Salience and Taxation with Imperfect Competition

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Abstract

This paper studies commodity taxation in a general model featuring imperfect competition and tax salience. We derive a sufficient statistics formula for the marginal excess burden of commodity taxation and show that it depends on: (1) the causal effect of taxes on prices, quantity, and product variety, (2) the causal effect of variety on consumer surplus, and (3) the degree of inattention to taxes. We estimate these objects by combining Nielsen Retail Scanner data covering grocery stores in the U.S. with detailed product-level and county-level sales tax data. We use the estimates to calibrate our new tax formula and conclude that the welfare effects of taxation are several times larger than standard formulas that ignore endogenous product variety and tax salience.
1 Introduction

Standard welfare analysis of commodity taxation typically makes two key assumptions: (1) the product market is perfectly competitive and (2) consumers respond to taxes in the same way they respond to price changes, as would be expected when taxes are fully salient to consumers. Several papers in public economics have relaxed the first assumption (see Auerbach and Hines (2002) for a review of some of this literature), but these papers have maintained the second assumption that taxes are fully salient. More recently, researchers have relaxed the second assumption, developing new theoretical and empirical tools to analyze the welfare effects of taxes when taxes are less salient than prices (see, e.g., Chetty et al. 2009 and Allcott and Taubinsky 2015), but have maintained the assumption of perfect competition. If markets are characterized by imperfect competition and consumers misperceive taxes, neither of these approaches is likely to provide a fully accurate characterization of the welfare effects of commodity taxes.

The first contribution of this paper is to derive a new formula for the marginal excess burden of commodity taxation in a general model featuring imperfect competition, differentiated products, endogenous product variety, and tax salience. On the firm side, the model follows Weyl and Fabinger (2013) and permits both price-setting and quantity-setting models of competition using conjectural variations. On the consumer side, the model imposes no income effects, but otherwise is flexible in leaving the sub-utility for the (taxed) differentiated products unspecified. Our first result (Proposition 1) is that the marginal excess burden in this general model is the sum of two terms: a term which depends on the distortionary effect of taxation on output and a term which depends on the effect of taxation on product variety. The effect of taxes on output is scaled by the markup of price over marginal cost as well as a measure of tax salience, as in Chetty et al. (2009). The effect of taxes on product variety is scaled by the difference between the effect of variety on consumer surplus – what Kroft et al. (2019a) label the “variety effect” – and the fixed cost of production of the marginal variety
(under constant marginal costs). The presence of the variety effect in the tax formula comes from the fact that when taxes affect the number of varieties available in the market – and consumers exhibit a “love of variety” – there will be an externality since firms do not take into account consumer surplus at the margin when deciding whether to offer a new variety. Interestingly, our analysis suggests that if the variety effect is less than the fixed cost, then welfare may increase when taxes are raised – even if taxes reduce product variety. In this case, entry is excessive and taxes play a corrective role.

This theoretical analysis generalizes and unifies several existing results in the literature on taxation. First, we show that with exogenous or socially optimal variety and assuming taxes are fully salient, our tax formula collapses to the formula in Auerbach and Hines (2002) with homogeneous goods, which depends only on the output response to the tax along with the firm-level markup. Second, we show that with endogenous, privately-optimal variety and homogenous goods (and continuing to assume taxes are fully salient), our formula collapses to the tax formula in Besley (1989), which depends additionally on the fixed cost of production and the response of variety to taxes. Intuitively, with homogeneous products, the variety effect is zero so the only welfare effect of changes in variety comes from fixed costs of production. Third, we show that our formula nests Chetty et al. (2009) when markups are zero (i.e., the product market is perfectly competitive) and variety is either fixed or is socially optimal.

The second contribution of this paper is to empirically implement the new tax formula. A key challenge to identifying the marginal excess burden of taxation is that marginal costs – and hence markups – are not directly observable to the econometrician. To make progress, we exploit a long-run free-entry condition and show that in our model, this condition results in the markup being equal to the ratio of the price effect to the output effect of the tax (Lemma 1). Substituting this condition into our tax formula shows that the marginal excess burden tax formula depends on the following: (1) the causal effect of taxes on prices and quantity, (2) the causal effect of taxes on product variety, (3) the causal effect of variety on
consumer surplus (the “variety effect”), and (4) a measure of the degree of inattention to taxes. These four inputs are sufficient statistics for welfare analysis.

We estimate each of these terms using Nielsen Retail Scanner data covering grocery stores selling consumer goods in the U.S. combined with product-level and county-level sales tax data. For (1), we identify the reduced-form effects of sales taxes – on prices and quantity – using county-level variation in sales tax rates and tax exemptions. We find full “pass-through” of sales taxes to consumer prices, and we estimate a large effect of taxes on quantity. For (2), we use the same sales tax variation and estimate a large effect of sales taxes on product variety. To our knowledge, this paper provides the first large-scale evidence (across many different types of consumer goods) that taxes meaningfully affect the variety of products available to consumers.\(^1\) For (3), we identify the variety effect by building on and extending the results in Kroft et al. (2019a) to allow for tax salience, and we again use variation in sales tax rates and tax exemptions for identification. We find a similar “love of variety” estimate to Kroft et al. (2019a) despite using a different source of variation for identification. For (4), we provide a new estimate of tax salience by taking the ratio of the reduced-form estimate of the effect of taxes on quantity to the effect of prices on quantity. The numerator is identified using sales tax variation, while the denominator uses an instrument for price that exploits the “uniform pricing” across stores within a retail chain (DellaVigna and Gentzkow, forthcoming). We find that consumers under-react to taxes relative to posted prices (so that the estimated ratio is less than one), and the estimated under-reaction is quite similar to other estimates that come from similar settings (Chetty et al. 2009; Allcott and Taubinsky 2015).

In the final part of the paper, we calibrate our new tax formula using our empirical estimates. We find that accounting for imperfect competition, endogenous product variety, and imperfect tax salience meaningfully changes the estimated marginal excess burden of

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\(^1\)Our results are consistent with Cawley et al. (2018), which finds that a beverage tax in Philadelphia resulted in fewer taxed products available in stores. We find a broadly similar pattern of results across many different product categories.
sales taxes. Chetty et al. (2009) shows that when consumers under-react to sales taxes, a standard Harberger formula is likely to exaggerate the true excess burden of sales taxes under a no income effects assumption. However, under imperfect competition and endogenous product variety, our new welfare formula shows that this may no longer be the case – in fact, our calibration results suggest that even though consumers under-react to taxes due to imperfect tax salience, the Harberger formula nevertheless actually understates, rather than overstates, the excess burden of sales taxes. Overall, we interpret the calibration results as revealing the importance of tax salience and imperfect competition for the welfare analysis of commodity taxation, and our general formulas show how to incorporate these features in a unified framework.

As we describe in more detail below, a key advantage of the general framework we develop in this paper is that it nests many different models of imperfect competition (such as price-setting and quantity-setting competition) as special cases. Additionally, building on Kroft et al. (2019a), we show how we are able to estimate consumers’ “love of variety” without specifying consumer preferences. This means that our welfare formula is robust to a wide range of underlying models of consumer choice and models of imperfect competition. We achieve this robustness by simplifying other aspects of the consumer and firm problems. For example, our theoretical analysis assumes symmetry in prices across the differentiated products. Under this assumption, our tax formula has the advantage of being implementable with market-level data – average prices, total quantity demanded, and number of products available (product variety) – and we provide precise conditions under which these market-level measures are sufficient statistics for welfare analysis. In this way, our framework is broadly related to work on sufficient statistics for welfare analysis in public economics, and so our framework inherits many of the same advantages and disadvantages highlighted in that literature (see, e.g., Chetty 2009 for a discussion of trade-offs).

Our paper is related to several streams of research. First, our paper builds on and contributes to a large literature on taxation and imperfect competition (see, e.g., Seade
(1987), Stern (1987), Myles (1989), Besley (1989), Delipalla and Keen (1992), Anderson, de Palma and Kreider (2001a, 2001b), Auerbach and Hines (2001), Weyl and Fabinger (2013), Gillitzer, Kleven and Slemrod (2015), Hackner and Herzing (2016), Adachi and Fabinger (2018) and Miravete et. al. (2018)). Our paper is innovative in two ways. First, we consider a general model of imperfect competition and do not impose a functional form for preferences. Second, most papers focus on the “short-run” equilibrium holding the number of firms and/or varieties fixed, so that taxes cannot cause entry or exit, or changes in the number of varieties available. These papers also do not allow for consumers to under-react to taxes.\(^2\) By allowing for endogenous variety and tax salience, we show how many existing tax formulas can be represented as special cases of our general tax formula. Unlike most of the research in this area, we also provide an empirical application that allows us to calibrate our formula.\(^3\)

Second, we contribute to the recent behavioral public economics literature that studies tax salience (Chetty et al. (2009), Goldin and Hominoff (2013), Allcott and Taubinsky (2015), Farhi and Gabaix (2017), Rees-Jones and Taubinsky (2018), and Allcott, Lockwood and Taubinsky (2018)). Our main contribution to this literature is that we are able to extend prior results that assume perfect competition, and we also show how we can estimate consumers’ “love of variety” using sales taxes as an instrument in the presence of salience effects.

