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Buenas notches: lines and notches in tax system design

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Abstract
A wide range of tax policies create discontinuous jumps—*notches*—in the choice set of individuals and firms, arising when incremental changes in behavior cause discrete changes in net tax liability. This paper presents a taxonomy of different types of notch policies. It then discusses the mechanics of, and limitations to, estimating structural parameters using notches. Next, it considers the welfare consequences of notches and their role in optimal tax design. It concludes by speculating on why notches persist. Notches are shown to be welfare inferior absent considerations of administrative cost or salience.

1. INTRODUCTION

A wide range of tax policies create discontinuous jumps—*notches*—in the choice set of individuals and firms, because incremental changes in behavior cause discrete changes in net tax liability. Recently, along with budget-set kinks, notches have attracted considerable attention on the grounds that the local behavioral response to their presence can provide especially convincing identification of the effect of taxation.[2]

Although this paper addresses tax policy, notch-like policies appear in other areas of economic policy. For example, certain regulations apply only to firms above a certain

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[2] Kinks in budget sets, a common feature of graduated income tax schedules, feature discontinuous marginal tax rates but not discontinuous jumps in the choice set itself; see Chetty, 2009; Chetty et al., 2009; Saez 2010.

size.[3] Earned income above a certain threshold renders one ineligible for Medicaid, which provides a basic set of free or subsidized medical services.[4] Notches appear commonly outside of government policy, as well. For example, nonprofit organizations often publicize the names of donors and assign 'titles' (eg 'leader,' 'founder') according to brackets of gifts.[5] Businesses often offer quantity discounts that create a notch, such that purchasing one extra unit discretely lowers the total price. Incentive contracts often include bonuses for reaching particular targets, and/or penalties for failing to reach certain quotas.[6]

In this paper I offer a critical review of tax policy notches, and the lines that create them. I begin, in Section 2, with a taxonomy of the wide range of policies that create notches. Sections 3 and 4 address some analytical and normative issues, respectively, raised by notches. Section 5 discusses the roles of different types of policy notches in optimal tax design. Section 6 concludes.

2. A TAXONOMY OF TAX NOTCHES

Tax notches come in many varieties. Perhaps the most important distinction is between what I will refer to as *quantity notches* and *characteristic notches*.

2.1 Quantity Notches

The simplest example of a notch arises when tax liability is a discontinuous, or step, function of the size of the quantity aspects of a tax base, conditional on the rules that determine the size of the base. Thus, it concerns the form of the T(B) function, where *T* is the tax liability and *B* is the size of the tax base, be it taxable income, retail sales, square footage, or some other base. I will refer to this type of notch as a *quantity notch*.

In principle, a notch can be built directly into the function that maps the tax base into tax liability.[7] A quantity notch can also occur when an incremental change in income triggers a discrete change in, for example, the value of a credit. Consider the US Saver's Credit, enacted in 2001, that provides for a nonrefundable credit equal to a percentage of (capped) contributions to retirement savings accounts. The Saver's Credit design features a notch because the percentage credit rate is a discontinuous function of adjusted gross income. For example, a married couple filing jointly with income of $30 000 receives a 50 per cent tax credit on up to $2 000 of deposits to a retirement account, but receives only a 20 per cent credit if income is $30 001 or more. Thus, reporting an extra dollar of adjusted gross income can cause a loss in tax credits of as much as $600: there is a notch

[3] See Kaplow (2013) for examples.
[4] See, for example, Yelowitz (1995).
[5] Harbaugh (1998a, 1998b) shows that donations bunch on the low side of the brackets, and characterizes the notch design that maximizes contributions, and Lacetera and Macis (2010) show the same kind of pattern for the frequency of blood donations in Italy, where there is public recognition for the frequency of donations above a threshold.
[6] See Oyer (1998).
[7] Slemrod (1985) provides evidence of bunching within the very small brackets that arise in the US income tax when taxpayers use the tax table to calculate liability, and argues that in this case bunching is a symptom of tax evasion.

in tax liability net of the Saver's Credit as a function of income.[8] The original version of the American Recovery and Reinvestment Act of 2009 contained a substantial notable notch: an $8 000 tax credit for first-time purchasers of a primary residence whose income did not exceed $75 000 for singles and $150 000 for married couples; when extended in 2010 the notch was replaced by an income-related phaseout, substituting kinks for a notch. The Child and Dependent Care Credit has a phase-out range with several notches, so that within this range the percentage of expenses allowed as a credit falls by 1 per cent for every $2 000 of adjusted gross income above a threshold. The phaseout of tuition deductions features two notches in adjusted gross income.

Quantity notches can be triggered by incremental changes in tax bases other than income. The Israeli municipal property tax, known as the *arnona*, has separate tax rates per square meter for different size categories. For example, in 2010 in Zone C of Jerusalem, the annual rate of tax was NIS 40.68 for apartments of up to 120 square meters and NIS 54.70 for apartments of more than 120 square meters, thus creating a notch equal to NIS 1 682.40 at 120 square meters.[9] The same feature applies to other property tax systems, both in the United States and outside of it. When the first marginal rate is effectively zero, the apparent objective of the notched tax schedule is to exempt low-value properties, for equity or administrative cost-saving reasons, and to deny the tax saving provided by the exemption to higher valued, taxable properties. When the first rate is positive, the objective is simply to recover the infra-marginal tax break for higher valued properties. This objective could alternatively be achieved, as it is in US income tax rates, by having a higher marginal tax rate for some bracket of income so that the average tax rate can 'catch up' to the higher marginal tax rate.

Notches can assume two shapes: a *pure notch* features identically sloped budget segments on either side of the notch point; with a *zigzag notch*, the slopes of the two budget segments differ. For example, the Israeli *arnona* is a zigzag notch with a higher marginal tax rate above the threshold; the second part of the tax rate schedule is what it would be if the higher marginal tax rate applied to the whole range of floor space.

2.2 Characteristic Notches

The other kind of notch, which I denote a *characteristic notch*, determines whether a given action or event falls within a tax base or what tax rate applies. Thus, it applies to a tax function where $T=T(B,C)$, where C is a vector of characteristics of the base, and the $T(.)$ is a step function of C.

To discuss the wide variety of characteristic notches, I appeal to the venerable framework in journalism for information gathering known as the Five Ws. This framework holds that, in order for an article to be complete, it must address five questions: Who (was

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[8] Ramnath (2013) provides evidence of significant bunching of reported taxable income around the taxable income notches created by the Saver's Credit, especially for those returns with business income, whose net value is subject to more taxpayer discretion.

[9] The *arnona* rates were taken from http://www.jerusalem.muni.il/jer_main/defaultnew.asp?lng=2, accessed on 1/4/2010; they have been changed since. Anecdotally one hears that the *arnona* notch induces some people to buy two adjacent apartments of less than 120 square meters and knock down the separating walls to create one dwelling for living, but not property tax, purposes.

involved)? What (happened)? When (did it take place)? Where (did it take place)? Why (did it happen)?

