Misperceptions of Nonlinear Budget Sets: Evidence from Administrative Tax Data*

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Abstract

Budget set kinks are much studied in economics, including in the context of "bunching" estimators that assume individuals react to the true marginal tax rate. We document that individuals disproportionately "left-bunch" below kinks in the context of the Social Security Earnings Test. We show that the left bunching in this case cannot be explained through standard, rational reactions to the incentives and instead find that a model of tax bracket misperception, where individuals mistake a kink in their budget set for a notch, provides a much better fit to the data. In the context of the Earnings Test, this misperception provides an explanation for why literature has found large earnings responses despite the fact that the Earnings Test typically creates weak incentives for rational agents to adjust earnings. More generally, if individuals perceive kinks as notches, then elasticities estimated from bunching at kinks where this misperception may be at play may be significantly over-estimated.

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1 Introduction

Nonlinear price schedules are common across a wide variety of economic applications, including labor supply (e.g. Hausman, Hausman and Holl 1981), health insurance (e.g. Einav and Levin 2015), electricity demand (e.g. Ito 2014), and retirement savings (e.g. Bernheim, Fradkin and Popov 2015). In particular, many price schedules and policies feature kink points, which are discontinuous changes in the price of a good. For example, many means-tested government transfer programs reduce or eliminate transfer benefits as income rises above threshold levels, and the individual income tax in many countries generates a piece-wise linear budget set with kinks at each point at which the marginal tax rate (MTR) jumps. Previous literature has developed methods for explicitly using kink points to estimate price or tax elasticities (e.g. Burtless and Hausman 1978; Hausman, Hausman and Holl 1981; Hoynes 1996; Saez 2010; Chetty et al. 2011*b*; Kleven and Waseem 2013; Bernheim, Fradkin and Popov 2015; Kleven 2016, for a review).

These papers that estimate elasticities from kinks have generally assumed that individuals respond to the marginal tax rate, as in standard models. However, outside the literature on elasticities and bunching at kinks, other papers have suggested that individuals confuse average and marginal tax rates (Liebman and Zeckhauser 2004; Rees-Jones and Taubinsky 2020). The notion that individuals react to the average tax rate, instead of reacting to the marginal tax rate as in the standard models, has been proposed as an explanation for the lack of "bunching" observed at some kink points (Ito 2014). In many settings, however, bunching does occur at kink points, and, puzzlingly, when bunching does occur, it is often asymmetric, with much more bunching below the kink point than above it, a phenomenon we call "left bunching."

In this paper, we perform a systematic analysis of left bunching, and explore two classes of possible explanations. We extend standard models of bunching to capture the empirical reality that bunching tends to be diffuse, following Saez (1999), and examine theoretical predictions under a number of scenarios. First, we note that if a kink is imposed in the presence of a downward-sloping density of earnings, left-bunching may arise if the density is steep enough. The imposition of the kink causes the density to shift downward, which leads to fewer bunchers above than below the kink. In principle, this phenomenon, which we refer to as the standard explanation, could explain the left bunching that has been observed in such circumstances. Second, individuals could left-bunch because of some "behavioral" deviation from standard theory, including misperceiving the tax schedule or reference-dependent preferences.

We tease apart these classes of explanations in the key context of the U.S. Social Security Earnings Test. The Earnings Test reduces Social Security Old Age and Survivors Insurance ("Social Security") benefits in a given year as a proportion of a Social Security claimant's earnings above an exempt amount in that year. For example, for Social Security claimants under age 66 in 2019, current Social Security benefits are reduced by one dollar for every two dollars earned above $17,640. Previous literature has found that Social Security claimants bunch at this convex kink (Burtless and Moffitt 1985; Friedberg 1998, 2000; Song and Manchester 2007; Engelhardt and Kumar 2014; Gelber, Jones and Sacks 2020), and that employment falls due to the Earnings Test (Friedberg and Webb 2009; Gelber et al. 2021, 2022). In addition to providing a laboratory for studying left bunching, the Earnings Test is important to policy-makers in its own right. In the latest year of the available micro-data, the Earnings Test led to an estimated total of $4.3 billion in current benefit reductions for around 538,000 beneficiaries, thus substantially affecting benefits and their timing. The importance of the Earnings Test has increased as the affected age range—those at or below the Normal Retirement Age (NRA)—has expanded gradually from 65 for cohorts born before 1938, to age 67 for those born in 1960 and later.[1]

Using administrative tax data from the Internal Revenue Service (IRS) on a one-hundred percent sample of the U.S. residents with a Social Security Number (SSN), born between 1939 and 1954, we show that nearly all bunching at the exempt amount is left-bunching. Two considerations show that the standard explanation does not entirely account for this left bunching. First, left bunching does not only occur amid the downward-sloping densities postulated in the standard explanation; it occurs even at ages when the distribution of earnings is close to flat around the exempt amount. Second, an illustrative simulation of a rational model of bunching fails to reproduce the left bunching we observe.