Lastly, by providing new estimates of consumers’ “love of variety”, we also contribute to a large literature that seeks to estimate how much consumers value product variety (Feenstra 1994, Broda and Weinstein 2006).\(^4\) Additionally, we connect our theoretical results to the

\(^2\)Weyl and Fabinger (2013) and Adachi and Fabinger (2018) also consider a general form of competition using the conjectural variations model. These papers however assume the number of firms is fixed.

\(^3\)Our empirical analysis contributes to the literature studying sales taxes empirically; see, e.g., Besley and Rosen (1999), Einav et al. (2014), Baker, Johnson, and Kueng (2018).

\(^4\)As we describe in more detail below, the estimation of consumers’ “love of variety” using sales taxes as instrumental variable extends results in Kroft et al. (2019a) which develops a new sufficient statistics approach to estimating “love of variety”. We extend that paper to allow for imperfect tax salience. Like Kroft et al. (2019a), we also need to make additional assumptions on the market (aggregate) demand curve, which relies on some of the technical results that are developed in Kroft et al. (2019b) on “parallel demands” (i.e., that the inverse market demand curve shifts vertically in parallel in response to an exogenous change in
literature on optimal product variety (Mankiw and Whinston 1986) by showing how tax variation can be used to identify the relative magnitude of the “business stealing effect” and the “variety effect”. We find that reductions in product variety (coming from an increase in sales taxes) lead to welfare losses that significantly exceed conventional estimates of the excess burden of sales taxes, but we refrain from making any conclusions about whether or not variety is higher or lower than is socially optimal.

The rest of the paper proceeds as follows. Section 2 derives a general formula for the marginal excess burden of commodity taxation and considers several special cases. The section wraps up by providing the tax formula that is empirically implemented. Section 3 describes the data used in the empirical analysis. Section 4 describes our main reduced-form estimates. Section 5 calibrates our formula using our empirical estimates. Section 6 concludes.

2 Marginal Welfare Gain of Taxation

We model the welfare effects of commodity taxation with imperfect competition. We consider a differentiated product market (the “inside market”) which is subject to a unit tax \( t \) on consumers that applies to each product in the market.\(^5\) We assume that markets for other goods are perfectly competitive and are not subject to taxation, implying that taxes in the inside market have no indirect welfare effects on other markets in the economy. We extend previous theoretical results on taxation with imperfect competition in two ways: first, we allow for “behavioral” agents that need not optimize with respect to taxes following Chetty et al. (2009); second, we allow taxes to affect product variety through the free-entry decision.

\(^5\)For simplicity, we limit the discussion in this section to the case of a unit tax, but we derive analogous results of all of the main formulas for the case of ad valorem tax in the Appendix. Additionally, our empirical implementation is based on the analogous ad valorem tax formulas.
of firms following Besley (1989). In this section, we first present results for the general case and then consider several specialized cases, in order to connect our results with the literature on taxation.

Following Auerbach and Hines (2001), we abstract from population heterogeneity and thus consider a single representative individual with exogenous income $Z$. Preferences when there are $J$ varieties available are given by the quasi-linear utility function $u'(q_1, \ldots, q_J) + y$, where $q_j$ is the quantity consumed of variety $j = 1, \ldots, J$ and $y \in \mathbb{R}$ is the numeraire (representing consumption in all the outside markets). We assume that the subutility function, $u'$, which represents preferences for the differentiated products, is strictly quasi-concave, twice differentiable and symmetric in all of its arguments. The pre-tax or producer price for product $j$ is given by $p_j$ and the post-tax or consumer price is given by $p_j + t$ for all $j = 1, \ldots, J$. We define $u(Q, J) \equiv u'(Q/J, \ldots, Q/J)$ to be the compact notation of utility for the symmetric case where the individual consumes $q = Q/J$ units of each variety $j = 1, \ldots, J$. Furthermore, we assume the planner’s problem is well behaved, in the sense that $u(Q, J)$ is concave in $J$, so variety has diminishing returns.

Following Chetty et al. (2009), consumer demand for product variety $j$ is given by $q_j = q_j(p_1, \ldots, p_J, t)$ which is a function of both prices and the commodity tax. In the neoclassical full-optimization model, demand depends only on the total tax-inclusive price: $q_j = q_j(p_1 + t, \ldots, p_J + t, 0)$. In this case, equal changes in prices and taxes affect demand symmetrically. We allow for tax salience by considering the possibility that $q_j(p_1, \ldots, p_J, t) \neq q_j(p_1 + t, \ldots, p_J + t, 0)$. In what follows, we assume that the “observed” demand function $q_j(\cdot)$ is symmetric and twice differentiable and denote by $q'(p, t)$ demand corresponding to symmetric prices and $J$ firms: $q'(p, t) \equiv q_j(p, \ldots, p, t)$. We define market demand as $Q(p, t, J) = Jq'(p, t)$ and inverse market demand as $P(Q, t, J) = Q^{-1}(p, t, J)$. For a fully salient tax, market demand is $Q(p + t, J)$ and inverse market demand is $P(Q, J)$.

On the supply side, there is an infinite pool of identical potential entrants. Each firm has the cost function $c_j(q_j) = c(q_j) + F$, where $c(\cdot)$ is the variable cost of production which is
increasing and twice differentiable with \( c(0) = 0 \) and \( F > 0 \) is the fixed cost of production. A given firm makes two decisions. First, each firm decides whether to produce given the fixed cost \( F \). Second, each firm chooses \( p_j \) to maximize profits \( \pi_j \):

\[
\max_{p_j} \pi_j = p_j q_j(p_1, \ldots, p_J, t) - c(q_j(p_1, \ldots, p_J, t)) - F
\]

s.t. \( \frac{\partial p_k}{\partial p_j} = \vartheta \) for \( k \neq j \)

The first-order condition for \( p_j \) is given by:

\[
q_j + (p_j - c'(q_j)) \left( \frac{\partial q_j}{\partial p_j} + \vartheta \sum_{k \neq j} \frac{\partial q_j}{\partial p_k} \right) = 0.
\]

We allow for different forms of competition by introducing the market conduct parameter \( \vartheta = \frac{\partial p_k}{\partial p_j} \) following Weyl and Fabinger (2013). By setting \( \vartheta = 0 \), we obtain Bertrand competition and by setting \( \vartheta = 1 \) we obtain perfect collusion.\(^6\) The conjectural variation term is a reduced-form version of a Nash equilibrium only when it corresponds to static solution concepts (e.g. \( \vartheta = 0, -1 \)) or are reduced-forms of truly dynamic models (see Vives 2001, Riordan 1985) or supply function equilibria (Hart 1982). We do not take a stand on the dynamic model that \( \vartheta \) captures in reduced-form, instead proving that our evaluation of welfare is robust to any of the specifications that can be modeled this way.

In a symmetric equilibrium, \( p_j = p \) solves:

\[
q_j(p_j, p, \ldots, p, t) + (p_j - c'(q_j)) \left( \frac{\partial q_j(p_j, p, \ldots, p, t)}{\partial p_j} + (J - 1)\vartheta \frac{\partial q_j(p_j, p, \ldots, p, t)}{\partial p_k} \right) = 0, k \neq j
\]

We assume that \( \frac{\partial \pi_j}{\partial p_j}(p_j, p) \) is strict single crossing (from above) in \( p_j \) and decreasing in \( p \) so that a unique symmetric equilibrium \( p(J, t) \) exists.\(^7\) Furthermore, we require that \( 1 + \vartheta \equiv \frac{dQ}{dq} \).

\(^6\)In the homogeneous good conjectural variation model, the first-order condition is given by:

\[
p + \frac{dp}{dQ}(1 + \vartheta) - c = 0
\]

where \( 1 + \vartheta \equiv \frac{dQ}{dq} \). The model nests various forms of competition such as Cournot (\( \vartheta = 0 \)), Bertrand (\( \vartheta = -1 \)), and perfect collusion (\( \vartheta = J - 1 \)) which, of course, gives the monopoly outcome.

\(^7\)The case of strategic complementarities, where \( \frac{\partial \pi_j}{\partial p_j}(p_j, p) \) is increasing in \( p \) allows for the existence of multiple symmetric equilibria. However, in that case if we assume there is a continuous and symmetric equilibrium selection \( p(t) \) the same results follow.
\( \pi_j(p(J, t), J, t) \) be decreasing in \( J \). In what follows, we will treat the number of firms as a continuous variable, a standard procedure in this literature following Seade (1980) and Besley (1989). In the “long run”, the number of firms \( J(t) \) in the symmetric equilibrium is determined by the free-entry condition \( \pi_j(p(J, t), J, t) = 0 \):

\[
p(J(t), t)q_j^*(p(J(t), t), t) - c(q_j^*(p(J(t), t), t)) - F = 0
\]

(1)

For concreteness, we define the long-run demand as \( Q_L(t) = Q(p(t), t, J(t)) \).

