Big)^{-\eta}S_{t_n}$$

such that

$$\frac{s_{i,t_{ss-1}}}{s_{i,t_{ss}}} = \Big(\frac{p_{i,t_{ss}}}{p_{i,t_{ss-1}}}\Big)^{\eta}\Big(\frac{P_{t_{ss}}}{P_{t_{ss-1}}}\Big)^{-\eta}\frac{S_{t_{ss-1}}}{S_{t_{ss}}}.$$

Substituting Euler equation (7) evaluated at $\rho = r$ yields

$$\frac{s_{i,t_{ss-1}}}{s_{i,t_{ss}}} = \Big(\frac{p_{i,t_{ss}}}{p_{i,t_{ss-1}}}\Big)^{\eta}\Big(\frac{P_{t_{ss}}}{P_{t_{ss-1}}}\Big)^{\sigma-\eta}\frac{f(\Delta t_{ss-1};\phi)}{f(\Delta t_{ss};\phi)}.$$

Using the fact that $\frac{d\ln(P_{t_{ss}}/P_{t_{ss-1}})}{d\ln(1+\tau_{t_{ss}})} = B_\tau$, the compensated short-run spending elasticity of a forward-looking consumer is

$$\varepsilon_{s_{i,t_{ss-1}}} \equiv \frac{d\ln(s_{i,t_{ss}}/s_{i,t_{ss-1}})}{d\ln(1+\tau_{t_{ss}})}$$
$$= -(\sigma-\eta)\frac{d\ln(P_{t_{ss}}/P_{t_{ss-1}})}{d\ln(1+\tau_{t_{ss}})} - \eta\cdot\frac{d\ln(p_{i,t_{ss}}/p_{i,t_{ss-1}})}{d\ln(1+\tau_{t_{ss}})} - \frac{d\ln\left(f(\Delta t_{ss-1};\phi)/f(\Delta t_{ss};\phi)\right)}{d\ln(1+\tau_{t_{ss}})}$$
$$= -(\sigma-\eta)B_\tau - \eta\cdot 1_{\{i=\tau\}} - \frac{d\ln\left(f(\Delta t_{ss-1};\phi)/f(\Delta t_{ss};\phi)\right)}{d\ln(1+\tau_{t_{ss}})}$$
$$= \varepsilon_i^c - \frac{d\ln\left(f(\Delta t_{ss-1};\phi)/f(\Delta t_{ss};\phi)\right)}{d\ln(1+\tau_{t_{ss}})}.$$

Hence, the additional sensitivity of spending relative to consumption is driven by the last term.

Elasticity Evaluating the derivatives of f around $d\tau = 0$ such that $d\ln f(\Delta t_{ss-1};\phi) \approx d\ln f(\Delta t_{ss};\phi)$ and using (11) we get

$$\frac{d\ln f(\Delta t_{ss-1};\phi)}{d\ln(1+\tau_{t_{ss}})} - \frac{d\ln f(\Delta t_{ss};\phi)}{d\ln(1+\tau_{t_{ss}})} \approx \frac{e^{\phi\Delta t_{ss}}}{f(\Delta t_{ss};\phi)}\frac{d(\Delta t_{ss-1}-\Delta t_{ss})}{d\ln(1+\tau_{t_{ss}})}$$
$$= \frac{e^{\phi\Delta t_{ss}}}{f(\Delta t_{ss};\phi)}\frac{B_\tau}{\delta+r}.$$

Taking a first order approximation of $G(\phi) \equiv \frac{e^{\phi\Delta t}}{f(\Delta t;\phi)} = \frac{\phi e^{\phi\Delta t}}{e^{\phi\Delta t}-1}$ around $\phi = 0$, $G(\phi) \approx \frac{1}{\Delta t} + \frac{1}{2}\phi$, yields

$$\frac{d\ln\left(f(\Delta t_{ss-1};\phi)/f(\Delta t_{ss};\phi)\right)}{d\ln(1+\tau_{t_{ss}})} \approx \frac{B_\tau}{\delta + r}\left(\frac{1}{\Delta t_{ss}} + \frac{\phi}{2}\right).$$

Evaluating G at $\phi = 0$ instead yields the approximation in (12).

Proof: Using de l'Hopital's rule, $G(0) = \lim_{\phi\to 0} G(\phi) = \frac{1}{\Delta t}$. After some algebra, the derivative of G simplifies to $G'(\phi) = \frac{e^{\phi\Delta t}(e^{\phi\Delta t}-1-\phi\Delta t)}{(e^{\phi\Delta t}-1)^2}$. Using de l'Hopital's rule again, $G'(0) = \lim_{\phi\to 0} G'(\phi) = \frac{1}{2}$.