Similar questions apply to the determination of most tax bases. Consider a retail sales tax. The tax liability of a retail firm depends on the volume of its sales and also generally on whether the sales are taxable or tax-exempt (what?), in which state the sales were made and the consumption occurred (where?), in which tax year the sales were made (when?), and which firm made the sales and the identity of the purchaser or receiver of income (who?).

In principle, most of these arguments of the tax liability function are continuous variables. This is obvious for the volume of sales, where a discontinuous relationship between tax liability and the volume of sales (of, say, a given retail establishment) would constitute a quantity notch, but is also generally true for the other arguments that may create characteristic notches. The location of a retail sale can be represented continuously with latitude and longitude (and, in principle, altitude). Firms may be characterized by size. The time of sale has a day, hour, and so on. Most characteristics of a good or service can also be measured continuously—how much salt is in a can of soup, what hexadecimal color code applies to a pair of trousers, etc. This is not to say that in all cases these aspects can be easily measured or even are always conceptually clear, as evidenced by the ongoing controversies about where an Internet sale takes place. For reasons discussed later, the who, what, where, and when of tax base determination are generally subject to notches and lines. Economic analysis of the policy issues that arise in this area is scarce, although under the moniker 'line drawing' it is a persistent theme in the legal tax literature.[10]

2.2.1 Income Determination and Classification

A non-capricious income tax system must have procedures for distinguishing whether a particular transaction or other aspect of taxpayer behavior generates taxable income or loss (or, more generally, whether a separate tax rate applies) is subject to myriad categorizing lines that create notches. Whether a transaction triggers ordinary income or preferentially taxed capital gains, whether a form of compensation is an untaxed fringe benefit or taxable salary, whether a contribution is deductible or not, whether the cost of raising capital is (deductible) debt or (nondeductible) equity are just a few examples. All of these categories create lines that are generally based on characteristics and, therefore, create notches in choice sets; because, close to a line, a small change in a characteristic discretely changes the tax treatment.

In almost all such cases the tax code and/or regulations establish a series of tests that determine on which side of a tax/tax-exempt or regular-tax/preferred-tax line a case lies. These tests are invariably multi-dimensional. Moreover, in almost all cases the ruling is either-or; for example, a corporate liability is, for tax purposes, either debt or equity. In

[10] Much of this literature is normative, concerning the appropriate placement of a specific distinguishing line, such as between debt and equity finance. With some exceptions, the criterion is not explicitly social welfare, but how closely the line reflects existing law and regulations, which may be instrumentally related to welfare. Weisbach (1999, 2000) are exceptions to both of these generalizations.

some cases the tax treatment depends on a characterization that is an artifact of law and is by its nature essentially discrete. The classification of business entities is an example; crossing a characteristic line between a partnership and a corporation triggers a discrete change in tax treatment, but it is difficult to think of a meaningful sense in which the tax treatment could be made continuous.[11]

2.2.2 Commodity Characteristics

A non-capricious tax system must have procedures for distinguishing among goods subject to different tax rates, and real-world consumption tax systems do that by appealing to the characteristics of the commodities. This implies that, although characteristics may be conceptually continuous, in characteristics space there are lines that determine where the discontinuous changes in tax status occur: where the notches lie.

For example, the retail sales taxes of US states often exempt food but not restaurant meals, requiring the tax law to draw a line between the two categories. This is done by appealing to a set of characteristics of restaurant meals and grocery purchases; the line must be precise when, for example, grocery stores sell pre-prepared meals that may or may not be eaten on the premises, set up in-store salad bars, or provide nearby tables, silverware, and napkins. This issue was recognized, but for the most part not pursued, in the early optimal taxation literature. For example, Stiglitz and Dasgupta (1971, p. 165) note that it is administratively difficult to have separate tax rates for every commodity, although in general an optimal tax structure would require good-specific tax rates; they note that as a result ‘almost all tax systems group commodities into fairly wide classes.’[12] Barzel (1976) stressed that tax statutes cannot cover all of the multiple dimensions of commodities, thus inducing substitution away from taxed attributes and into untaxed attributes.

Characteristic lines may create incentives for firms to introduce new goods that are more intensive in the high-tax characteristic but (just) on the low-tax side of the line, allowing the consumer to obtain more of the high-tax characteristic without triggering the tax liability associated with the high-tax good. This can occur through marginal product shifting around existing goods, as in supermarkets that provide restaurant-like characteristics via in-store salad bars. These are local adjustments, as the goods provided are only slightly socially inferior to the goods they replace. Or firms may generate entirely new goods, situated just on the low-tax side of the line. For example, the preferential tax treatment of motorcycles in Indonesia led to the creation of a new type of motorcycle with three wheels and long benches at the back seating up to eight passengers–car-like but not so car-like as to be taxed as cars. When Chile imposed much higher taxes on cars than on panel trucks, the market soon offered a redesigned panel

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[11] I thank Mitchell Kane for raising this point with me.

[12] Stiglitz and Dasgupta (1971, p. 165) also mention that it is often impossible for tax authorities to differentiate between different kinds of income such as, in unincorporated enterprises, differentiating between the labor of the owner, returns to his capital, and pure profits, and thus they are generally taxed at the same rate, ‘even though the optimal tax structure almost certainly would instruct us to tax them differentially.’ They note this to motivate their result that production efficiency is not necessarily part of an optimal tax system when there are constraints on levying differentiated taxes on goods or factors.

truck that featured glass windows instead of panels and upholstered seats in the back.[13] Depending on the location of the line, these new goods may not be socially optimal, although they are privately optimal given the abrupt differential tax liability generated by the line.

In some cases tax treatment is differentiated on the basis of one quantifiable characteristic of a commodity. An example of this is the US Gas Guzzler Tax, under which high-performance cars are subject upon initial sale to a per-vehicle tax that is higher the lower is the fuel economy of the car, a car characteristic. For cars (but not light trucks or SUVs) that get less than 22.4 miles per gallon, the tax levy rises discontinuously as the miles-per-gallon rating crosses downward from a (rounded) 0.5 decimal ending to a 0.4 decimal ending, with the change in the tax amounting to as much as $1 300 and averaging about $800. Note that this tax schedule is discontinuous in miles-per-gallon even though this variable is continuous and fairly easy to measure, and the social benefit of more fuel-efficient cars is certainly not a step function. In this case basing the tax on a single characteristic is facilitated by the transparent motivation for the tax—to increase the fuel efficiency of new cars—so that the tax can be related to a measure of that one aspect of a vehicle.[14] Based on a similar motivation, in several countries notched taxes apply to vehicles whose engine exceeds a given size. However, as the commodity tax example illustrates, in the more common scenario the line depends on multiple, difficult-to-quantify underlying characteristics. In all commodity notch cases, though, a marginal change in some characteristic can change the classification so as to produce a discrete change in the tax consequences.