### 2.1 Salience, Elasticity Concepts, Sufficient Statistics and Simplifying Assumptions

The marginal welfare gain formula depends on several sufficient statistics: the degree of inattention or salience, elasticities, and the “variety effect”, which we define as the effect of a change in varieties on consumer surplus (holding prices constant) following Kroftet et al. (2019a). The next set of definitions, which are inputs to our marginal welfare gain formula, are defined as follows:

- \( \theta \): the degree of inattention to the tax is formally defined as the ratio of the tax elasticity of demand and the price elasticity of demand \( \theta = \frac{\partial Q}{\partial t} \frac{\partial t}{\partial p} = \frac{\varepsilon_{Q,t}}{\varepsilon_{Q,p}} \) where \( \varepsilon_{Q,t} = \frac{\partial Q}{\partial t} \frac{p + t}{Q} \) and \( \varepsilon_{Q,p} = \frac{\partial Q}{\partial p} \frac{p + t}{Q} \).
- \( \frac{dp}{dt} \): the effect of taxes on producer prices, which is related to pass-through, \( 1 + \frac{dp}{dt} \).
- \( \frac{dQ_L}{dt} \): the effect of taxes on long-run demand, equal to \( \frac{\partial Q}{\partial t} + \frac{\partial Q}{\partial J} \frac{dJ}{dt} + \frac{\partial Q}{\partial p} \frac{dp}{dt} \).
- \( \Lambda \): the variety effect which captures the effect of a change in varieties \( J \) on consumer surplus \( CS = u(Q, J) - (p + t)Q \), keeping \( p \) and \( Q \) fixed, equal to \( \frac{\partial CS}{\partial J} = \frac{\partial u^J}{\partial J} \).

In order to connect our tax formulas to empirically estimable objects, it is necessary to relate observed demand \( q_j(p_1, \ldots, p_J, t) \) to consumer willingness to pay. We begin with the following assumptions which mirror assumptions A1 and A2 in Chetty et al. (2009).

**Assumption 1.** Taxes affect utility only through their effects on the chosen consumption

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8Here we use the assumption that for each tax \( t \) there is a unique symmetric price equilibrium \( p(t) \) where \( J(t) \) firms enter the market. The notation \( Q_L \) serves to mathematically differentiate the functions \( Q(\cdot, \cdot, \cdot) : \mathbb{R}^3 \to \mathbb{R} \) and \( t \to Q(p(t), t, J(t)) \).
bundle. Indirect utility is given by:

\[
V(p, t, Z) = u'(q^J(p, t), \ldots, q^J(p, t)) + Z - (p + t)Q(p, t, J)
\]

Assumption 1 requires that taxes or salience have no impact on utility beyond their effects on consumption. Next, we require that when tax-inclusive prices are fully salient, agents maximize utility:

**Assumption 2.** When tax-inclusive prices are fully salient, the agent chooses the same allocation as a fully-optimizing agent.

\[
(q_1, \ldots, q_J)(p_1, \ldots, p_J, 0) = \arg \max_{(q_1, \ldots, q_J)} u'(q_1, \ldots, q_J) + Z - p_1 q_1 - \cdots - p_J q_J
\]

Assumption 2 implies that \(P(Q, J) = \frac{\partial u}{\partial Q}(Q, J)\) through the first-order condition for \(Q\).

Next, assuming that demand \(Q(p, t, J)\) is linear in \(p\) and \(t\), we get \(P(Q) = p + \frac{dp}{dQ}(Q(p, t, J) - Q(p, 0, J)) = p + \frac{dp}{dQ}dt = p + \theta t\) which we will use below.

### 2.2 Welfare and Tax Salience

In this section, we consider the marginal welfare gain associated with a small increase in the tax \(t\) which applies to all goods in the inside market. We assume throughout that tax revenue \(R = tQ\) and profits \(J\pi\) are redistributed to the representative consumer as a lump-sum transfer. As is standard in this literature, the consumer treats profits and tax revenue as fixed when choosing consumption, failing to consider the external effects on the lump-sum transfer. Given the assumption of quasi-linear utility, the consumer will choose to allocate the lump-sum transfer to the outside market \(y\). Thus, total welfare, \(W\), is given by the sum of consumer surplus, profits and government tax revenues.

\[
W(p, t, J) = \underbrace{u(Q, J)}_{CS} - \underbrace{(p + t)Q + pQ - Jc \left( \frac{Q}{J} \right) - JF}_{J\pi} + \underbrace{tQ}_{R}
\]

**Proposition 1.** Consider a change in the tax from \(t_0\) to \(t_1\). Under Assumptions 1 and 2, a first-order approximation to the marginal excess burden of taxation is:
\[
\frac{dW(p(t), t, J(t))}{dt} = (\theta t_0 + p_0 - c'(q_0))\frac{dQ}{dt} + (\Lambda_0 + \pi_0 - [p_0 - c'(q_0)] * q_0)\frac{dJ}{dt}
\]

where \(p_0, q_0, Q_0, J_0, \pi_0, \Lambda_0\) are all variables evaluated at the equilibrium corresponding to \(t_0\).

**Proof.** The proof is in the Appendix. \(\square\)

Equation (3) shows that the welfare excess burden of taxation is a combination of two main terms. The first term represents the distortionary effect of taxation on output. Intuitively, the social marginal value of output is given by the difference between willingness to pay \(p_0 + \theta t_0\) and the social marginal cost \(c'(q_0)\). With no pre-existing taxes \((t_0 = 0)\) or when \(\theta = 1\), the first term depends only on the markup which represents a distortionary “wedge” in output due to the presence of market power.

The second term represents the distortion to product variety. To see the intuition for this expression, consider the case of constant marginal cost. The second term becomes \((\Lambda_0 - F) \frac{dJ}{dt}\). Thus, whether the change in variety induced by taxes lowers (increases) welfare at the margin depends on whether the love of variety exceeds (is less than) the fixed cost.

The term \(\Lambda_0 - F\) thus represents the distortionary wedge on the entry margin due to free-entry. This relates to the well-known result that free-entry may be inefficient (Mankiw and Whinston 1986).

This discussion shows that welfare is maximized when there are no wedges in the economy either due to taxation, market power or free-entry. This occurs when \(t = 0, p = c'(q^*)\) and \(\Lambda = -\pi\). This can be stated formally as follows:

\[
\max_{Q,J} u(Q, J) - Jc\left(\frac{Q}{J}\right) - JF
\]

**Corollary 1.** The first-best allocation of variety and output that maximizes welfare is characterized by:

1. The marginal cost of production is equal to the willingness to pay for the marginal unit:
   \[
   \frac{\partial u}{\partial Q}(J^* q^*, J^*) = c'(q^*).
   \]
2. The variety effect is equal to the losses of the marginal entrant: \( \Lambda - F = 0 \) (assuming \( p = c'(q^*) \) to calculate profits).

An indirect implementation of first-best can be achieved setting \( t = 0 \) (implying \( p = c'(q^*) \)) and choosing \( J \) to set \( \Lambda = F \).

Proof. Observe that for each \( J \) by quasi-concavity of \( u \) and convexity of \( c(q) \) we can implement the first-best \( Q \) by setting price equal to marginal cost and \( t = 0 \). Substituting in (3) for \( \frac{dW}{dt} = 0 \) we get \( \Lambda = F \).

2.3 Interpreting the Formula: Special Cases and Additional Intuition

Equation (3) nests canonical formulas in public economics for: homogeneous or differentiated products, perfect or imperfect competition, fixed or endogenous variety, fully optimizing or behavioral agents. We now describe the special cases and the connection to the literature on taxation.

2.3.1 Perfect competition with homogeneous products

Harberger (1964) and Chetty (2009) consider the case of perfect competition, where \( p = c'(q) \), and fixed \( J \). In this case, equation (3) reduces to:

\[
\frac{dW}{dt} = \theta t_0 \frac{dQ_L}{dt}
\]

which is the familiar calculation of excess burden represented by the Harberger triangle scaled by the inattention parameter. The simple case with fully optimizing agents (\( \theta = 1 \)) corresponds to the classic analysis by Harberger, while the extension to behavioral agents corresponds to the analysis in Chetty et al. (2009).
2.3.2 Imperfect competition with homogeneous products and exogenous or second-best variety

Auerbach and Hines (2001) consider a model of homogeneous products ($\Lambda_0 = 0$) with imperfect competition and fixed variety ($\frac{dJ}{dt} = 0$) and fully optimizing consumers ($\theta = 1$). In this case, the marginal excess burden of taxation is given by:

$$\frac{dW}{dt} = (p_0 + t_0 - c'(q_0))\frac{dQ_L}{dt}. \quad (5)$$

There are two additional points regarding the welfare formula (5). First, one can derive an equivalent represent of $\frac{dW}{dt}$ expressed in terms of the conduct parameter.\(^9\) Although we do not attempt to identify the conduct parameter in our empirical application, in principle, one could apply the methods in Bresnahan (1989). Second, formula (5) also holds in the case of second-best variety: a central planner chooses $J$ optimally considering that pricing decisions are left to firms.\(^{10}\)

2.3.3 Imperfect competition with homogeneous products and endogenous variety

We now allow for the possibility that taxation may affect the equilibrium number of firms when $J$ is determined by the free-entry condition, as in Besley (1989). When goods are homogeneous ($\Lambda = 0$), consumers optimize ($\theta = 1$) and the marginal cost is constant ($c'(q) = \frac{1}{\eta(q)p(q)} \left( p_c(q) - \frac{t + c'(q)}{1 - \nu} \right) = \vartheta \quad (6)$

where $\eta(q)$ is the inverse of the price elasticity of market demand $q(p)$, $p_c$ is the consumer price and $\nu$ is an ad valorem tax. Using equation (6) and equation (5) they derive an expression for the marginal cost of public funds in Proposition 1 in terms of what they label an *elasticity-adjusted Lerner index*.