B.2.4 Pre Tax Change Periods (until t_{ss-1})

Consider the problem of choosing how to space N trips planned to occur before the interim shopping trip at $t_{ss-1} = t_\tau^-$.[31] Without much loss of generality we start model time at a date that corresponds to a shopping transaction. The goal is to show that for an appropriate choice of tax change date t_τ there is a solution involving a constant trip interval $\Delta t = \Delta t_{ss-2} = \Delta t_{ss-q}$ $\forall q \geq 2$ and constant beginning-of-period consumption $C = C_{t_{ss-2}} = C_{t_{ss-q}}$ $\forall q \geq 2$. Define the start and end dates of the pre tax change period

$$t_0 = 0$$
$$t_N = t_\tau^- = t_{ss-1}.$$

There are $N+1$ transaction dates and N transaction intervals. Also define $V(w_{t_\tau^-})$ as the value of the problem starting from the interim shopping trip at t_τ^- given accumulated wealth $w_{t_\tau^-}$. The problem is

$$V(w_0) = \max_{w_{t_\tau^-},\Delta t_0,\ldots,\Delta t_{N-1},C_{t_0},\ldots,C_{t_{N-1}}} \sum_{k=0}^{N-1} e^{-\rho\sum_{j=0}^{k-1}\Delta t_j} U(C_{t_k},\Delta t_k) + e^{-\rho t_\tau^-} V(w_{t_\tau^-})$$

subject to

$$t_\tau^- = \sum_{k=0}^{N-1} \Delta t_k$$
$$w_0 = \sum_{k=0}^{N-1} e^{-r\sum_{j=0}^{k-1}\Delta t_j} K_{t_k} + e^{-rt_\tau^-} w_{t_\tau -}$$

where the multiplier on first constraint is λ_1 and on second constraint is λ_2.

[31] Note that it is best for the household to take the interim trip as close to t_τ as possible, all else constant.

Necessary condition for Δt_n

$$e^{-\rho t_n}\lambda_1 = \Big[\partial_\Delta U'_{t_n} - \rho \sum_{k=n+1}^{N-1} e^{-r\sum_{j=0}^{k-1}\Delta t_j} U_{t_k}\Big] - \lambda_2\Big[\partial_\Delta K'_{t_n} - r \sum_{k=n+1}^{N-1} e^{-\rho\sum_{j=0}^{k-1}\Delta t_j} K_{t_k}\Big]. \tag{20}$$

Necessary condition for C_{t_n}

$$\partial_C U'_{t_n} = \lambda_2 \cdot \partial_C K'_{t_n}. \tag{21}$$

Necessary condition for $w_{t_\tau^-}$

$$e^{-\rho t_\tau^-} V'(w_{t_\tau^-}) = \lambda_2 e^{-r t_\tau^-} \tag{22}$$

Using (22) and $r = \rho$ we get

$$\lambda_2 = V'(w_{t_\tau^-})$$

The consumption Euler equation is

$$\frac{\partial_C U'_{t_n}}{\partial_C U'_{t_{n+1}}} = \frac{P_{t_n}}{P_{t_{n+1}}} \frac{f(\Delta t_n;\phi)}{f(\Delta t_{n+1};\phi)} \frac{f(\Delta t_n;\gamma)}{f(\Delta t_{n+1};\gamma)}$$

The transaction Euler equation is obtained using (20),

$$\partial_\Delta U'_{t_n} - \rho e^{-\rho\Delta t_n} U'_{t_{n+1}} - [\partial_\Delta K'_{t_n} - r e^{-r\Delta t_n} K_{t_{n+1}}] V'(w_{t_\tau^-}) = e^{-\rho\Delta t_n}\partial_\Delta U'_{t_{n+1}} - e^{-r\Delta t_n}\partial_\Delta K'_{t_{n+1}} V'(w_{t_\tau^-}).$$

Using the constant guess for the solution, $\Delta t_n = \Delta_{t_{ss-2}} = \Delta t$ and $C_{t_n} = C_{t_{ss-2}} = C$, we obtain a condition similar to the steady state equation for the post tax transaction interval,

$$\partial_\Delta U' - \rho \frac{e^{-\rho\Delta t}}{1 - e^{-\rho\Delta t}} U = [\partial_\Delta K' - r \frac{e^{-r\Delta t}}{1 - e^{-r\Delta t}} K] V'(w_{t_\tau^-}).$$

Using similar steps as in the derivation of the steady state above, we can combine this relationship with (21) to yield

$$(1-\sigma)\frac{\kappa}{P_{t_{ss-2}} S_{t_{ss-2}}} = e^{\phi\Delta t_{ss-2}} \frac{f(\Delta t_{ss-2};r)}{f(\Delta t_{ss-2};\phi)} - 1. \tag{23}$$