2.2.3 Border Notches

Physical borders that divide jurisdictions are lines that create discontinuous tax treatment depending on the location of, for example, retail sales. These discontinuities create notches in budget sets where the location of the tax-triggering event matters.[15] People may cross borders to buy lower taxed items.[16] Where a good or service is purchased, or consumed, may determine the amount of tax liability and to which entity the liability is owed. The characteristic is of varying importance to consumers depending on where they live (and/or work or otherwise visit), because this determines the transportation cost of obtaining the item. Under some conditions each consumer will buy in one place or the other depending on whether the transportation costs exceed the saving from the tax differential. We would expect few cigarettes purchases just on the high-tax side of the border, and a mass of purchases just on the low-tax side of the border.[17] Similar issues apply to the location of income.

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[13] These examples are taken from Harberger (1995).
[14] Sallee and Slemrod (2012) examine the consequences of this tax.
[15] Differential tax rates also create incentives for the location of production and taxable income for multinational corporations, but the incentives do not depend on where within a country the activity takes place.
[16] The incentive to do so is diminished to the extent that the retail sales tax systems are residence based. Many US states levy 'use' taxes at the same rate as their retail sales taxes that are triggered by out-of-state goods consumed in-state, but these are notorious for being poorly enforced.
[17] See Lovenheim (2008).

Clearly where a jurisdictional border lies is not a policy choice, at least not a choice made by the tax authorities. It does, though, raise the question of why relatively high sales tax rate jurisdictions do not levy continuous tax rates at borders so that the closer to a low-tax neighboring jurisdiction, the lower the tax. For example, why doesn't high-alcohol-tax Massachusetts, which borders low-tax New Hampshire, levy lower excise taxes the closer one gets to the New Hampshire border? This policy would just codify what is effectively true when the full price includes transportation costs—a lower price for those who live close to New Hampshire—but keeps more revenue for Massachusetts. If not everyone drives to New Hampshire, there are horizontal equity and efficiency issues, but these issues arise even with no geographical differentiation. The welfare economics of border notches is unique because each government jurisdiction presumably cares only about its own residents' welfare and there may be fiscal externalities across jurisdictions.[18]

2.2.4 Time Notches

The use of accounting periods, generally years, implies that there will often be discrete changes in tax treatment (ie notches) with respect to certain activities undertaken at year-end versus year-start. This may occur for two reasons: (1) anticipated legislated changes in the tax rules from one year to the next; or (2) with a graduated tax schedule, a given taxpayer's marginal tax rate is expected to change because of expected changes in the tax base. In these cases, the same taxable action taken just days, or even hours apart, can trigger a discretely different tax liability.

Just as administrative considerations limit the number of distinct commodity tax rates, they limit the number of distinct tax accounting periods. The income tax accounting period is typically one year, although this is arbitrary. In some transfer systems, the accounting period is shorter because of concerns that income support must be delivered quickly to households with temporarily low income.[19]

Examples of the sensitivity of behavior to time notches abound. When the US top income tax rate increased from 1992 to 1993, Wall Street bonuses shifted from one-third end-of-year, two-thirds beginning-of-year, to the reverse.[20] When the US top capital gains tax rate increased from 20 per cent in 1986 to 28 per cent in 1987, there was an extraordinary amount of realizations at year-end 1986.[21] This is particularly notable because, under a realizations-based capital gains tax system like that of the United States, the tax obligation depends on the date of sale. This is generally unrelated to, for example, the date of consumption of the proceeds of the sale, which in any event is not well-defined. So the line is drawn in a space different from the arguments of individuals' utility functions.[22]

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[18] See Agrawal (2011).

[19] For example, in 2012 the United Kingdom piloted the Universal Credit, a social assistance program that assesses household earnings on a monthly basis in order to determine benefit eligibility, with the goal of reducing credit constraints and issues of annual over- or under-payment.

[20] Note that, under cash accounting for tax purposes within limits, the payment for labor income can be recorded in either year, regardless of when work was 'done'. Thus, we can expect that the substitutability of dated payments to exceed the substitutability between dated consumption.

[21] See Burman et al. (1994).

[22] Cole (2009) shows a large time sensitivity of purchases of goods—especially computers—subject to state retail sales tax 'holidays' that have become widespread in the United States.

2.2.5 Taxpayer/Remitter Notches

This brings us to the 'who' of tax base determination.[23] The same tax base may trigger different tax liabilities depending on some characteristics of the taxpayer or remitter of the tax. For example, under the US federal income tax there are separate schedules for four different categories of taxpayer marital status. When tax is based on family income, marriage penalties and bonuses arise where the sum of two individuals' tax liability depends on whether they are married. Under an individual-based system, the total tax liability of a couple depends on the division of earnings between the spouses. These sharp distinctions obtain in spite of the fact that there are many dimensions to relationships among adults that are, in principle, continuous.

Remitter notches arise when tax-remitting firm characteristics, often size-related, trigger discrete changes in tax treatment. Onji (2009) discusses the Japanese VAT, where firms below a certain size threshold may opt for a favorable regime, and documents the presence of bunching in firm size right below the size threshold.[24] Many countries' VATs feature thresholds, usually in terms of turnover, below which a firm need not register for the VAT.[25] Differentiation of tax liability based on firm size apparently violates production efficiency, which Diamond and Mirrlees (1971) showed characterized an optimal tax system under some conditions. But, as Dharmapala et al. (2011) argue, firm-size differentiation can indeed be part of an optimal tax system when there are fixed-per-firm elements in the administrative costs of running a tax system.

Permitting firms below a size threshold the option of a simplified VAT is an example of a case where the consequence of moving from one side of the notch to the other cannot be naturally continuous (ie it is difficult to imagine a continuous gradation of regular VAT rules and simplified VAT rules). It is easy to find other examples of nondiscrete tax aspects of a tax system: In the United States only corporations with greater than $10 million of assets must file the Schedule M-3 as part of their corporate tax return, which requires a complete reconciliation from financial accounting net income to taxable income in a standardized and detailed format. Corporations with less than $5 million of gross receipts averaged over the three previous years may use the cash method of accounting, and are exempt from the corporate alternative minimum tax. For such discrete tax-system aspects, notches are inevitable.

3. NOTCH ANALYTICS - QUANTIFYING BEHAVIOR WITH NOTCHES

3.1 Measuring Price Elasticity Using Quantity Notches

Recently, Saez (2010) and Chetty et al. (2009) have argued that the behavioral responses to kinks and notches can provide an estimate of price and income elasticity that is immune to identification concerns that plague other estimation methodologies. This advantage relies on the premise that individuals whose consumption and leisure choice are located in the neighborhood of a kink or a notch differ only in the local shape of their budget set.