\(^9\)Adachi and Fabinger (2018) show that the first-order condition for the firms’ problem is summarized in the following expression

$$\eta(q)p(q)

= \frac{1}{\eta(q)p(q)} \left( p_c(q) - \frac{t + c'(q)}{1 - \nu} \right) = \vartheta \quad (6)$$

\(^{10}\)The proof is the following: the planner seeks to maximize $\max_J W(Q,J) = u(Q,J) - Jc\left( \frac{Q}{J}\right) - JF$ taking the pricing decisions of firms as given. When the planner solves for the second-best variety, she chooses $J$ to set $\frac{\partial W(Q,J)}{\partial J} = \frac{\partial W}{\partial Q} \frac{dQ}{dJ} + \frac{\partial W}{\partial J} = 0$. Then:

$$\frac{dW}{dt} = \left( \frac{\partial W}{\partial Q} \frac{dQ}{dt} + \frac{\partial W}{\partial J} \frac{dJ}{dt} \right) + \frac{\partial W}{\partial Q} \frac{dQ_L}{dt} = \frac{\partial W}{\partial Q} \frac{dQ_L}{dt} = (p + \theta t - c'(q))\frac{dQ_L}{dt}$$
For $c_0$, the tax formula collapses to:\(^{11}\)

$$\frac{dW}{dt} = (p_0 + t_0 - c_0) \frac{dQ_L}{dt} - F \frac{dJ}{dt}. \quad (7)$$

In this case, the direct entry effect enters as a negative. The intuition is easiest to see in the case where there is a reduction in taxes which induces entry of new firms. Since firms are symmetric and marginal cost is constant, it is more efficient to produce output with existing firms than to have new firms enter and incur the fixed cost of production.\(^ {12}\)

### 2.3.4 Imperfect competition with differentiated products and endogenous variety

Finally, we can re-express equation (3) in terms of the responsiveness of firm output to taxation by substituting for aggregate demand using the relation $\frac{dQ_L}{dt} = J \frac{dq}{dt} + q \frac{dJ}{dt}$ to get the following:

$$\frac{dW}{dt} = (p_0 + \theta t_0 - c'(q_0)) J_0 \frac{dq}{dt} + (\Lambda_0 + \theta t_0 q_0 + \pi_0) \frac{dJ}{dt}. \quad (8)$$

This welfare formula bears resemblance to the formula for the marginal welfare gain of an additional variety in Mankiw and Whinston (1986). In particular, the sign of the marginal excess burden of is related to the question of socially optimal variety, since the zero-profit condition implies:

$$\frac{dW}{dJ} = (p_0 + \theta t_0 - c'(q_0)) J_0 \frac{dq}{dt} + \Lambda_0 + \theta t_0 q_0.$$

This leads to the following proposition:

**Proposition 2.** Starting from no tax $t_0 = 0, \theta \in [0,1], and \pi_0 = 0$, increasing the tax

\(^{11}\)Besley (1989) assumes Cournot competition but the formula is valid for other types of competition through the conduct parameter.

\(^{12}\)One can also show that $\frac{dW}{dt} = \theta t_0 \frac{dQ_L}{dt} + (p_0 - c'(q_0)) J \frac{dq}{dt}$. \(\square\)
increases welfare if and only if the business stealing effect is greater than the variety effect:

\[
(p_0 - c'(q_0))J_0 \left( -\frac{dq_L/dt}{dJ/dt} \right) > \Lambda_0
\]

Intuitively, if there is excessive entry in the Mankiw and Whinston (1986) sense, then \( \Lambda_0 < (p_0 - c'(q_0))J_0 \left( -\frac{\partial q}{\partial J} \right) \); in this case, increasing the tax reduces the number of entrants, thus improving welfare through this margin. The difference between \( \frac{dq_L/dt}{dJ/dt} \) and \( \frac{\partial q}{\partial J} \) is an empirical question; however, since \( \frac{dq_L/dt}{dJ/dt} = \frac{\partial q}{\partial J} \frac{dJ}{dt} + \frac{\partial q}{\partial p} \frac{dp}{dt} + \frac{\partial q}{\partial t} \) and in our empirical implementation \( \frac{dp}{dt} = 0 \) and \( \frac{\partial q}{\partial t} \) is relatively small, \( \frac{dq_L/dt}{dJ/dt} \approx \frac{\partial q}{\partial J} \). Therefore, the question of a positive effect of taxes and too much entry in the Mankiw-Whinston sense are isomorphic.

2.4 Empirical Implementation

In practice, equation (3) may be difficult to implement empirically since it is challenging to measure marginal cost \( c'(q) \), and hence the markup \( p - c'(q) \). We now show how one may exploit the long-run free-entry condition to provide a remarkably simpler representation for the marginal excess burden that maps more easily to empirically estimable objects. We begin with the following lemma.

**Lemma 1.** In the long run (when the free-entry condition (1) is satisfied), for any tax rate \( t \), the following envelope condition holds:

\[
\varepsilon_{p,t} = \frac{p - c'(q)}{p} = \frac{\frac{\partial p}{\partial t}}{\frac{\partial q}{\partial t}}
\]

where \( \varepsilon_{p,t} = \frac{t dp}{p dt} \) and \( \varepsilon_{q,t} = \frac{t dq}{q dt} \).

This condition follows by totally differentiating the zero-profit condition with respect to the tax, \( \frac{dp}{dt} = 0 \). In economic terms, it requires that entry is such that after the tax change, the zero-profit condition continues to hold. We restate the tax formula using this result.

**Proposition 3.** Under Assumptions 1 and 2 and Lemma 1, the marginal excess burden of taxation is given by:

\[
\frac{dW}{dt} = \Lambda_0 \frac{dJ}{dt} - Q_0 \frac{dp}{dt} + \theta t_0 \frac{dQ_L}{dt}
\]
Proof. The equation follows immediately from Proposition 1 and Lemma 1.

The welfare formula is composed of the following effects:

- The variety effect $\Lambda_0 \frac{dJ}{dt}$.
- The price effect $-Q_0 \frac{dp}{dt}$.
- The output effect $\theta(0) \frac{dQ}{dt}$.

While the price and output effects are straightforward to estimate, it is less obvious how to identify the variety effect, particularly when consumers do not optimize with respect to taxes.

In order to identify the variety effect, we follow Kroft et al. (2019a) and introduce a restriction on preferences that will help us identify the variety effect, $\Lambda$. If $\frac{\partial P}{\partial J}(Q, J_0) = \frac{\partial P}{\partial J}(Q, J_1)$ for all $J_0, J_1$ and $Q$ we say that the inverse aggregate demands are parallel.

**Assumption 3.** The inverse market demands $P(Q, J)$ are parallel.

Inverse market demands are parallel if and only if they are linearly separable in $Q$ and $J$. Therefore any family of parallel inverse aggregate demands can be written as $P(Q, J) = a(J) - f(Q)$ for differentiable functions $a(J)$ and $f(Q)$, where $f(Q)$ is strictly increasing.

**Example 1.** Assume preferences are given by

$$u'(q_1, \ldots, q_J) + y = \left( \int_0^J a(J) J^{p-1} q(j)^p dj \right)^{\frac{1}{p}} - G \left( \int_0^J q(j) dj \right) + y$$

where $a(J)$ is strictly increasing and differentiable, with $a(0) = 0$; and $G$ is strictly convex, twice continuously differentiable and $G(0) = 0$. Then inverse demands are parallel and Assumption 3 is satisfied. In Kroft et al. (2019b) we show that commonly-used discrete choice models feature parallel market demands.

Using the parallel demands assumption, Kroft et al. (2019a) show – in the absence of taxation – how one may identify the variety effect as $\Lambda = \frac{\partial u}{\partial J}$ using a supply-side instrument $z$ that is uncorrelated with preferences and demand and that is observed in two scenarios: (1) when variety is held fixed and (2) when variety can vary:

$$\Lambda = Q \left[ \frac{dp}{dJ} - \frac{dp}{dz} \left. \frac{dQ}{dz} \right|_J \right] \frac{1}{\frac{dJ}{dz}}$$

(11)
A potential instrument is sales taxes which vary along several dimensions: across products, across states and over time. However, as shown in Chetty et al. (2009) and Goldin and Homonoff (2013), sales taxes are not fully salient and as a result, consumers may underreact to them relative to prices. In order to see how one may identify the variety effect in the presence of salience effects, consider a reduction in market demand due to a tax increase \( dt \) which leads to lower variety, as shown in Figure 1. The figure depicts the tax-demand curve as more inelastic than the price-demand curve since consumers respond less to taxation than prices, consistent with the empirical evidence. The initial equilibrium \((P_0, Q_0)\) features no taxes and so the tax-demand curve and price-demand curve intersect by Assumption 2. If we calculated the decrease in willingness to pay for unit \( Q_1 \) using the tax-demand curves (in blue), we would obtain \( P^{**} - (P_1 + t_1) \). However, the true change in willingness to pay is \( P^* - P_1^* < P^{**} - (P_1 + t_1) \) and so using the observed demands in the calculations overestimates the variety effect. The following proposition shows how one may identify the variety effect using the salience parameter along with the observed behavioral responses to the tax and Assumption 3 (parallel demands) when there is a pre-existing tax.