Having dispatched the standard explanation as the sole origin of these patterns, we explore other explanations. One plausible candidate is loss aversion, since individuals may perceive their withheld Social Security benefits as a loss relative to the reference point of full benefit receipt. We show that loss aversion can in some cases generate left bunching. A second possibility is that some individuals misperceive the discontinuity in their *marginal* tax rate for a discontinuity in their *average* tax rate, i.e. they misperceive the kink for a notch. We call this phenomenon "tax bracket misperception." Such individuals perceive a large loss in benefits from earning just above the exempt amount, and hence perceive a strong incentive to left bunch.

To distinguish between these explanations, we examine a prediction of tax bracket misperception that separates it from standard models and from models of loss aversion. If people believe their benefits fall discontinuously as their earnings exceed the exempt amount, and if there are frictions involved with making intensive margin responses, then some of them should prefer to drop out of employment entirely rather than earn just above the exempt

[1] Reductions in current benefits due to the Earnings Test sometimes lead to increases in later benefits through an actuarial adjustment of benefits. In particular, there is a little-understood " notch" in the budget set just over the exempt amount: when individuals earn just above this level, their benefits once they reach the NRA are adjusted upward by five-ninths of one percent. Thus, the incentives—understood properly—should lead Social Security beneficiaries to locate just above the exempt amount, i.e. they should " right-bunch." This has led to a longstanding puzzle in the Earnings Test literature: why do earnings respond strongly to the Earnings Test, despite the actuarial adjustment of benefits (Burtless and Moffitt 1985; Gelber, Jones and Sacks 2020)? The types of misperceptions we explore below may be one explanation.

amount. Therefore, tax bracket misperception predicts a downward discontinuity in the employment probability as a function of counterfactual earnings in the absence earnings test. We find that, indeed, the employment rate falls by about 0.3 percentage points right at the exempt amount. We emphasize that while standard models imply a more general employment response to the Earnings Test (e.g. Gelber et al. 2021), they also imply that the employment rate should be continuous at the exempt amount. It is the discontinuity that provides evidence for tax bracket misperception. Although a discontinuity of 0.3 percentage points may seem small, we show that this discontinuity nonetheless implies that at least 4.5 percent of our sample misperceives the kink for a notch, and these misperceivers explain a large share of left bunching. Intuitively, most people would prefer to adjust their earnings by a tiny amount to get below the exempt amount than to drop out of employment entirely, so even a small employment response implies a meaningful share of tax bracket misperceivers.

If bunching at other kinks is due to bracket misperception, then estimates of elasticities based on bunching at such kinks will not apply more generally. Much of the literature estimates elasticities at kinks under the assumption of a standard reaction to the kink incentives. This can be considered a "policy elasticity" (Hendren 2016)—but if many individuals are instead reacting to a perceived notch, then the elasticity with respect to the perceived marginal tax rate is much lower. In other words, the elasticity necessary to rationalize a given amount of observed bunching is far lower with a (perceived) budget set notch than with a kink, because a notch creates much sharper incentives than a kink. We therefore propose an approach that accounts for a portion of the population misperceiving kinks for notches. Our correction relies on knowledge of the share of misperceivers, as well as strong functional form assumptions, and thus has some limitations, but it also gives researchers a straightforward way to account for tax bracket misperception.