[23] There are also 'why' notches; for example, in the United States and other countries a given tax understatement is subject to discretely different penalties depending on the judged intent of the taxpayer.
[24] See also Best et al. (2013).
[25] VAT thresholds are discussed in Ebrill et al. (2001, pp. 113-124).

Alternative strategies, such as the panel data methods employed by Auten and Carroll (1999) and Gruber and Saez (2002), rely on different assumptions, namely that secular changes in income year to year can be controlled for, thereby allowing the researcher to estimate a difference-in-differences parameter for the effect of a tax change. These assumptions can prove problematic in the face of income inequality or mean reversion.

At first blush, studying behavior in the neighborhood of a discrete change in tax treatment may sound like a regression discontinuity (RD) research design, where the treatment in the case of a kink is a discretely different relative price, and in the case of a pure notch is a discretely different virtual income. In RD design, one is interested in the causal effect of a binary intervention or treatment where assignment to the treatment is determined, either completely or partly, by the value of a predictor being on either side of a fixed threshold. Assuming that the association of the predictor to the outcome is smooth, any discontinuity of the conditional outcome at the threshold value can be interpreted as the causal effect of treatment.

Under some conditions, a notch can enable an RD design. Lemieux and Milligan (2008) examine the labor market effects of a Canadian social assistance program that gave recipients over age 30 a higher level of support than received by those under age 30. Because the treatment is a deterministic function of a forcing variable (age) that individuals cannot manipulate, any observed response among the treated in the neighborhood near the discontinuity has a compelling causal interpretation. However, in cases such as Saez (2010), individuals can manipulate the forcing variable, thereby violating a key assumption of RD design. For example, in the standard quantity notch the forcing variable is taxable income, which can be chosen by the taxpayer. Indeed, in tax analysis understanding the behavioral response of the forcing variable is often the *purpose* of the exercise. Nevertheless, studying the behavior of agents in the neighborhood of policy notches retains the essence of the RD advantage in that it compares the behavior of arguably similar individuals who may face different relative prices and have different virtual incomes.

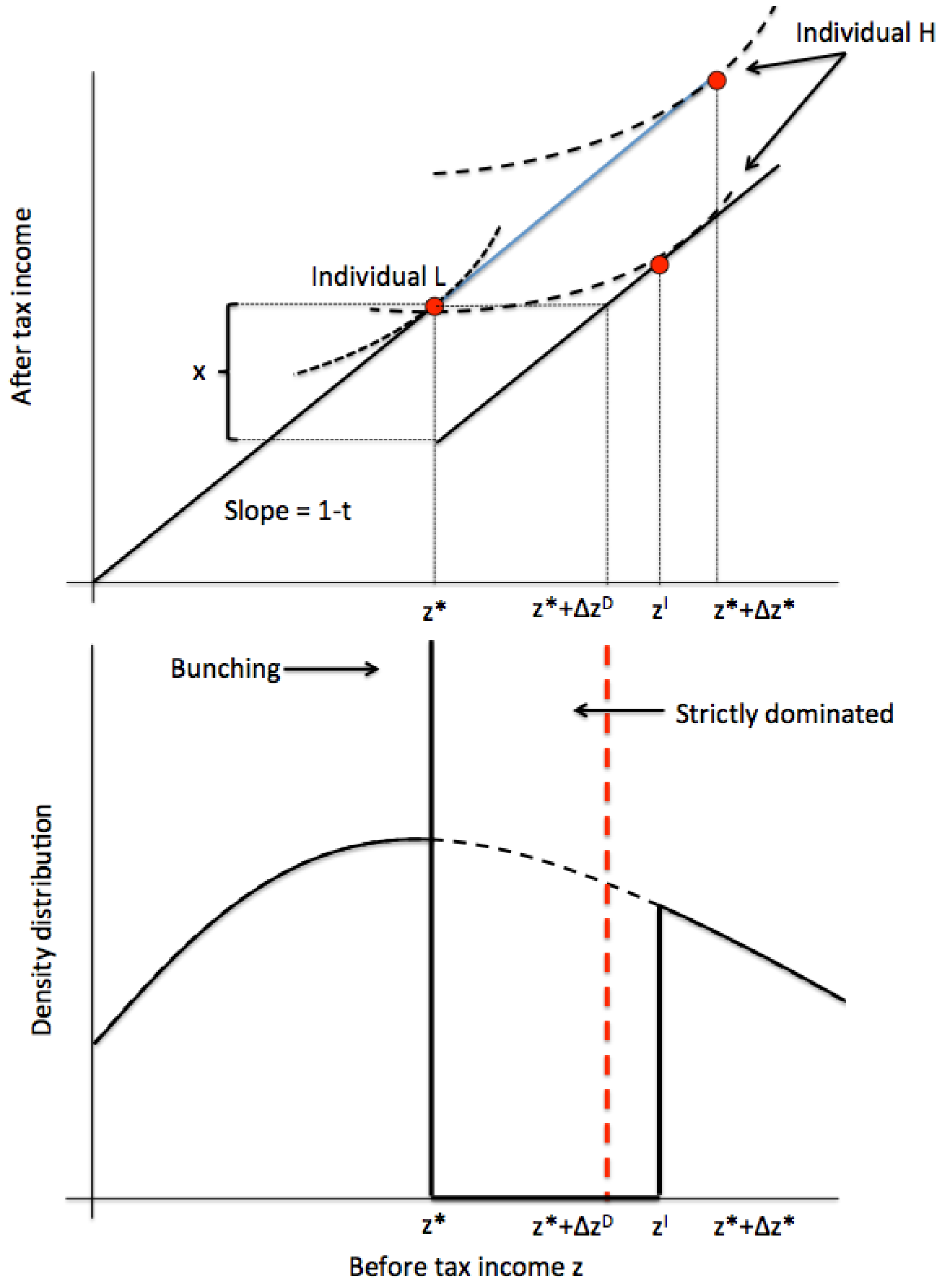
As an illustration I consider behavior in the presence of quantity notches in the space of after-tax income and before-tax income. Before-tax income represents the effort put toward earning income, and enters negatively into the utility function; in a simple model where individuals supply labor, before-tax income is simply labor income. After-tax income equals consumption, and enters positively into the utility function. A notch in this space represents a point where a small change in before-tax income yields a discrete change in consumption (after-tax income). When consumers have heterogeneous preferences and/or wage rates,[26] one would expect to see bunching at the more tax-attractive side of the notch. To be sure, bunching would also arise in the presence of kinks in convex budget sets. However, unlike the case of kinks, in the presence of a notch a consumer should never elect to be on the ‘wrong’ side of the notch—the density distribution should feature a ‘hole’ on the tax-disfavored side of the notch. This

[26] When the choice variables are specified as after-tax income and before-tax income, heterogeneous preferences can arise from underlying taste differences as between leisure and consumption, or because the wage rate differs for given leisure-consumption preferences. Note that preferences can vary while the elasticity of response is uniform.

implication holds if we assume consumers make rational decisions and face no adjustment costs, an issue to which I return below.