**Proposition 4.** Under Assumptions 1, 2 and 3, the variety effect is identified:

\[
\Lambda \frac{dJ}{dt} = -Q \left( \frac{dp}{dt} + \theta \left( \frac{1}{\partial Q_L/\partial t} - \frac{1}{\partial Q/\partial t} \right) \frac{dQ_L}{dt} \right)
\]  

(12)

**Proof.** The proof is in the Appendix.

In the particular case where taxes are fully salient, \( \theta = 1 \), we can substitute \( \partial Q/\partial t = \partial Q/\partial p \) to recover the formula in Kroft et al. (2019a):

\[
\Lambda \frac{dJ}{dt} = -Q \left( \frac{dp}{dt} + 1 - \frac{dQ_L}{dt} \right) = -Q \left( \frac{d(p+t)}{dt} \frac{dQ_L}{dt} - \frac{1}{\partial Q/\partial p} \right) \frac{dQ_L}{dt}
\]

Therefore, for fully salient taxes, the difference in slopes of the fixed-variety and variable-variety demands times the direct effect of taxes on aggregate demand \( \frac{dQ_L}{dt} \) pins down the average change in willingness to pay under the parallel demands assumption. However, when taxes are less-than-fully salient, the variety effect formula from Kroft et al. (2019a) requires
a modest adjustment. Since we ultimately find that taxes are not fully salient, when we calibrate our welfare formula we will use the formula for the variety effect that allows for imperfect salience.

3 Data

To estimate the reduced-form coefficients necessary to implement the welfare formula, we rely on several data sets. For measures of $p$, $Q$, and $J$, we use Nielsen’s Retail Scanner Data. This is micro data which records weekly prices and output by product (Universal Product Code, UPC) for stores across the U.S. from 2006-2014. Each UPC in the data belongs to a “product module.”\textsuperscript{13} We aggregate the micro data to the store-module-time level to create two samples, one for the long-run analysis (time = yearly) and another for the short-run analysis (time = quarterly). Price is constructed as a time-varying module-store level index. To measure output, we create a price-weighted quantity index by aggregating UPC-level expenditures within store-module-time cells fixing each product’s price at its national average. Variety is defined as the count of UPCs with positive sales within a module and store (over the relevant time period). To measure the tax rate, we rely on hand-collected local sales tax rates and exemptions. These rates and exemptions vary by county, quarter and module.\textsuperscript{14} Note that even though the finest level of sales tax variation is at the county level, we collapse the Nielsen data to the store level and limit our sample to grocery stores only since the distribution of store types, and therefore products, varies substantially across locations. Details on data construction and descriptive statistics for our sample (Table A3) are provided in the Online Appendix.

Grocery stores sell products that are subject to sales taxes (e.g., toothpaste) and other products that are exempt (e.g., food) generating within-store differences in after-tax prices.

\textsuperscript{13}See Table A1 in the Appendix for examples of UPCs and the organizational hierarchy of the Nielsen data.

\textsuperscript{14}See Table A2 in the Appendix for examples of sales tax exemptions (Panel A is food modules and Panel B is non-food modules).
between products. This provides an additional source of variation in tax liabilities across states which is useful for identifying the long-run effect of taxation. Table 1 presents the tax status of the top selling food and non-food modules in our sample. There are several noteworthy observations. First, modules such as soft drinks, ice cream, and candy are taxed in some states that generally exempt food, like Connecticut, Florida, and Wisconsin. Second, several non-food modules are exempt from taxes. For example, toilet tissue and diapers are exempt in New Jersey and Pennsylvania and magazines are exempt in Maine, Massachusetts, New York and Oklahoma.

Additionally, local sales taxes vary substantially across the U.S., ranging from zero in Montana, Oregon, New Hampshire and Delaware to a maximum rate of 9.75 percent in Tennessee, as can be seen in Appendix Figure A1. This gives us two layers of identification, one that operates across stores and another that operates across products within stores. We combine these cross-sectional sources of variation, which correspond to the steady-state, to identify the long-run effects of taxation. In particular, our estimates will incorporate the response of product variety to sales taxes.\textsuperscript{15}

To estimate the short-run effects of taxation, we rely on the panel structure of our data spanning the 2006-2014 period. We estimate regression models that control for module fixed effects interacted with store fixed effects, thus exploiting only within-store, time-series variation in sales tax rates. In practice, exemptions rarely change over our sample period so the identification is coming from changes in rates both at the state and county level. We interpret these regression results as corresponding to the “short-run” effects of taxation because firm entry and exit, and hence variety, is unlikely to adjust instantaneously to high-frequency variation in sales taxes, an assumption we empirically test below.

\textsuperscript{15}Similarly, Atkin, Faber and Gonzalez-Navarro (2018) use cross-sectional variation in store-level prices to estimate long-run elasticities of substitution across stores.
4 Empirical Effects of Sales Taxes

4.1 Empirical Estimates of \( \frac{d\log J}{d(1+\tau)} \), \( \frac{d\log p}{d(1+\tau)} \), and \( \frac{d\log Q}{d(1+\tau)} \)

To illustrate what sources of variation pin down cross-sectional reduced-form tax elasticities, consider an example where food modules are exempt in all locations and non-food products are taxed everywhere, and sales tax rates are set by legislators independently of local differences in sales/prices between food and non-food products. In this case, we can recover a consistent estimate of the long-run elasticity of taxation by estimating the following difference-in-differences (DD) regression model:

\[
\log y_{mrcs} = \beta_{LR} \log(1 + \tau_{cs}) \times Nonfood_m + \delta_r + \delta_m + \varepsilon_{mrcs}
\]  

(13)

where the outcome \( y_{mrcs} \) is either price, output, or product variety for module \( m \) and store \( r \) located in county \( c \) and state \( s \). The terms \( \delta_r \) and \( \delta_m \) are store fixed effects and module fixed effects, respectively, \( Nonfood_m \) is a dummy variable for non-food modules and \( \tau_{cs} \) is the sales tax rate in county \( c \). Any county-level differences that do not vary across modules are absorbed by the store fixed effects. Any systematic differences in taxability across modules are soaked up by the module fixed effects. The coefficient of interest is \( \beta_{LR} \). Under the assumptions stated above, we can use OLS to estimate the long-run causal effect of taxes on prices, output, and variety.

Our preferred specification builds on the DD approach by additionally incorporating variation in tax rates across modules within the broad categories of food and non-food products. This mainly arises due to product-specific exemptions, such as the taxation of candy products in some states or the exemption of diapers. In this case, the long-run estimating equation is given by:

\[
\log y_{mrcs} = \beta_{LR} \log(1 + \tau_{mcs}) + \delta_r + \delta_m + \varepsilon_{mrcs}.
\]  

(14)

The main difference between equations (13) and (14) is the definition of the sales tax rate.
For the latter equation, taxes may vary across food (non-food) products within a store, hence the tax rate is also subscripted by \( m \). The long-run parameter \( \beta^{LR} \) is identified under the assumption that the within-store differences in statutory rates across modules do not systematically vary across counties with within-store differences in unobservables. For example, our estimates of \( \beta^{LR} \) for output would be biased upwards if jurisdictions where the consumption share of unhealthy food products (e.g., candy, soft drinks) is relatively high responded by specifically subjecting these goods to the sales tax.

We also consider an alternative strategy based on a border-design following Holmes (1998), Dube, Lester and Reich (2010), and Hagedorn, Manovskii and Mitman (2016). Here, we restrict the sample of stores to those located in contiguous counties located on opposite sides of a state border. Two contiguous counties located in different states form a county-pair \( d \), and counties are paired with as many cross-state counties they are contiguous with. The estimating equations are modified such that module fixed effects are now county-pair specific:

\[
\log y_{mrcsd} = \beta^{LR} \log(1 + \tau_{mcs}) + \delta_r + \delta_{md} + \varepsilon_{mrcsd}. \quad (15)
\]

To estimate equation (15), the original dataset is rearranged by stacking all pairs. For instance, a module-store cell located in county \( c \) appears as many times as the number of counties county \( c \) is paired with. Regressions are weighted by the inverse of the number of pairs a county is part of.