This work builds on two strands of literature on perceptions of policy-related incentives. First is a survey literature documenting in general that Americans misperceive their tax rates (for example, Gideon 2017; Ballard and Gupta 2018), and specifically showing that some people believe their average tax rates change discontinuously when they change tax brackets (for example, Lyon and Catlin (2020)). Sullivan (Forthcoming) further shows that videos explaining the mechanics of tax brackets reduce the rate of misunderstanding. We contribute to this strain of the literature by showing that misperception affects an important aspects of economic behavior, earnings supply and retirement timing, going beyond survey evidence.[2]

A second strand of the literature identifies particular forms of misperception, using both survey experiments and revealed preference. Building on ideas in Liebman and Zeckhauser (2004), this literature has investigated the prevalence of "ironing" and "spotlighting", in

[2]In a related paper, Brown, Kapteyn and Mitchell (2016) show that Americans misunderstand Social Security incentives in general and their reported claiming intentions vary with the framing of information. Brown, Kapteyn and Mitchell (2016), however, do not specifically develop evidence on the nature of the misunderstanding.

which people behave as if their average tax rate applies globally ("ironing") or their marginal tax rate does ("spotlighting"). Ito (2014) and Taubinsky and Rees-Jones (2018) find evidence for ironing in electricity provision and in households' understanding of the tax code. Our work complements these papers by providing evidence for bracket misperception, which is distinct because it is a misperception of how marginal tax rates change as brackets change.

Our study is closely related to work by Anagol et al. (2025), who model bunching in the presence of kinks and notches. As in our simulations, they also micro-found diffuse bunching arising from frictions that cause realized earnings to differ from optimal earnings. While their model features a sparse menu of earnings options that prevent precise bunching, our model could be framed as a menu that includes only one choice, and, interestingly, both approaches build off of different models of diffuse bunching in Saez (1999).[3] As in our case, they also consider an application where individuals may be mistaking a kink for a notch in the budget set, and also note the left-bunching pattern that is consistent with a misperceived notch. Relative to their approach, we leverage an additional moment, the extensive margin response to a perceived notch, to learn about the share of the population that are misperceivers.

Our work also contributes to a literature on employment and earnings responses to the Social Security Earnings Test. Since at least Burtless and Moffitt (1985), economists have noted that the Earnings Test reduces short-run intensive margin work incentives; subsequent work documenting intensive margin responses includes Friedberg (2000); Song and Manchester (2007); Gelber, Jones and Sacks (2020)). Other work has found evidence of extensive margin responses (for example, Gruber and Orszag (2003); Gelber et al. (2021, 2022), though this literature has not looked for extensive margin *discontinuities* because such discontinuities are not implied by the standard model. Some of this literature estimates preference parameters such as labor supply elasticities, and the typical approach is to assume that people both correctly recognize the incentives created by the Earnings Test and are able to fully optimize in response to these incentives (Burtless and Moffitt 1985; Friedberg 2000). Gelber, Jones and Sacks (2020); Gelber et al. (2021) assume full knowledge about incentives but allow for intensive margin adjustment frictions, meaning people cannot freely choose any level of hours worked. Our work here contributes to this literature by documenting an additional deviation from the standard model, bracket misperception, which generates quantitatively important intensive and extensive margin responses, and implies that prior elasticity estimates may have been too large.

We next describe the features of the Earnings Test in more detail, followed by a framework for interpreting left bunching. Subsequently, we describe our data and our empirical results. Finally we develop a model of misperception, use it to quantify the misperception share, and show that even a small share of misperceivers can explain a large share of left

[3]As we discuss in Appendix B.3, our model and that of Anagol et al. (2025) have important distinctions. In our model, agents take frictions into account when choosing their target earnings, while in their preferred model this anticipation becomes irrelevant. Second, we assume agents only pay the disutility associated with target earnings, while they assume agents pay the disutility associated with realized earnings.

bunching. Finally, we demonstrate a method for adjusting elasticity estimates for potential misperception.[4]

2 Policy Setting

Social Security Old-Age and Survivors Insurance (OASI)—hereafter referred to simply as "Social Security"—provides benefits to older Americans and survivors of deceased workers, but delivery of benefits can be affected by whether one is currently working. For those who are simultaneously working and claiming Social Security benefits, the Social Security Annual Earnings Test (AET) reduces current benefits in proportion to earnings above an exempt amount, while typically adjusting future benefits upward in an actuarial fair fashion. For example, consider a 63-year-old earning $25,400 in 2019, receiving $1,000 in monthly benefits, and facing a $23,640 exempt amount and a 50 percent benefit reduction rate (BRR). Their current annual benefits would be reduced by $1,000 = ($25,400 - $23,400)×50%, equal to 1 months of benefits. In general, the exempt amount and the benefit reduction rate depend on age. People can claim benefits on their own record as early as age 62, the Early Entitlement Age (EEA), and the Earnings Test applies until one reaches the Normal Retirement Age (NRA).