Furthermore, since $V'(w_{t_\tau^-})$ is also the multiplier in the post-tax steady state, we can relate $C_{t_{ss-2}}$ and $C_{t_{ss}}$ through (21),

$$\partial_C U'_{t_n} = V'(w_{t_\tau^-}) \partial_C K'_{t_n},$$

such that

$$u'(C_{t_{ss-2}}) f(\Delta t_{ss-2};\gamma)^{1/\sigma - 1} f(\Delta t_{ss-2};\phi) = V'(w_{t_\tau^-}) P_{t_{ss-2}} \frac{f(\Delta t_{ss-2};\phi)}{f(\Delta t_{ss-2};\gamma)}$$

which reduces to

$$u'(C_{t_{ss-2}}) = V'(w_{t_\tau -}) P_{t_{ss-2}} f(\Delta t_{ss-2};\gamma)^{-1/\sigma}.$$

Hence,

$$C_{t_{ss-2}} = \Big(P_{t_{ss-2}} V'(w_{t_\tau^-})\Big)^{-\sigma}$$

and

$$C_{t_{ss}} = \Big(P_{t_{ss}} V'(w_{t_\tau^-})\Big)^{-\sigma}$$

such that

$$\frac{C_{t_{ss-2}}}{C_{t_{ss}}} = \Big(\frac{P_{t_{ss-2}}}{P_{t_{ss}}}\Big)^{-\sigma}.$$

If we use $S_{t_{ss-2}} = C_{t_{ss-2}} f(\Delta t_{ss-2}; \phi)$ in (23), we have two equations in Δt_{ss-2} and $C_{t_{ss-2}}$, which we solve to get the pre tax change solution

$$(1-\sigma)\frac{\kappa}{P_{t_{ss-2}} C_{t_{ss-2}} f(\Delta t_{ss-2}; \phi)} = e^{\phi \Delta t_{ss-2}} \frac{f(\Delta t_{ss-2}; r)}{f(\Delta t_{ss-2}; \phi)} - 1$$

$$\frac{C_{t_{ss-2}}}{C_{t_{ss}}} = \Big(\frac{P_{t_{ss-2}}}{P_{t_{ss}}}\Big)^{-\sigma}$$

To make sure $\sum_{k=0}^{N-1} \Delta t_k = t_\tau$ is satisfied we set

$$t_{\tau-} = N \cdot \Delta t_{ss-2}.$$

This solution has a straightforward interpretation: Intertemporal consumption allocation satisfies the standard consumption Euler equation (even in the presence of transaction fixed costs and product storability) and the optimal trip interval in the pre tax change period reflects the same trade-offs as in the final steady state. Figure 4 highlights these two features of optimal transaction intervals and spending and consumption plans.

C. Tax Salience and Announcement Effects

C.1 Tax Salience: Evidence from Ballot Initiative

A natural question that arises given the results displayed in Figure 2 is whether tax salience plays an additional role in consumers response to a sales tax rate chang and whether news about future sales tax changes prompt a response via an income or wealth effect. While the results in Section 4 document a significant degree of tax foresight on average, it seems reasonable that some households are not fully aware of the tax rate changes, or some aspects of the tax code such as the exemption status of certain goods is not fully salient (e.g., cookies vs. candies). In this section, we test whether more salient tax changes elicit larger spending responses. This analysis is motivated by several highly influential previous studies that document a large degree of non-salience of sales tax rates among consumers (see the literature mentioned in the introduction). Table A.1 presents the results from this analysis.

Panel A uses two measures of tax salience and examines their impact on changes in household spending. The first is the aforementioned index of sales tax news coverage in the month prior to the change. Given that the size of the sales tax change strongly impacts the level of coverage, we first obtain the residuals from a regression of the amount of sales tax news coverage on the size of the change, the squared size of the change, and time fixed effects. With this approach, we interpret the resulting residuals as a measure of news coverage of the impending sales tax change that is unrelated to the size of the change (ideally driven by the amount of other important news in that period, editorial decisions, etc.). Here, the assumption is that the more that sales taxes are written about in local newspapers, the more likely it is that a given household will be aware of the upcoming change in sales taxes and that they will be in position to react to the change.

Columns 1 to 3 interact this news-based measure with changes in state sales taxes. To facilitate the quantitative interpretation, we normalize the news measure by its standard deviation. Since it is a residual, the resulting transformation has mean zero and a unit standard deviation (i.e., a standard score). We again find that, in general, sales tax changes have a negative relationship with spending in the month of the tax change, comparable with the baseline effects reported in Column 2 of Tables 1 and 4. Moreover, changes that had more news coverage (conditional on the size of the change) also had larger declines. The coefficient on the interaction term of Column 1 shows that an increase in news coverage of one standard deviation would increase the spending response to a 1ppt sales tax change by about 20% (from -1.8% to -2.1%). The effect is again similarly shared by taxable and tax-exempt spending.