Our main estimates for the long-run effects of taxation are contained in Table 2. We estimate cross-sectional regression models separately for each year between 2006 and 2014, and then take a simple linear combination of all the coefficient estimates. Standard errors are clustered at the state-module level, the broadest level at which sales taxes are determined. The dependent variable is price in columns (1) and (2), quantity in columns (3) and (4), and variety in columns (5) and (6). Note that because we use consumer (after-tax) price, a coefficient of one in columns (1) and (2) implies full pass-through of the sales tax to consumers. Columns (1), (3) and (5), present the results for specifications which control for
store and module fixed effects. Our estimates indicate that there is slight overshifting of
taxes onto consumer prices with a coefficient of 1.148 (s.e. 0.036). We can reject the null of
complete pass-through \((d(p + t)/dt = 1)\). The tax elasticity of output is \(-0.864\) (s.e. 0.270),
and the elasticity of product variety with respect to sales taxes is \(-0.854\) (s.e. 0.126). To
address the concern that sales tax rates and exemptions are spatially correlated across regions
of the U.S. in ways that may endogenously reflect the geographic distribution of consumer
preferences, we consider a specification that allows module fixed effects to vary across census
regions (columns (2), (4), and (6)). All of our results gain in precision with the inclusion of
module-by-region fixed effects, and the point estimates are robust.\(^{16}\)

Panel B of Table 2 presents the results of a border-counties analysis.\(^ {17}\) To account for
spatial auto-correlation, standard errors are clustered two-way – by state-module as well as by
border-segment-module in all specifications (Cameron et al. 2011). In columns (1), (3) and
(5), the regression model is equivalent to the one in Panel A but the sample is restricted to
border-counties. This sample restriction has little impact on the magnitude of the coefficient
for consumer prices, but yields slightly smaller point estimates for both quantity and variety.
We then allow module fixed effects to vary by county pairs in columns (2), (4) and (6). The
implied tax elasticity of output \(-0.721\) (s.e. 0.151) is in line with our baseline results, as is
the coefficient for prices \(1.037\) (s.e. 0.017). The effect of taxes on variety \(-0.317\) (s.e. 0.073)
is smaller in this specification, but remains statistically different from zero at the 1% level.
Both the pooled cross-sectional results and “border county” results suggest large effect of
taxes on variety, with an elasticity approximately between \(-0.3\) and \(-0.8\).\(^ {18}\)

\(^{16}\)In Table A4, we report estimates from a simplified DD model by restricting the sample to counties where
food products are fully exempt from the sales and to modules that are either taxed or exempt in all stores
in this subset of counties. Reassuringly, our estimates are qualitatively similar to the estimates reported in
Table 2.

\(^{17}\)There is evidence that border counties set local sales tax rate strategically to compensate for cross-border
difference in state-level sales tax rates (Agarwal 2015). In unreported regressions, we verified that results
are not driven by this possible source of bias by instrumenting the statutory county-level tax rate with its
state-level value.

\(^{18}\)In Appendix Table A3, we consider an alternative measure of product variety, and in Appendix Table A5
we report a variety of robustness checks on our long-run estimates and show they are similar to our baseline
estimates. These are described in more detail in the Appendix.
4.2 Empirical Estimates of $\frac{d \log p}{d(1+\tau)}$ and $\frac{d \log Q}{d(1+\tau)}$

We next report estimates of the short-run effects of taxation using our quarterly panel covering 2006-2014. The baseline short-run specification is the following:

$$
\log y_{mrcst} = \beta^{SR} \log(1 + \tau_{mrcst}) + \delta_t + \delta_{mr} + \delta_m \times t + \varepsilon_{mrcst}
$$

(16)

where the unit of time ($t$) is a quarter, and $\delta_t$ and $\delta_{mr}$ are quarter and module-by-store fixed effects. In some specifications, we include a module-specific time trend $\delta_m \times t$ while in others we include module-by-quarter fixed effects, $\delta_{mt}$. The dependent variables are normalized within store-time cells to account for module-invariant store-specific trends. The identifying assumption is that states and counties do not differentially change effective sales tax rates across products endogenously with respect to changes in consumer demand. Additionally, we require that any quarter-to-quarter variation in product variety is unrelated to sales tax policy changes – an assumption we test.

The main results are reported in Panel A of Table 3. Standard errors are clustered at the state-module level to allow for correlation across stores located in a given state and to adjust for serial correlation. Columns (1) to (2) contain our estimates for prices and columns (3) to (4) contain our results for output. In columns (1) and (3), we include module, store and time fixed effects, module effects interacted with store effects and module-specific linear time trends. By including module effects interacted with store effects, we effectively shut down the cross-sectional variation in taxes and rely exclusively on within-store, across module time variation. Our estimates indicate an output elasticity of $-0.448$ (s.e. 0.149) and a price elasticity of 1.064 (s.e. 0.049), consistent with full pass-through. We cannot reject the null hypothesis that the coefficient for prices is equal to one at conventional levels of statistical significance. In columns (2) and (4) we control for module-specific trends more flexibly by including module effects interacted with quarter fixed effects instead of linear time trends. The output elasticity remains negative but is smaller in magnitude $-0.216$ (s.e. 0.138), and the price elasticity is again statistically indistinguishable from one. Finally, as
a placebo test we report results using variety as the outcome variable in columns (5) and (6). Reassuringly, the coefficient is statistically insignificant and close to 0, supporting our interpretation of the evidence as representing an effect of taxation holding variety fixed. To further assess the robustness of our short-run estimates, we also report results from a state border sample in Panel B. In columns (1), (3) and (5), our main specification is estimated on the restricted state border sample, and columns (2), (4) and (6) include pair-specific module trends. Reassuringly, these results closely mirror our main estimates, with coefficients for output and prices slightly smaller in this sample. Overall, we find larger effects of taxes on variety and output in the long-run, while pass-through estimates are similar in the long-run and in the short-run. The coefficient on price remains relatively close to one and is considerably smaller than estimates reported in Besley and Rosen (1999).

5 Calibration

As a final step in the paper, we numerically implement our welfare formula using our empirical estimates. First, we obtain an estimate of the degree of inattention to taxes $\theta$ by combining our estimates of the tax elasticity of demand with corresponding estimates of the price elasticity of demand reported in Kroft et al. (2019a). With estimates of $\theta$ in hand, we calculate the associated variety effect and then implement our formula for the marginal excess burden. Our calibrations are contained in Tables 4 and 5.

Table 4 presents estimates of $\theta$ and of the variety effect $\Lambda$. Columns (1) to (3) report different reduced-form estimates of the effect of taxation, whereas columns (4) and (5) report corresponding reduced-form estimates based on a chain-level pricing instrument (Kroft et al. 2019a). Column (1) focuses on our baseline tax estimates (odd numbered columns in Table A6 in the Appendix reports a variety of robustness checks on our short-run estimates. To do this, we derive the analogues of equations (10) and (12) for ad valorem taxes, which are the appropriate formulas to use given our empirical application. Additionally, all terms are scaled by $J/pQ$, so the numbers reported in Table 4 correspond to equation (A5), and the numbers reported in Table 5 correspond to equation (A3).
Tables 2 and 3), while columns (2) and (3) use long-run estimates from the border-design analysis. Below, we report ranges of estimates of the associated salience parameter, which we calculate as $\theta = \frac{\frac{d \log Q}{d \log (1+\tau)}}{\frac{d \log z}{d \log z} / \frac{d \log P}{d \log z}}$ where $z$ is the pricing instrument used in Kroft et al. (2019a). Across cross-sectional specifications, we find values of $\theta$ ranging between 0.34 and 0.52. Short-run estimates similarly yield a value of $\theta$ of 0.43. In comparison, Taubinsky and Rees-Jones (2018) report experimental estimates of $\theta$ of 0.25 for standard tax rates and of 0.5 in a triple-tax condition, whereas Chetty et al. (2009) find that $\theta = 0.35$ in an analysis of grocery store purchases.

Next, we report estimates of the variety effect either assuming full salience or adjusting for inattention.\footnote{In the Appendix we derive the analogous of equations (10) and (12) for ad valorem taxes, which are adequate given our empirical application. Furthermore, all terms are scaled by $J/pQ$, so the numbers reported in Table 4 correspond to equation (A5), and the numbers reported in Table 5 correspond to equation (A3).} If one assumes that $\theta = 1$, the variety effect parameter varies between 0.6 and 1.9. In contrast, variety effects based on the pricing instrument – for which full salience holds by definition – are equal to 1.2. This estimate suggests that an exogenous decrease in variety of 1 percent will decrease average willingness-to-pay by 1.2 percent. Adjusting for inattention, we find tax-based variety effects of a smaller magnitude, ranging between 0.2 and 0.7. In Appendix Table A7, we maintain a value of $\theta = 0.43$ but use alternative reduced-form estimates from our robustness checks and report variety effect estimates in the range of 0.2 and 1.4.

In Table 5, we implement several welfare formulas with our preferred set of reduced-form estimates from the empirical analysis. Panel A reports the key inputs used into the welfare formula. In all calibrations we assume an initial tax rate of 3.6%, the average value of $\tau_{mcs}$ in our dataset. We begin by calculating the conventional Harberger formula in the case of perfect competition and homogeneous products. Under the assumption of full salience, our long-run tax elasticity of demand imply marginal excess burden of commodity taxation in the range of $-0.031$ to $-0.023$. Still maintaining the assumption that $\theta = 1$, we then implement our long-run welfare formula (eq. (10)) which allows for imperfect competition with differentiated
products and endogenous variety. The scaled estimates of $dW/dt$ here range between $-0.55$ and $-0.99$, more than an order of magnitude greater than the Harberger triangle. Ignoring endogenous variety would lead one to greatly understate the welfare cost of taxation. Yet, by ignoring the fact that consumers tend to underreact to sales taxes, these estimates likely exaggerate the true excess burden. Using a value of $\theta = 0.43$, our estimates imply values of the Harberger triangle closer to $-0.01$. Finally, the complete long-run welfare formula that accounts for salience while allowing for endogenous variety produces estimates of $dW/dt$ in the range of $-0.2$ to $-0.43$. Overall, both endogenous variety and salience appear very consequential in welfare analysis of commodity taxation.

6 Conclusion

In this paper, we develop a sufficient statistics formula for the welfare effects of commodity taxation in a general model featuring imperfect competition, differentiated products, endogenous product variety, and tax salience. We provide new empirical estimates for each of the key inputs to our formula by combining Nielsen Retail Scanner data covering grocery stores in the U.S. with detailed product-level and county-level sales tax data. We find full pass-through of sales taxes into prices and large effects of taxes on quantity and variety. We also find that consumers place a high value on product variety. Lastly, we find that consumers “under-react” to taxes, which is consistent with taxes being less salient to consumers than prices.