To illustrate, refer to Figure 1 and consider the following notation drawn from Kleven and Waseem (2013). Imagine that individuals have quasi-linear and iso-elastic utility over before-tax earnings z and after-tax earnings c, u=c-$f(z)$. Let $f(z)$ be a function parameterized by the individual's ability and her elasticity of earnings with respect to the marginal tax rate. At the optimum, z is an increasing function of ability and a decreasing function of the tax rate, with responsiveness to the latter governed by the elasticity. Suppose a pure notch is introduced at z^*: the marginal tax rate on either side of z^* remains the same, but individuals with before-tax earnings greater than z^* incur a tax liability increased by a discrete amount. In the absence of frictions, some individuals will choose to bunch at z^*. Individual L, the person with the lowest pre-notch income who chooses to bunch, would have chosen z^* even in the absence of the notch. Individual H, the person with the highest pre-notch income who chooses to bunch, would have chosen $z^*+\Delta z^*$ in the absence of the notch and is indifferent between z^* and the interior point z^I after the tax change. A region defined by $(z^*, z^*+\Delta z^D]$ is created by the notch where individuals could increase both leisure and consumption by electing to bunch at z^*; this is the strictly dominated set of consumption choices. Even when the structural elasticity parameter is zero, individuals will choose to bunch instead of being in this region, unlike with a kink. A larger region, (z^*, z^I), contains the strictly dominated set and defines the range of before-tax incomes that no individual is willing to choose after the tax change because the utility loss from reduction in after-tax income outweighs the utility gain from the fall in before-tax income. As a result, the distribution of before-tax earnings in the presence of the notch will feature a 'hole' in that region.

Figure 1.



By measuring the extent of bunching, one can deduce the implied price elasticity using a methodology similar to that used for kinks by Saez (2010). With a kink, a sudden change in relative prices at one point on the budget set induces a behavioral response: consumers on the affected budget segment substitute toward the kink, with many bunching exactly at that point. One estimates the price elasticity by observing the largest such change in the consumption basket in the direction of the kink point; a larger maximal change implies a bigger elasticity. Formally, given a change in the marginal tax rate at the kink of *dt*, the compensated elasticity of earnings *e* can be defined as

$$e = \frac{dz^*}{z^*}\frac{1-t}{dt} \tag{3.1}$$

where z^* is the kink point and $\frac{dz^*}{z^*}$ is the degree of bunching. To empirically estimate this quantity, one must assume a density of before-tax earnings that is smooth in the neighborhood of the kink to measure the extent of bunching that actually occurs. The elasticity can then be recovered from the equation

$$B = z^*\left[\left(\frac{1-t_0}{1-t_1}\right)^e - 1\right]\frac{h(z^*)_- + h(z^*)_+/\left(\frac{1-t_0}{1-t_1}\right)^e}{2} \tag{3.2}$$

where $h(z^*)_-$ and $h(z^*)_+$ represent the densities of before-tax income just below and above the kink and *B* is the measured extent of bunching.

With pure notches, there is no explicit change in relative prices at any single point on the budget set, but there is an implicit relative price change between the tax-favored notch point and an alternative point on the tax-disfavored region of the budget set. The minimum implicit price change that causes an individual to remain on the tax-disfavored region reveals the price elasticity; the smaller the price change needed to induce a move, the more sensitive (ie the bigger is the elasticity). As with kinks, more bunching implies a higher price elasticity. For a given notch size, the shorter the length of the strictly dominated budget segment, the larger is the minimal implicit price change required to affect bunching; a small hole in the density distribution corresponds to a small price elasticity. Formally, Kleven and Waseem (2013) demonstrate that, under the standard assumptions regarding iso-elastic and quasi-linear utility, the first-order optimality condition can be rewritten as an expression containing the elasticity, tax parameters, and the degree of bunching:

$$\frac{1}{1+\Delta z^*/z^*}\left[1 + \frac{\Delta T/z^*}{1-t}\right] - \frac{1}{1+\frac{1}{e}}\left[\frac{1}{1+\frac{\Delta z^*}{z^*}}\right]^{1+\frac{1}{e}} - \frac{1}{1+e}\left[1 - \frac{\Delta t}{1-t}\right]^{1+e} = 0 \tag{3.3}$$

Unlike the formula for kinks in Saez (2010), this expression relies on the change in average, rather than marginal, tax rates, as this is the driving force behind the behavioral response to a notch. Even when the elasticity approaches zero, the resulting estimate for the bunching interval is still positive, reflecting the fact that individuals will always avoid the strictly dominated region.

Empirically estimating the elasticity is less straightforward with notches than with kinks. With a kink, the researcher must choose some bandwidth around the kink point that defines the region containing excess mass. With a notch, the researcher must first choose the point on the tax-favored side of the notch where bunching in before-tax income begins to occur. Then, she must choose a corresponding point on the tax-disfavored side of the notch where the 'hole' in the post-notch density of before-tax earnings ends. The former point is typically easier to visually identify than the latter. Kleven and Waseem (2013) exploit the fact that, absent frictions, the missing mass on the tax-disfavored side of the notch should equal the excess mass on the tax-favored side, and use this to pin down the upper bound of the excluded range.

3.2 Which Elasticity Are We Measuring?

3.2.1 Real/Fundamental versus Avoidance Elasticities

Can patterns of bunching around notches inform our understanding of fundamental economic parameters? For example, what does bunching of consumption precisely at a time notch, after which the consumption tax rates change, reveal about the intertemporal elasticity of consumption? To answer this particular question requires one to distinguish between purchases, which are subject to an abrupt tax rate change at the time notch, and consumption. As first noted by Eichenbaum and Hansen (1990), the mapping from consumption good purchases into consumption services can be viewed as a dynamic version of the household technology suggested by Gorman (1980) and Lancaster (1966, 1975) in which consumption *goods* produce the ultimate arguments of utility functions — consumption *services* in current and future periods. Perhaps the most common interpretation of this model arises from considering durability (and storability), where consumption goods are durable and are purchased to augment the stocks of household capital. Because the marginal utility of goods purchased is decreasing in the quantity of carried-over stock, purchases that are closely spaced in time are relatively more substitutable.