When current Social Security benefits are lost to the AET, future scheduled benefits may be increased. For beneficiaries below the NRA, the benefit enhancement, also known as the "actuarial adjustment," raises future benefits whenever a claimant earns over the AET exempt amount.[5] Future benefits are raised by 0.55 percent per month of benefits withheld during the years prior to the NRA. Returning to the example above, consider the 63-year-old receiving $1,000 in monthly benefits due to the AET. Upon reaching the NRA, their monthly benefits would increase by around $16.50 = 0.0055 x 3 x $1,000. On average, this adjustment is roughly actuarially fair when considering the timing of claiming Social Security (Gruber and Wise 1999; Diamond and Gruber 1999).

We plot the short-run budget set created by the earnings test in Figure 1, which shows after-tax-and-transfer income against gross income. People start off with a benefit amount B_0. After tax income rises with a slope of $(1-\tau)$, where τ is the marginal tax rate. At the exempt amount, z^*, there is a kink as benefits start to fall by the BRR per dollar earned on the margin. For people who misperceive the kink for a notch, there is a perceived downward notch of $BRR \cdot B_0$ at the exempt amount. Note that, in this depiction, households who misperceive the Earnings Test correctly identify where the exempt amount, z^* is, and also understand that benefits are reduced in the short-run if they earn beyond this amount. This is consistent with Liebman and Luttmer (2012), who find that that 40% of survey respondents think benefits decrease, and the median respondent believes the exempt amount to be just

[4]Because the policy environment and data are similar to Gelber, Jones and Sacks (2020); Gelber et al. (2021, 2022), the corresponding sections of this paper have overlap with those previous papers.

[5]Social Security Administration (2012); Gruber and Orszag (2003).

below the actual threshold. We are not aware, however, of clear qualitative evidence on how large of a notch is misperceived, or whether individuals think the marginal tax rate changes as well. However, what is most important for our purposes is that some think a nontrivial notch is present.

3 Conceptual Framework

We begin by noting evidence that individuals tend to left-bunch across a variety of contexts. Kleven (2016) notes that a number of papers find more bunching below the threshold of a kink than above – citing the examples of Devereux, Xing and Maffini (2016), Gelber, Jones and Sacks (2020), and Seim (2017) – though none of these papers notes the left bunching themselves, and neither these papers nor Kleven (2016) explores left bunching further. These papers span the disparate contexts of corporate taxes in the U.K., earnings responses to Social Security in the U.S., and wealth responses to wealth taxes in Sweden. Other examples are plentiful, including Peng, Wang and He (2019), studying income taxes in China, Le Barbanchon (2016), studying unemployment insurance in the U.S., and Asatryan and Peichl (2017) studying Armenian firms. Moreover, we have not yet observed a context with significant right-bunching. However, in all of the left bunching cases above, the density is downward-sloping, leading to the question of whether the left bunching is due to the shape of the density in a standard model or due to non-standard factors like misperceptions.[6] In one notable exception, Anagol et al. (2025) find left-bunching in response to kink created by a VAT in South Africa in the presence of a relatively flat earnings density.

In this section, we sketch a basic framework that is helpful in interpreting left bunching and highlighting the types of underlying models that could generate this phenomenon.

3.1 Baseline Case

We start with a standard model of bunching in the presence of a kink, as in Saez (2010). In anticipation of our empirical application, we adapt the setting to incorporate features of the Earnings Test, where a convex kink is created by a reduction in current benefits, as opposed to the standard jump in marginal tax rates. As in Saez (2010), agents draw utility from consumption c and disutility associated with earning income z (i.e. the disutility of labor supply), captured by the function $U(c, z)$. These two outcomes are linked through the budget constraint:

$$c(z) = z - T(z) + B(z)$$

where the function $T(\cdot)$ represents the tax and transfer system, which we will assume is locally linear. The function $B(\cdot)$ represents the flow of current Social Security benefits and

[6] Other papers appear to find relatively symmetric bunching. Our conclusions in this paper do not appear to apply in such cases.

captures the earnings test:

$$B(z) = \begin{cases} B_0 & \text{if } z \leq z^* \\ \max\{0, B_0 - BRR \cdot (z - z^*\} & \text{if } z > z^* \end{cases}$$

In particular, current benefits are reduced at the benefit reduction rate (BRR) for every dollar earned above the exempt amount z^*, creating a kink in the budget set where the marginal return to earning an additional dollar falls discontinuously.