We use these estimates to calibrate our new welfare formula, and we conclude that the standard marginal excess burden formula substantially understates the welfare costs of commodity taxation, even after accounting for consumers’ under-reaction due to salience effects. Ignoring endogenous product variety and the effects of variety on consumer surplus leads one to greatly understate the welfare costs, and assuming perfect competition but allowing for salience effects understates the welfare costs even more. As a result, we conclude that both
imperfect competition and tax salience are important factors to consider when analyzing the welfare consequences of commodity taxation. Focusing on either one in isolation will lead to misleading estimates.

Our analysis can be extended and generalized in several dimensions. Most directly, researchers can continue to generalize the theoretical analysis in this paper by allowing for asymmetric prices. Building on the results in Kroft et al. (2019a), we conjecture that our new formulas will be robust to certain types of asymmetric prices and products, under some additional technical assumptions (such as assuming “uniform pass-through” of taxes into prices across all of the products within the market). We also ignored the possibility of multi-product firms in our analysis, and it would be useful to extend our methods to accommodate that scenario. Lastly, we focused on salience of taxes but assumed that consumers were fully aware of all of the products available. If variety is not full salient to consumers, this is something that is important to study in future work, both theoretically and empirically.

References


Figure 1: Identification of Variety Effect Under Imperfect Salience

Notes: This figure shows graphically how the variety effect is identified using a change in taxes $t_0$ to $t_1$, which also causes an endogenous change in variety from $J_0$ to $J_1$. In the figure, the endogenous reduction in variety from tax increase causes the aggregate demand curve to shift downward in parallel, as in Kroft et al. (2019a). However, since taxes are not fully salient consumers under-react to sales taxes. The key assumption is that consumers under-react to sales taxes both in the short-run and the long-run, which allows identification of $\Lambda = (P^* - P_1^*)Q_0$ using same reduced-form statistics from Kroft et al. (2019a) along with a measure of tax salience (which governs magnitude of under-reaction to the tax at each tax level).
<table>
<thead>
<tr>
<th>Module</th>
<th>Avg. Mkt. Share</th>
<th>Panel A: Food Modules</th>
<th>State taxing module at reduced rate (but otherwise exempt food)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAIRY - MILK</td>
<td>3.04%</td>
<td>AL, ID, KS, MS, OK, SD</td>
<td>AR, IL, MO, NC, TN, UT, VA, WV</td>
</tr>
<tr>
<td>SOFT DRINKS - CARBONATED</td>
<td>2.88%</td>
<td>AL, ID, KS, MS, OK, SD</td>
<td>AR, IL, MO, TN, UT, VA</td>
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<tr>
<td>BAKERY - BREAD - FRESH</td>
<td>2.19%</td>
<td>AL, ID, KS, MS, OK, SD</td>
<td>IL, MO, TN, UT, VA, WV, WV</td>
</tr>
<tr>
<td>CEREAL - READY TO EAT</td>
<td>1.93%</td>
<td>AL, ID, KS, MS, OK, SD</td>
<td>AR, IL, MO, NC, TN, UT, VA, WV</td>
</tr>
<tr>
<td>SOFT DRINKS - LOW CALORIE</td>
<td>1.62%</td>
<td>AL, ID, KS, MS, OK, SD</td>
<td>AR, IL, MO, TN, UT, VA</td>
</tr>
<tr>
<td>WATER-BOTTLED</td>
<td>1.42%</td>
<td>AL, ID, KS, MS, OK, SD</td>
<td>AR, IL, MO, NC, TN, UT, VA, WV</td>
</tr>
<tr>
<td>ICE CREAM - BULK</td>
<td>1.22%</td>
<td>AL, ID, KS, MS, OK, SD</td>
<td>AR, IL, MO, NC, TN, UT, VA, WV</td>
</tr>
<tr>
<td>COOKIES</td>
<td>1.21%</td>
<td>AL, ID, KS, MS, OK, SD</td>
<td>AR, IL, MO, NC, TN, UT, VA, WV</td>
</tr>
<tr>
<td>CANDY-CHOCOLATE</td>
<td>0.64%</td>
<td>AL, ID, KS, MS, OK, SD</td>
<td>AR, IL, MO, UT, VA, WV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Module</th>
<th>Avg. Mkt. Share</th>
<th>Panel B: Non-Food Modules</th>
<th>State with no sales tax</th>
<th>State exempting module</th>
<th>State taxing module at reduced rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>WINE - DOMESTIC</td>
<td>2.11%</td>
<td>DE, MT, NH, OR</td>
<td>PA, KS, KY, MA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIGARETTES</td>
<td>1.70%</td>
<td>DE, MT, NH, OR</td>
<td>CO, MN, OK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOILET TISSUE</td>
<td>1.07%</td>
<td>DE, MT, NH, OR</td>
<td>PA, NJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DETERGENTS - LIQUID</td>
<td>0.75%</td>
<td>DE, MT, NH, OR</td>
<td>NJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAPER TOWELS</td>
<td>0.66%</td>
<td>DE, MT, NH, OR</td>
<td>PA, KS, KY, MA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUM</td>
<td>0.54%</td>
<td>DE, MT, NH, OR</td>
<td>NJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DISPOSABLE DIAPERS</td>
<td>0.50%</td>
<td>DE, MT, NH, OR</td>
<td>MA, MN, NJ, PA, VT</td>
<td>IL</td>
<td></td>
</tr>
<tr>
<td>MAGAZINES</td>
<td>0.41%</td>
<td>DE, MT, NH, OR</td>
<td>MA, ME, NY, OK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAT FOOD - DRY TYPE</td>
<td>0.35%</td>
<td>DE, MT, NH, OR</td>
<td>CT, FL, MD, MN, NJ, NY,</td>
<td>IL</td>
<td></td>
</tr>
<tr>
<td>COLD REMEDIES - ADULT</td>
<td>0.28%</td>
<td>DE, MT, NH, OR</td>
<td>NJ, NY, PA, TX, VA, VT</td>
<td>IL</td>
<td></td>
</tr>
<tr>
<td>DOG &amp; CAT TREATS</td>
<td>0.25%</td>
<td>DE, MT, NH, OR</td>
<td>PA, KS, KY, MA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALE</td>
<td>0.25%</td>
<td>DE, MT, NH, OR</td>
<td>PA</td>
<td>IL</td>
<td></td>
</tr>
<tr>
<td>DOG FOOD - WET TYPE</td>
<td>0.23%</td>
<td>DE, MT, NH, OR</td>
<td>NJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FACIAL TISSUE</td>
<td>0.22%</td>
<td>DE, MT, NH, OR</td>
<td>NJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOOTH CLEANERS</td>
<td>0.22%</td>
<td>DE, MT, NH, OR</td>
<td>PA</td>
<td>IL</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Average market shares are calculated at the store-level for the year 2008.
## Table 2: Cross-Sectional Estimates of Sales Taxes on Consumer Prices, Quantity, and Product Variety

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Consumer Prices</th>
<th>Quantity</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Panel A: Full sample</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \log(1 + \tau_{mcs}) )</td>
<td>1.148 (0.036)</td>
<td>1.062 (0.025)</td>
<td>-0.864 (0.270)</td>
</tr>
<tr>
<td>Specification:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Store fixed effects</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>Module fixed effects</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>Module × Region fixed effects</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>N (observations)</td>
<td>17,320,024</td>
<td>17,320,024</td>
<td>17,320,024</td>
</tr>
<tr>
<td>N (modules)</td>
<td>198</td>
<td>198</td>
<td>198</td>
</tr>
<tr>
<td>N (stores)</td>
<td>11,487</td>
<td>11,487</td>
<td>11,487</td>
</tr>
<tr>
<td>N (counties)</td>
<td>1,625</td>
<td>1,625</td>
<td>1,625</td>
</tr>
<tr>
<td>N (county-modules)</td>
<td>308,977</td>
<td>308,977</td>
<td>308,977</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.404</td>
<td>0.503</td>
<td>0.836</td>
</tr>
<tr>
<td>Panel B: Border counties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \log(1 + \tau_{mcs}) )</td>
<td>1.096 (0.031)</td>
<td>1.037 (0.017)</td>
<td>-0.642 (0.246)</td>
</tr>
<tr>
<td>Specification:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Store fixed effects</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>Module fixed effects</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>Module × Pair fixed effects</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>N (observations)</td>
<td>14,113,781</td>
<td>14,113,781</td>
<td>14,113,781</td>
</tr>
<tr>
<td>N (modules)</td>
<td>198</td>
<td>198</td>
<td>198</td>
</tr>
<tr>
<td>N (stores)</td>
<td>4,040</td>
<td>4,040</td>
<td>4,040</td>
</tr>
<tr>
<td>N (counties)</td>
<td>636</td>
<td>636</td>
<td>636</td>
</tr>
<tr>
<td>N (county-modules)</td>
<td>120,876</td>
<td>120,876</td>
<td>120,876</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.392</td>
<td>0.698</td>
<td>0.837</td>
</tr>
</tbody>
</table>

Notes: The independent variable, \( \tau_{mcs} \), is yearly sales tax rate of module \( m \) in county \( c \) in state \( s \). For each year, we take the rate effective on September 1 to define the yearly tax rate. Sales, consumer prices and variety are measured yearly.