Columns 4 to 6 take a different approach to testing heterogeneity in household responses across sales tax changes with different salience. Here we utilize data on state-level ballot measures that changed state sales taxes. Our prior is that sales tax changes enacted through state-wide ballots would garner more media attention than those enacted through a vote solely by their state representatives and also would force all voters to be at least somewhat aware of the initiative that they are voting on. Consistent with this hypothesis, we find that changes in sales tax rates that were authorized by a state-wide ballot measure tended to produce much larger responses among households.

C.2 'News' Response: Income, Wealth and Substitution Effects

Panel B of Table A.1 demonstrates some evidence for an announcement effect of sales taxes. For most of the changes in our sample, we are unable to determine when exactly the sales tax change was finalized (often 3 months to 12 months prior to the change taking place). For state ballot provisions, however, we can precisely measure this date, allowing us to look for changes in household spending behavior prior to the change actually taking place.[32]

In a model with fully informed and rational consumers, households would perceive this future tax increase as a persistent increase in future prices. At the time of the announcement (which is before time 0 in the model of Section 5), this leads to a spending response that is the combination

[32] Ideally we would weigh the responses by how close the outcome of the ballot proposition was in order to interpret the spending response as a rational response to a change in expected tax rates. Unfortunately, we do not yet have this data.

of a negative income effect (the same pre-tax consumption plan is more expensive) and a positive intertemporal substitution effect (spending is temporarily cheaper in the period before the sales tax increase). In addition, there could be wealth effects that depend on the consumer's perception and valuation of what the government plans to do with the additional revenue.

Column 7 provides suggestive evidence that this effect might play a role, on average, across all ballots (whether they passed or failed), with the act of voting on the ballot being associated with a 0.5% decline in household retail spending. We further refine the analysis by separating these ballots into those that failed and those that passed, finding opposite signed coefficients. Judging the point estimates, we find a near zero effect on spending following a failed tax increase initiative, while we see a much larger decrease in spending following a successful tax increase vote. These results are consistent with forward-looking behavior on the part of consumer, although they are not statistically significant.

Table A.1: Salience and Announcement Effects

	A. Salience Effects						B. Announcement Effects	
	newspaper coverage			ballot-induced tax changes				
Dependent variable:	Δln(total)	Δln(taxable)	Δln(exempt)	Δln(total)	Δln(taxable)	Δln(exempt)	Δln(total)	Δln(total)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δln(1 + sales tax rate)	-1.738***	-2.124**	-1.572**	-1.526**	-2.238*	-1.310**		
	(0.581)	(1.053)	(0.603)	(0.687)	(1.179)	(0.591)		
Δln(1 + sales tax rate) × Score(newspaper coverage)	-0.361***	-0.336	-0.439**					
	(0.110)	(0.257)	(0.166)					
Δln(1 + sales tax rate) × I(state ballot proposition)				-4.195***	-4.765**	-5.043***		
				(1.050)	(2.038)	(0.889)		
I(date tax rate change proposed)							-0.529	-1.706
							(0.330)	(1.444)
I(date tax rate change proposed) × I(ballot proposition failed)								1.434
								(1.493)
Score(newspaper coverage of state sales tax changes)	-0.001	-0.001*	0.001					
	(0.001)	(0.001)	(0.001)					
I(date ballot proposition failed)				0.022***	0.030***	0.022***		
				(0.005)	(0.009)	(0.005)		
I(ballot proposition failed)								-0.002
								(0.006)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,822,806	5,777,878	5,865,177	5,865,949	5,928,421	5,777,966	5,860,476	5,860,476
R-squared	0.016	0.015	0.014	0.014	0.012	0.013	0.014	0.014

Notes: The dependent variables are monthly changes in logged household spending as measured by Nielsen Consumer Panel data. Taxability and tax-exemption status of household spending is defined at a state level depending on what categories of goods are exempt from sales taxes (e.g., groceries, clothing, medication). Columns 1-3 interact changes in state sales tax rates with the level of newspaper coverage (measured as the demeaned ratio of articles mentioning sales taxes to the total number of articles in newspapers within the state covered by Access World News, normalized by its standard deviation). Columns 4-6 interact changes in sales tax rates with an indicator for whether the change in state sales tax rates was driven by a ballot measure (as opposed to being enacted by the legislature). Columns 7 and 8 use, as independent variables, indicators for dates when ballot initiatives that would change state sales tax rates were voted on (as opposed to the dates they were enacted). Column 8 interacts these indicators with another indicator that signifies the ballot not being successfully passed (and thus resulting in no change in sales tax rates). For robustness, the dependent variables are winsorized at the 1% level. Regressions span years 2004-2014. Robust standard errors in parentheses adjust for arbitrary within-household correlations and heteroskedasticity and are clustered at the state level.