We abstract from the upward adjustment in future benefits at the Earnings Test threshold, mentioned above. Both awareness and responsiveness to this feature of the policy appear to be rare (Liebman and Luttmer 2012). In principle, this adjustment offsets the kink in current benefits and, if anything, generates incentives for right-bunching. For a given level of observed bunching and left-bunching, then, incorporating this additional component into our analysis would tend to result in larger elasticity estimates and/or a larger role for factors that result in left bunching.

We add one additional feature to the baseline case to better capture the reality of earnings data: diffuse bunching. Empirically, bunching at kinks tends to be humped-shaped, rather than a sharp mass point exactly as the kink (Kleven 2016), which could be due to a number of optimization frictions. Following Saez (1999), we model this with a two-step process. First, the agent chooses a level of earnings z, and disutility of earnings is realized. Second, the realized levels of earnings that determines the level of consumption, net of taxes and transfers, and benefit reduction will be $z + \epsilon$, where ϵ, a symmetrically distributed, mean zero shock, is an uncertain component of earnings.

We now can characterize the baseline maximization problem:

$$\max_z \int u(c(z+\epsilon), z) f(\epsilon) d\epsilon$$
$$\text{where } c(z+\epsilon) = z + \epsilon - T(z+\epsilon) + B(z+\epsilon)$$

As has been detailed in previous literature (Saez 2010; Kleven 2016), the kink in the budget set results in a set of agents who choose earnings at or near the kink, in response to the higher implicit marginal tax rate above the exempt amount. In this version of the model, the agent also takes into account the subsequent uncertainty represented by ϵ. Importantly, under this model, there is no inherent incentive for agents to bunch to the left of the kink, a result we will explore in more detail below. We note that our approach to modeling diffuse bunching shares similarities with that of Anagol et al. (2025). In their setting, agents choose a target earnings level, and then are faced with a sparse menu of earnings options that are offsets from that target level of earnings. Our model can be thought of as a sparse menu containing only one choice.[7] Importantly, their model also does not predict left-bunching

[7]We discuss other differences between our model and that of Anagol et al. (2025) in Appendix B.3.

when agents are responding to a kink.

3.2 Extensions to the Baseline Case

We now introduce a number of extensions to the baseline model that might induce asymmetric bunching near a kink. We begin with specific pattern of underling heterogeneity that may generate left bunching, and then explore behavioral sources of asymmetric bunching.

3.2.1 Downward sloping ability distribution

First, and most simply, we can generate the appearance of left bunching in the case where the distribution of earnings, even in the absence of a kinked budget set, is steeply downward sloping. This creates more mass to the left than to the right of any point on a downward-sloping portion of the earnings distribution. The pre-existing asymmetry in earnings in the absence of a kink combined with a relatively symmetric pattern of bunching once a kink is introduced will tend to result in left-skewed bunching.

3.2.2 Reference dependent preferences with loss aversion

Second, we consider the phenomenon of reference-dependent preferences, originally pioneered by Kahneman and Tversky (1979) and reviewed extensively by O'Donoghue and Sprenger (2018). Agents with reference-dependent preferences may exhibit loss aversion, where the disutility of losses, relative to a reference point, loom larger than equally sized gains. We can introduce this feature into our baseline model, and also incorporate the phenomenon of diminishing sensitivity, where the curvature of the gain-loss utility function differs on either side of the reference point. Reference-dependence has been related to bunching behavior in the setting of bunching in effort by marathon runners (Allen et al. 2017) and in the case of manipulation of reported taxable income (Rees-Jones et al. 2018). In the former case, diminishing sensitivity was shown to contribute to left-bunching. Reck and Seibold (2023) explore the complex welfare considerations that arise in the setting of tax policy with reference-dependent preferences.