Consumer prices \( p(1 + \tau_{mcs}) \) are tax inclusive. Reported coefficients are linear combinations of 9 cross-sectional estimates (one for each year). The Retail Scanner data is restricted to modules above the 80th percentile of the national distribution of sales. All coefficients are linear combinations of nine coefficients -- one for each year from 2006 to 2014. In Panel A, standard errors are clustered at the state-module level. In Panel B, the sample is restricted to border counties and observations are weighted by the inverse of number of pairs a county belongs to. Standard errors are clustered two-way at the state-module level and at the border segment-module level.
### Table 3: The Short-Run Effect of Sales Taxes on Consumer Prices, Quantity, and Product Variety

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Consumer Prices</th>
<th>Quantity</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>( \log(1 + \tau_{mcst}) )</td>
<td>1.064 (0.049)</td>
<td>1.012 (0.032)</td>
<td>-0.448 (0.149)</td>
</tr>
</tbody>
</table>

**Panel A: Full sample**

**Specification:**
- Store, Time, Module fixed effects
- Module × Store fixed effects
- Module-specific linear time trend
- Module × Time fixed effects

<table>
<thead>
<tr>
<th>N (observations)</th>
<th>68,076,928</th>
<th>68,076,928</th>
<th>68,076,928</th>
<th>68,076,928</th>
<th>68,076,928</th>
<th>68,076,928</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (modules)</td>
<td>198</td>
<td>198</td>
<td>198</td>
<td>198</td>
<td>198</td>
<td>198</td>
</tr>
<tr>
<td>N (stores)</td>
<td>11,487</td>
<td>11,487</td>
<td>11,487</td>
<td>11,487</td>
<td>11,487</td>
<td>11,487</td>
</tr>
<tr>
<td>N (counties)</td>
<td>1,625</td>
<td>1,625</td>
<td>1,625</td>
<td>1,625</td>
<td>1,625</td>
<td>1,625</td>
</tr>
<tr>
<td>N (quarters)</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>N (county-modules)</td>
<td>308,977</td>
<td>308,977</td>
<td>308,977</td>
<td>308,977</td>
<td>308,977</td>
<td>308,977</td>
</tr>
<tr>
<td>R²</td>
<td>0.650</td>
<td>0.746</td>
<td>0.948</td>
<td>0.968</td>
<td>0.956</td>
<td>0.965</td>
</tr>
</tbody>
</table>

**Panel B: Border counties**

**Specification:**
- Store, Time, Module fixed effects
- Module × Store fixed effects
- Module-specific linear time trend
- Module × Pair-specific linear time trend

<table>
<thead>
<tr>
<th>N (observations)</th>
<th>55,419,758</th>
<th>55,419,758</th>
<th>55,419,758</th>
<th>55,419,758</th>
<th>55,419,758</th>
<th>55,419,758</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (modules)</td>
<td>198</td>
<td>198</td>
<td>198</td>
<td>198</td>
<td>198</td>
<td>198</td>
</tr>
<tr>
<td>N (stores)</td>
<td>4,040</td>
<td>4,040</td>
<td>4,040</td>
<td>4,040</td>
<td>4,040</td>
<td>4,040</td>
</tr>
<tr>
<td>N (counties)</td>
<td>636</td>
<td>636</td>
<td>636</td>
<td>636</td>
<td>636</td>
<td>636</td>
</tr>
<tr>
<td>N (quarters)</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>N (county-modules)</td>
<td>120,876</td>
<td>120,876</td>
<td>120,876</td>
<td>120,876</td>
<td>120,876</td>
<td>120,876</td>
</tr>
<tr>
<td>R²</td>
<td>0.645</td>
<td>0.669</td>
<td>0.947</td>
<td>0.949</td>
<td>0.954</td>
<td>0.957</td>
</tr>
</tbody>
</table>

Notes: The independent variable, \( \tau_{mcst} \), is quarterly sales tax rate of module \( m \) at time \( t \) in county \( c \) in state \( s \). A unit of time is a quarter, and the period covered is 2006-2014. Consumer prices \( p(1 + \tau_{mcst}) \) are tax inclusive. The Retail Scanner data is restricted to modules above the 80th percentile of the national distribution of sales. In Panel A, standard errors are clustered at the state-module level. In Panel B, the sample is restricted to border counties, observations are weighted by the inverse of number of pairs a county belongs to, and standard errors are clustered two-way at the state-module level and at the border segment-module level.
### Table 4: Plug-In Estimates of the Variety Effect

<table>
<thead>
<tr>
<th>Cross-sectional reduced-form estimate</th>
<th>Sales Tax Estimates</th>
<th>Reduced-form estimates using chain-level instrument [Kroft et al. (2019), Tables 2 and 3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-run reduced-form estimates</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Full Sample</td>
<td>Border Pair Full Sample</td>
</tr>
<tr>
<td>Cross-sectional estimates (endogenous J)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price response, dlog(p)/dz</td>
<td>1.15</td>
<td>1.10</td>
</tr>
<tr>
<td>Output response, dlog(Q)/dz</td>
<td>-0.86</td>
<td>-0.64</td>
</tr>
<tr>
<td>Variety response, dlog(J)/dz</td>
<td>-0.85</td>
<td>-0.56</td>
</tr>
<tr>
<td>Short-run estimates (fixed J)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price response, dlog(p)/dz</td>
<td>J</td>
<td>1.06</td>
</tr>
<tr>
<td>Quantity response, dlog(Q)/dz</td>
<td>J</td>
<td>-0.45</td>
</tr>
<tr>
<td>Implied attentiveness/salience parameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-run tax salience,</td>
<td>[0.458,0.517]</td>
<td>[0.34,0.384]</td>
</tr>
<tr>
<td>dlog(Q)/dlog(1+t) / dlog(Q)/dp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-run tax salience,</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>(dlog(Q)/dlog(1+t)</td>
<td>J)/ (dlog(Q)/dp</td>
<td>J)</td>
</tr>
<tr>
<td>Variety effect &quot;plug-in&quot; estimate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety Effect Parameter (θ=1)</td>
<td>0.947</td>
<td>0.621</td>
</tr>
<tr>
<td>Adjusted Variety Effect (θ=0.43)</td>
<td>0.311</td>
<td>0.171</td>
</tr>
</tbody>
</table>

**Notes:** Columns (1) to (3) report "plug-in" variety effect estimates using different combinations of estimates from Tables 2 and 3. Columns (4) and (5) report estimates from Kroft et al. (2019) which use a leave-self-out pricing instrument. For long-run tax salience, we report two values of θ; one based on column (4) reduced-form estimates of dlog(Q)/dp and one based on column (5) estimates. The variety effect estimates are based on an initial tax rate of 3.6%, which is the average effective rate τmcs in our cross-sectional sample.
### Table 5: Calibration of Welfare Formulas

<table>
<thead>
<tr>
<th>Sales Tax Estimates</th>
<th>Cross-sectional reduced-form estimates</th>
<th>Full Sample</th>
<th>Border Pair</th>
<th>Border Pair</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short-run reduced-form estimates</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Cross-sectional estimates (endogenous J)</td>
<td>Price response, dlog(p)/dt</td>
<td>1.15</td>
<td>1.10</td>
<td>1.04</td>
</tr>
<tr>
<td></td>
<td>Output response, dlog(Q)/dt</td>
<td>-0.86</td>
<td>-0.64</td>
<td>-0.72</td>
</tr>
<tr>
<td></td>
<td>Variety response, dlog(J)/dt</td>
<td>-0.85</td>
<td>-0.56</td>
<td>-0.32</td>
</tr>
<tr>
<td>Short-run estimates (fixed J)</td>
<td>Price response, dlog(p)/dt</td>
<td>1.06</td>
<td>1.06</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>Quantity response, dlog(Q)/dt</td>
<td>-0.45</td>
<td>-0.45</td>
<td>-0.45</td>
</tr>
<tr>
<td></td>
<td>Implied variety effect parameter (θ = 0.43)</td>
<td>0.31</td>
<td>0.17</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>Initial tax rate (per dollar)</td>
<td>$0.036</td>
<td>$0.036</td>
<td>$0.036</td>
</tr>
</tbody>
</table>

#### Panel A: Key Inputs Into Welfare Formula (Equation (9))

- **Assuming Full Salience (θ = 1)**
  - Eq (3): Harberger benchmark (t*dlog(Q)/dlog(1+t))
  - Eq (9): Full LR formula, full salience

- **Assuming Imperfect Salience (θ = 0.43)**
  - Eq (3): Harberger benchmark (θ*t*dlog(Q)/dlog(1+t))
  - Eq (9): Full long-run formula, with salience

#### Welfare shares
- Share of dW/dt due to endogenous J: 97%, 96%, 96%
- Bias in LR formula from assuming full salience: 131%, 170%, 160%

**Notes:** This table reports calibration of the welfare formula in main text. All columns use actual long-run estimates reported in Table 2, and short-run estimates reported in Table 3. Calibrations assuming imperfect salience relies on a value of θ = 0.43, our main short-run salience parameter estimate. In all calibrations we assume an initial tax rate of 3.6%, which is the average effective rate τ_{mcs} in our cross-sectional sample.