This implies that the pattern of behavior around a time notch does not directly provide evidence about intertemporal substitutability, but about the combination of intertemporal substitutability and the durability (or storability) of the goods in question.[27] Clearly time moves in only one direction, which limits the applicability of this approach to notches in other characteristics. But the Gorman-Lancaster framework, where there exists a mapping of goods into characteristics space and characteristics alone enter the utility function, remains insightful for the interpretation of the behavioral response to notches. I expand on this point below.

The anatomy of the behavioral response to tax changes is crucial to understanding what the elasticity of taxable income is measuring. Because taxable income is a function both of the income earned from labor supply and a variety of sheltering activities, as well as decisions regarding how income is reported, its responsiveness to a tax change depends on how flexible individuals are in choosing these quantities. Broadening the tax base, for example, may limit individuals' ability to shelter their income. This point is emphasized in Slemrod and Kopczuk (2002), who argue that the elasticity of taxable income (ETI) is a function of the tax base and therefore can be thought of as a policy-dependent, rather than as a structural, parameter. An empirical estimate of ETI should only be thought of as a measure of the responsiveness of taxable income to a change in tax rates *under the studied*

[27] See Cashin (2012).

tax regime, and not one that may obtain in other contexts. Furthermore, Chetty (2009) argues that the implications for calculating deadweight loss differ depending on whether the response to a tax change derives from changes to labor supply or sheltering behavior because the latter is a transfer rather than a 'real' response.

3.2.2 Structural versus Nonstructural Elasticities

A further caveat to recovering structural estimates of elasticities from bunching at kinks or notches is the presence of optimization frictions. Individuals may desire to adjust their consumption to the notch point, but are unable to do so in the short term, thus diminishing the observed bunching. For example, a reduction in labor supply may require changing jobs. If we believe that such constraints matter only in the short term, then optimization frictions 'artificially' diminish the observed bunching, biasing downwards the estimate of long-run behavioral response. Chetty (2012) shows formally that the presence of even relatively small optimization frictions can be consistent with a wide range of intensive-margin tax price elasticities. Unlike with a kink, a notch creates a strictly dominated consumption choice set that individuals will avoid in the absence of frictions, making the discontinuities created by notches valuable opportunities for econometric identification.

The method developed by Kleven and Waseem (2013) relies on exactly this insight: the strictly dominated region should be empty in the absence of optimization frictions. Any observed mass in the dominated region can therefore be used to identify the degree to which frictions drive behavior without making parametric assumptions, and can be combined with excess mass estimates to disentangle the underlying *structural* elasticity—the responsiveness absent any adjustment frictions—and the short-run elasticity, which measures the actual observed behavioral response. Assuming that these frictions diminish in the long run, the structural parameter represents the elasticity relevant to welfare and optimal policy discussions.

Using administrative data on income tax filings, they report two findings about the responses of wage earners to notches in the Pakistani income tax system: a significant degree of bunching and many individuals located in the strictly dominated region. They conclude that while some individuals, particularly the self-employed, are responsive to the strong tax incentives created by the notches, the majority of wage earners are subject to optimization frictions.

As mentioned earlier, what triggers a tax in practice is often different from what triggers a tax liability in stylized models. For example, retail *purchases* rather than *consumption* trigger retail sales tax liability, receipt of labor income rather than the physical labor itself often determines the timing of tax liability. Sales of appreciated capital assets trigger tax liability rather than accrual of gain or consumption itself. Operational definitions of taxable income differ on many dimensions from the Haig-Simons definition of income. These tax bases, which we might call *surrogate* tax bases, may be part of an optimal tax system because of the difficulty of measuring or monitoring the otherwise optimal tax base. Most, if not all, actual tax systems have elements of surrogate tax bases. The local response to lines and notches is appropriately characterized as *tax avoidance*, in the sense of Slemrod and Yitzhaki (2002) — taxpayer efforts to reduce their tax liability that do not alter their consumption basket other than due to income effects— and gives rise to an excess burden of avoidance as defined by Slemrod and Gillitzer (forthcoming). Substitution across elements of a surrogate tax base does not directly alter one's consumption basket although, through the function linking the surrogate tax base to the consumption basket, it may alter the effective relative prices of the latter and thereby change consumption choices.

The presence of notches in surrogate tax bases sheds light on the hierarchy of behavioral responses proposed by Slemrod (1990, 1992), which asserts that of behavioral responses, timing responses are the most elastic, followed by avoidance/accounting responses, with the least responsive being real responses such as labor supply and saving. Although much evidence is broadly consistent with the hierarchy hypothesis, a satisfactory explanation has not yet been offered. But now consider that the evidence cited in favor of a high elasticity of response, exemplified by the striking increase in capital gains realizations in advance of known increases in the capital gains tax, is response of a surrogate tax base (capital gains do not enter utility functions directly) around a notch, the notch in time at the end of a year. This largely reflects the response to effectively very high tax rates per day of postponement near the year-end notch, plus the fact that the sale itself does not constrain the time pattern of consumption. Thus the reduced-form estimates of capital gains realization elasticities do not provide direct evidence about any fundamental, or structural, parameters. The same is true for the high observed elasticity of response to sales tax holidays or expiring investment incentive provision,[28] where the durability of the consumer or investment good comes into play.

3.2.3 Why Does the Anatomy of Elasticities Matter from an ETI/ETB Perspective?

The foregoing discussion about *which* elasticity a notch analysis identifies is, at first blush, inconsistent with the spirit of the elasticity of taxable income, or tax base—that *all* behavioral responses to tax are symptoms of inefficiency, and so a decomposition of the overall behavioral response is not instructive.

This is only partially true. It is completely consistent to distinguish between short-term and long-term elasticities, a difference that will obtain in the presence of adjustment costs. This issue applies to any behavioral elasticity, although in the case of notches what is relevant is the cost of making relatively small adjustments in, say, reported taxable income.

The anatomy of behavioral response can matter for the important issue of the generalizability of behavioral elasticities derived from notch analysis. Trivially, one is learning only about local responses, so what is learned from analysis of the response to a notch in the neighborhood of $30,000 in annual income may not apply around $300,000; this is likely to be relatively important when avoidance responses are at issue, and especially when there are fixed costs to undertaking avoidance.

The generalizability issue also applies to the salience of notches, especially in light of the abundant evidence that many taxpayers are unaware of relevant aspects of the tax code.

[28] See House and Shapiro (2008) for an analysis of the response of investment to a time-notched bonus depreciation scheme.

Apparently notches are often implemented precisely because they stand out and are more comprehensible than a schedule with multiple kinks or with continuously changing marginal incentives, and precisely when these characteristics are deemed to matter. This suggests that the implicit price response (of those who are aware of the notch) may be greater than in other situations; after all, for small responses close to the kink, the implicit price approaches infinity.