We need a model that fits the particular empirical patterns in our setting. We have left-bunching at the onset of Social Security benefit reduction and thus need the "loss-domain" to be on the right side of the Earnings Test threshold. We therefore cannot use as a reference a general level of consumption or earnings—both are increasing as one passes through the Earnings Test threshold. It will also not suffice to posit a reference point of leisure, below which individuals enter the loss-domain, since the Earnings Test threshold represents a different, somewhat arbitrary level of leisure for each agent. What does decrease, commonly for everyone, as one crosses the exempt amount are Social Security benefits. Thus, we necessarily require a narrowly-bracketed version of reference dependence where the baseline level of Social Security benefits, B_0, is the reference point. Reductions of this benefit amount due to the Earnings Test then place the agent in the loss-domain. Relative to our baseline model above, the utility function now takes the following form:

$$u_{RD}(c(z), z) = u(c(z), z) + r\left(u(c(z), z) - u(c_0(z), z)\right)$$

where the function $r(\cdot)$ is a reference-dependent component of utility:

$$r(x) = \begin{cases} \lambda_G x^{\alpha_G} & \text{if } B(z) \geq B_0 \\ -\lambda_L(-x)^{\alpha_L} & \text{if } B(z) < B_0 \end{cases}$$

and

$$c_0(z) = z - T(z) + B_0$$

In other words, the so-called "gain-loss" component of utility compares actual utility to a reference point where labor supply and after-tax income are the same, but Social Security benefits are held fixed at their initial value of B_0. This is a version of the reference dependence modeled in Kőszegi and Rabin (2006). In general, when $\lambda_L > \lambda_G$, losses loom larger than gains, and we have loss aversion. In practice, benefits never exceed the reference level in our setting: there is only the possibility of benefit reduction. In that case, the so-called "gain domain" is not relevant, and whenever benefits are reduced, they adversely affect utility both through the standard utility function and the reference-dependent component. We therefore refer to this model as one with loss aversion preferences.

3.2.3 Tax bracket misperception

Finally, we consider the case where agents misperceive changes in marginal tax rates as changes in average tax rates. Survey evidence supports this view.[8] For example, Lyon and Catlin (2020) asked 1,131 Americans to consider the statement "If a person gets a raise that moves them into a higher tax bracket, they could end up taking home less money than they did before the raise because all of their income will be taxed at a higher rate." 74% of respondents said this was true. Sullivan (Forthcoming) reports similar results. Anagol et al. (2025) find evidence consistent with such misperception in the case of VAT in South Africa.

In the case of a kink in the budget set, tax bracket misperception implies that a discontinuous change in the marginal tax rate is mistaken for a discontinuous change in the *level*

[8] This case is related to but distinct from the "spotlighting" heuristic described by Liebman and Zeckhauser (2004). Under spotlighting, people assume their marginal price applies everywhere, so they believe for example that if health care is expensive in the deductible region, it will continue to be expensive if they spend through the deductible. They therefore do not think their choices change their marginal prices. Under bracket misperception, people think their choices change their marginal incentives, believing that if they change brackets, their marginal price changes along with their average price.

of tax liability. We represent this with a perceived benefit schedule $\hat{B}(z)$, defined as follows:

$$\hat{B}(z) = \begin{cases} B_0 & \text{if } z \leq z^* \\ (1 - BRR) \cdot B_0 & \text{if } z > z^* \end{cases} \tag{1}$$

Now, instead of reduction in benefits proportional to the marginal dollar, the agent believes a discrete fraction, BRR, of benefits will be loss when earnings exceed the exempt amount z^* by even a dollar. As explained in detail in Kleven and Waseem (2013), this induces a strong incentive for those just above the threshold to locate on the left side of the tax change. We denote the perceived after-tax income under mispercpetions as:

$$\hat{c}(z) = z - T(z) + \hat{B}(z)$$

3.3 Summary of Bunching Predictions

As a tool to visualize the incentives created by both the kink and uncertainty in earnings, as well as specific behavioral factors, we can make use of an effective budget set, as in Saez (1999). That is, we find the nonlinear tax schedule, $\tilde{T}(z)$, that generates the same optimal earnings decision as our more complicated optimization problem with potentially behavioral preferences, misperceptions, a budget set that features taxes, transfers, and Social Security benefits, and income uncertainty:

$$u\left(z - \tilde{T}(z), z\right) \equiv \int u\left(\hat{c}(z+\epsilon), z\right) + r\left(u\left(\hat{c}(z+\epsilon), z\right) - u\left(c_0(z+\epsilon), z\right)\right) f(\epsilon)\, d\epsilon$$

By plotting the effective budget set and comparing it to the actual budget, we can get a sense of how different features of the model—misperceptions of the budget set, non-standard preferences, uncertainty, and the like—might cause behavior to deviate from a standard model of bunching. This general model reduces to the baseline model when $\hat{B}(z) = B(z)$ and $\lambda_G = \lambda_L = 0$, which imply $\hat{c}(z) = c(z)$ and $r(\cdot) = 0$, respectively.

We now detail how the expected distribution of earnings varies as we introduce the various extensions to our baseline model. To illustrate our results, we carry out numerical simulations, featuring agents with a particular set of preferences, uncertainty in income, and perceptions of the budget set. We either assume a distribution of ability calibrated to match the age 61 earnings distribution in the absence of any kink, or, in one case, a downward sloping ability distribution, as discussed above. In each case, we include a set of agents (50 percent) who remain at their initial earnings in the absence of a kink. This captures the empirical facts that (1) some subset of agents appears to not be able to respond on the margin to kinks and or notches in budget sets, at least not in the near term (Chetty 2012; Kleven and Waseem 2013; Gelber, Jones and Sacks 2020). Additional details regarding our simulations are provided in Appendix B, and left- and right-bunching amounts are summarized in Appendix Table B.2.

Figure 2a plots the nominal, kinked budget set, driven by $T(z)$ and $B(z)$, along with the effective budget set implied by $\tilde{T}(z)$ for four cases of interest: (1) our baseline agent facing a kinked budget set and uncertainty in realized earnings $z + \epsilon$, (2) the same agent with the addition of loss aversion in the Social Security benefit, with parameters $\lambda_L = 0.25$ and $\alpha_L = 1$ (3) a modified loss-averse agent with diminishing sensitivity, i.e. $\lambda_L = 0.25$ and $\alpha_L = 0.8$, and (4) an agent with stronger loss-aversion and diminishing sensitivity, $\lambda_L = 0.8$ and $\alpha_L = 0.8$. Distributions of earnings for agents facing each of these four, effective budget sets are presented in Panels (b) through (e).

We begin with simulations from the baseline model. In all models, the effective budget has a less pronounced kink than the actual budget set, due to the uncertainty in income. This effectively smooths out any nonlinearities, since agents on the lower marginal tax rate side of the kink can end up on the higher marginal rate side, and vice versa, once earnings are realized. In Panel (b), we show the resulting distribution of earnings. There is diffuse bunching at the kink, with a skew toward right-bunching—only one-third of the excess mass lies to the left of the kink. We provide intuition for this phenomenon, earlier noted in Saez (1999), in Appendix B.2. If any of our alternative models below are to generate left bunching, they must more than compensate for this right shift.

We next simulate a set of models with loss aversion. Loss aversion magnifies the size of the kink by amplifying the benefit reduction rate. We start with a moderate amount of loss aversion in panel (c). In this case, bunching continues to peak to the right of the nominal kink, and furthermore, the distribution of earnings begins to taper off further to the right of the kink. A similar pattern emerges when we additionally introduce diminishing sensitivity in panel (d). In neither case do we recreate left bunching—again, no more than one-third of the excess mass is to the left of the kink. In a final case, we increase the bite of the loss aversion, while maintaining diminishing sensitivity in panel (e). As can be seen in the corresponding budget set in Panel (a), if loss aversion is strong enough, it can bend the budget set backward. In this case, there is enough incentive to generate modest left-bunching in panel (e)—left bunching is between 59 and 67 percent of excess mass, depending on whether a polynomial or counterfactual distribution is used to measure excess mass. Overall, however, loss aversion does less in the immediate neighborhood of the kink than it does further beyond the kink, once a significant amount of the benefit has been clawed back. The most noticeable effects involve missing mass further to the right of the kink, but in the most extreme case, a slight amount of left-bunching is observed.

In the final panel of Figure 2, Panel (f), we return to our baseline model, but instead assumed a steeply downward sloping counterfactual earnings distribution. This model also results in a slight left-bias in bunching, but a relatively steep decline in counterfactual earnings is needed to generate this outcome. Even in that case, just over 50 percent of bunching is left of the kink. Such a model is less able to explain the left-bunching we will observe, especially in cases where the counterfactual earnings distribution appears to be relatively flat.