The extreme local rewards (or penalties) generated by notched budget sets also provide large incentives to smooth the tax-triggering activity across accounting periods. Just as salesmen who qualify for a bonus once they hit their annual sales target don't want to 'waste' recording sales above the target and instead shift them to the next year, some of the bunching one observes around tax notches is likely to be a symptom of intertemporal shifting, which affects how the measured elasticity enters a welfare cost calculation: the revenue implications in the 'other' periods must be accounted for to the extent that time shifting is part of the behavioral response.[29]

Finally, the anatomy of behavioral response also matters for the generalizability of the findings because in different situations the relative importance of the component elasticities is likely to be different. To see this, consider the example of a sales tax holiday, where for a short period of time (say a week) certain purchases (say school clothes and supplies) are exempt from sales tax. The elasticity with respect to price that one would estimate from behavior around this time notch will largely represent a purchase elasticity rather than a consumption elasticity; it would be mistaken to extrapolate this elasticity if the sales tax holiday were offered for lawn mowing services that had to be provided (in a verifiable way) within the holiday, because in that case consumption must equal purchases in each time period and thus the consumption elasticity constrains the overall elasticity. Furthermore, elasticities that include evasion response estimated in an environment of lax enforcement will not be applicable to situations where enforcement precludes evasion. In these examples the measured elasticity (ignoring the short-term long-term distinction discussed above) will be useful for welfare analysis, but not necessarily in environments that are dissimilar from the one in the case under study.

One indisputable contribution of studying the behavioral response to tax notches is the compelling demonstration that at least some people and firms do notice and react to the tax system. While this is not at all surprising to people in the field, there remain doubters that taxes matter. But the myriad documented responses to quantity, characteristic, border, and time notches put this possibility to rest. As George Bernard Shaw is alleged to have said in an entirely different context, 'Now we're just haggling over the price [response]!'

4. THE WELFARE COST OF NOTCHES

A tax notch creates a discontinuity in budget sets and, in its pure form, does not change relative prices across segments. However, for local choices between consumption baskets

[29] This argument is presented in Slemrod (1990).

on different segments, a notch creates widely varying effective relative prices depending on the size of the notch and the initial distance from the notch point.

The welfare cost, or gain, of a notched policy must be measured relative to the alternative policy instruments available. For example, if the optimal income tax schedule is highly nonlinear, then a notched policy could be welfare-improving compared to a linear system.[30] General statements about the welfare implications of notches cannot be made.[31]

We can, though, say more regarding some particular situations. What are the welfare implications of a notched system when the optimal scheme is linear? Sallee and Slemrod (2012) address this question in the context of notched subsidies to fuel-efficient cars in Canada and the United States. Presumably, the positive externality to the environment is a smooth, rather than notched, function of fossil fuel emissions. As a result, the optimal Pigouvian tax correction would similarly be smooth, equal to the marginal social benefit of increased fuel efficiency, measured as a vehicle's miles-per-gallon (MPG). The US Gas Guzzler Tax features notches at each 0.5 decimal of MPG under 22.4; increasing a vehicle's MPG by 0.1 can reduce the tax liability by as much as $1 700, and on average does by $800. As a result, manufacturers producing cars with an initial MPG far from a notch have little incentive to increase fuel efficiency, while manufacturers with an initial MPG ending in 0.4 or 0.9 have a strong incentive to increase MPG by 0.1 that is disproportionate to the social gain generated by such a change. Increases to fuel efficiency induced by notches may even result in a welfare loss if the private costs of these adjustments exceed the social benefit of reduced emissions. Sallee and Slemrod (2012) observe bunching on the low-tax side of notches in the distribution of vehicles' fuel efficiency, and calculate the weighted-average subsidy per MPG to be $4 720, compared to the optimal Pigouvian subsidy per MPG of $800. Further, they calculate the social gain, net of the private cost of changing MPG, is *negative*, with a magnitude five times the net social gain from the Pigouvian incentive to improve MPG.

5. WHY NOTCHES?

5.1 Quantity Notches

Would notches be part of an optimal income tax system, if there were no particular administrative cost associated with them? The seminal optimal income tax paper of Mirrlees (1971) implies that, when the income tax schedule can be completely flexible, the answer is no. He shows that, in an optimal nonlinear income tax, the marginal tax rate always lies between zero and one, which precludes either a discrete drop or increase in after-tax income as pre-tax income increases. As Diamond (1998, p. 84) discusses, the reason for the two proscriptions is different. Marginal tax rates should not be greater than 100 per cent because 'Assuming that labor supply can be continually adjusted, there is no gain from having marginal tax rates above 100 percent since no one will have such a tax at the margin. That is, the same outcome can be achieved with taxes no greater than 100 percent.' He goes on to explain that marginal tax rates should not be less than 0 per cent

[30] The same statement holds for, say, kinks.

[31] Although, see Kaplow (2013) for a comprehensive treatment of the optimality of size exemptions for both taxation and regulation.

because: 'It is usually presumed that preferences are such that consumption is an increasing function of the wage. Then, earnings will be nondecreasing in skill. It follows that the optimal tax structure has nonnegative marginal rates…'

However, as mentioned earlier, no theorem rules out the possibility that a notch can be part of an optimal schedule when the flexibility of the income tax schedule is constrained, say to be linear. This possibility is in the same spirit as the argument made by Blinder and Rosen (1985) that, in cases where the objective is to encourage consumption of a particular activity (in their example, charitable giving), notch schemes may be more effective than per-unit subsidies. Compared to a constant per-unit subsidy that applies to all charitable donations, a notch grant that kicks in only for those whose consumption exceeds a certain amount limits the amount of subsidy for infra-marginal giving. In principle, when revenue is costly to collect, the ideal subsidy scheme would provide a subsidy only at the margin of favored consumption but, in the absence of personalized incentive schemes or other nonlinear consumption taxes or subsidies, a notch may increase welfare.[32] Whether a nonlinear consumption tax, and indeed an extreme version of a nonlinear consumption tax with a notch, could be part of an optimal tax system would depend on how flexible the income tax schedule can be.

5.2 Characteristic Notches

Canonical optimal tax theory, which ignores administration and enforcement costs, prescribes staggeringly complex tax features such as nonlinear, age-dependent income taxes, discretely different consumption taxes for each good and service, and tax liabilities that are a function of every available variable that is correlated with earning ability (ie height, genomic information). Policy does, and should, forego many such features.

Consider first commodity taxation. In a world with administration and enforcement costs, plus continual creation and disappearance of available goods, a large number of distinct tax rates would be too costly to administer (ie infeasible). As a result, commodity tax systems inevitably feature a small number of distinct tax rates based on observable characteristics, where the domain of each tax rate is delineated by a line, which causes a notch. Characteristics are a relatively natural and intuitive way to distinguish among commodities, and shared characteristics plausibly signal something about substitutability. Additionally, characteristics-based rules are broad enough to admit development of new goods without requiring creation of novel taxes for each.

The counterfactual to most characteristic notches—a smoothly changing tax base definition—depends on the characteristic considered. Consider 'When.' The exact time of an event that triggers tax liability is continuous and generally knowable at relatively small cost. But under an annual system of accounting the date, other than the year, has no tax consequences, so having to keep track of that would be an added burden, as would

[32] Blinder and Rosen (1985) do not, though, pose this question within a formal optimal taxation problem, nor would this be easy in their framework, in which there is no explicit reason to subsidize consumption of the 'favored' good, nor any other (eg Ramsey, 1927) reason to differentiate the tax on the two goods (there is no valued leisure in the individuals' utility functions).

enforcing it.[33] Discrete accounting periods, generally annual, have many advantages. Daily income, as measured by current means, would be a highly variable measure of ability to pay. Even absent policy changes from year to year, however, the graduated income tax system provides incentives for cross-year movement of taxable income. The realization system plus deferral limited loss offset provides incentives for capital gains transactions at year-end, and there are rules to limit this kind of behavior.

Similar arguments apply to 'Where.' Precise location is cheaply knowable, but is not now an argument to tax liability functions. There are advantages to the decentralization of political and economic authority that are beyond the scope of this paper. Once in place, though, decentralization provides incentives for movement of economic activity across borders, including but not limited to local borders.

The hardest issue is 'What,' which arises in all tax systems. Although standard optimal tax theory prescribes it, it is practically infeasible to levy as many tax rates as there are separate goods. So it is natural to think of grouping goods that are close substitutes with each other. The infeasibility is even clearer when one considers that new goods are constantly being created. Occasionally what it is about a good that justifies tax differentiation is easily measurable and of low dimension: the Gas Guzzler Tax is an example. More common is the distinction in the US (and other) income tax systems between an employee and an independent contractor, which depends on a twenty-factor test where many of the factors are themselves difficult or impossible to measure. Over time regulations and rulings clarify what combinations of characteristics are on one side of the line, and which combinations are on the other. Once that becomes clear, bunching will follow.

Characteristic notches can also generate *tax-driven product innovation*, as new goods are created just on the low-tax side of the line.[34] In response, Kleven and Slemrod (2011) re-formulate optimal commodity tax theory in the language of characteristics using the Gorman-Lancaster framework in which utility is derived from characteristics produced by goods, rather than the goods themselves. They establish that, the closer two goods are in characteristics space, the smaller the optimal tax rate differential. Secondly, the authors show how non-uniform tax systems may spur the creation of goods that are socially inferior (eg awkward car-like motorcycles), but that may be privately optimal for tax avoidance purposes. This represents a distortion in the set of available goods—a production inefficiency—distinct from the demand and supply distortions that typically concern public finance economists. Under certain assumptions on the production of new goods, the notches associated with line drawing create an incentive to bunch production and consumption of goods just on the low-tax side of a line that separates two tax rate regions. If feasible administratively, optimal lines should be drawn to avoid tax-driven product innovation completely. In a world with just two goods and two tax rates, this implies that the line should be 'close enough' to the characteristics of the low-tax good.

[33] Even in an annual accounting system, dates of transaction may matter, for example to distinguish short-term from long-term holding periods for capital gains tax. The holding period distinctions are, of course, themselves examples of time notches. Thanks to Leandra Lederman for alerting me to this set of issues.

[34] Belan and Gauthier (2006) and Belan et al. (2008) investigate the optimal grouping of goods when only a limited number of commodity tax rates can be levied.

This result harkens back to the Diamond-Mirrlees production efficiency theorem, which acknowledges taxes are inevitably distortionary, but argues distortions in consumption behavior are welfare-preferred to distortions in production.

5.3 Other Justifications for Notch Use in Tax Design

It may be that notches get people's attention in ways that programs that feature smooth or kinked budget sets do not, so that they may be more effective in influencing behavior. It may be that they are more easily understood, an issue that is related but not identical to attracting attention. It is also possible that notches are widely misperceived, and so induce people to behave in ways that are not in their self-interest.[35] As of now these reactions to notches are a matter of speculation, as there is little evidence about the salience or related properties of notches, relative to either kinked or smooth policies.[36] Are, for example, most people more confused by a notch than by a series of kinks that approximate the notch? Is a system with continually adjusting marginal tax rates, thus requiring neither notches nor kinks, beyond anyone's comprehension? Apparently not, as since 2004 the German income tax system has featured continuously increasing marginal tax rates over certain income ranges. For example, in 2010, the marginal tax rate on income increased linearly from 14 to 24 per cent for those earning more than Euro 8 004 and less than Euro 13 469 (Federal Ministry of Finance, 2012). Tax economists have typically assumed that the administrative cost of such a system is prohibitive relative to one with a discrete number of marginal tax rates, but some speculate the high rate of electronic return filing through government-provided software eases the burden.[37]

To the extent that disputes arise about the arguments of the tax base, be they quantities or characteristics, notches limit the scope of these disputes to those in the neighborhood of the notch while raising the stakes to being on the wrong side of a notch.[38] In other words, the varying incentives created by notches result in a large infra-marginal segment and a small marginal segment. The latter group is strongly induced to respond, its incentives to relocate raised sharply by the existence of the line. This observation runs in parallel to the argument that notches create capricious[39] and widely varying local incentives. The cost of the adjudication system may vary across these dimensions.

6. Conclusions

[35] Based on my personal observation, at least half of undergraduates beginning a public finance class believe that the kinks in the US income tax structure are in fact notches; after much discussion of this issue during the class, about a quarter of those completing the class do, too.

36 It may also be that policy makers are subject to the same type of cognitive bounds in formulating policy.

[37] OECD (2012).

[38] Consider the adjudication costs of alternative class grading systems of 0-to-100 number grades versus (a small number of) letter grades. Under the former system all students have an incentive to complain, while in the latter only those near letter grade notches have the incentive to complain, but will do so more vigorously. Professors may have the incentive to not reveal who is close to a notch.

39 I am presuming that the exact placement of a notch is usually arbitrary. That is certainly true for the case of the Gas Guzzler Tax (at .5 decimals of miles-per-gallon), but may not be true in all cases. Knowledge of local areas where response elasticities are relatively high would be a factor in the optimal placement of notches.

The ubiquity of tax policy notches calls for further inquiry into their consequences for behavior and their role in an optimal tax system. The taxonomy of notches proposed here is a first step. The demonstration of their welfare inferiority absent considerations of administrative cost or salience suggests that the latter issues warrant attention. While they persist, taxpayer behavior in the presence of notches has the potential to provide information about behavioral response, a task complicated by the need to separate out preferences and technologies on the one hand from mitigating salience factors on the other. Finally, the indisputable evidence about behavioral response to notches, unsullied by the need for arguable identification assumptions, puts to rest serious discussion of whether taxes matter. They do.

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