Our final model of left bunching is a model of tax bracket misperception, so that the effective budget set here falls discontinuously at the kink point. We plot the effective budget for such an agent in Panel (a) of Figure 3. We plot a corresponding earnings distribution in Panel (b), which features a mix of inert agents (50%), agents who respond to a kink (20%), and a set who perceive a notch (30%). The distribution now features a disproportionate amount of bunching to the left of the earnings threshold z^*—essentially all of the excess mass is to the left of the threshold, regardless of the counterfactual used. There are two forces that generate this result. First, the drop in after-tax-and-transfer income perceived at the threshold generates asymmetric incentives to locate to the left of the Earnings Test exempt amount. Second, the notch generates a dominated region of earnings where reducing labor supply results in an *increase* in consumption. The earnings distribution for those perceiving a notch will feature a hole, or missing mass within this region. The bunching to the right of the Earnings Test exempt among those who only perceive a kink (See Figure 2, Panel (b)) will be mixed with this missing mass, further driving the appearance of asymmetric bunching. This can be seen in Panel (b) of Figure 3, where the ex-post distribution lies below the counterfactual one as one moves to the right of the Earnings Test exempt amount.[9]

To summarize, while not all of our alternative models result in left-bunching, we do have at least three cases that have the potential to result in left-bunching: downward sloping density, strong loss aversion, and tax bracket misperception . In the next section, we explore additional moments that may aid in deciding between these candidate explanations.

3.4 Distinguishing between models with extensive margin responses

Thus far, we have presented multiple models that might generate left bunching. To distinguish among these models, we turn to an additional outcome: extensive margin behavior, i.e. the decision to work or not. We generate extensive margin responses by introducing a heterogeneous fixed cost of working, say q. Our key result is that tax bracket misperception, along with intensive margin frictions, implies an extensive margin response at the the kink point z^*, i.e. a discontinuous drop in employment among workers who would have earned just above z^* in the absence of the Earnings Test. Our other models, alone or in combination with frictions, do not generate comparable patterns. A model with loss aversion or a model with a steep downward earnings distribution does not generate a discontinuous jump in exit because in each case continuity of the *level* of after-tax-and-transfer income is preserved. In that case, earning just above the exempt amount is preferred to exiting for those who would like to bunch, but cannot.

Here we present the basic setup and intuition. Appendix C contains a model and formal statements. The model extends Saez (2010) to accommodate frictions and extensive margin responses.[10] The intuition is as follows. Introduce a kink at z^*, where the effective marginal

[9] This missing mass also emerged in Panel (e) of Figure 2, where strong loss aversion and diminishing sensitivity similarly resulted in a dominated region.

[10] The material presented here on extensive margin responses to notched budget sets was originally presented

tax rate increases from τ to $\tau + BRR$. Consider an individual with baseline earnings (i.e., earnings under τ) that are close to, but above z^*, say $z = z^* + dz$. This individual will want to adjust their earnings, and they can do so on the extensive margin—drop out of work entirely—or on the intensive margin. Which do they choose? In the absence of both tax bracket misperception and intensive margin frictions, they will adjust on the intensive margin, to z^*. This is because if their baseline earnings are near z^*, they are roughly indifferent between that and z^* (by the envelope theorem), and so incur no welfare loss by adjusting on the intensive margin. But dropping out of employment does involve a first order loss, except in the probability zero case that they were indifferent between working and not.[11] Thus, in the absence of either adjustment frictions and tax bracket misperception, we do not get an extensive margin response.

Now let us introduce adjustment frictions, so that the individual cannot adjust their earnings to exactly z^* without incurring some cost. With a discrete adjustment cost, those very near to z^* will not find it worth it to make a small move to z^*. However, these agents will also not choose an extensive margin response, because the kink changes their utility by $BRR \cdot dz$. Since dz is small, this utility loss is small, whereas, again, exiting employment entails a large utility loss with high probability. So adjustment frictions alone do not generate an extensive margin response.

Finally introduce tax bracket misperception, so that the individual perceives the kink as a notch. In the absence of intensive margin frictions, they will adjust to just below z^* instead of exiting employment—that is, they will left bunch—because they continue to prefer intensive adjustment to exit. However, with intensive margin frictions, adjustment to z^* is costly. On the other hand, remaining just above the threshold z^* now entails a first-order cost, because a perceived notch reduces consumption by $BRR \cdot B_0$. Either way, the notch introduces a first-order cost for those just above z^*, and there is now a positive probability that they prefer exiting employment to making a costly adjustment or remaining at their baseline earnings.

Thus, tax bracket misperception and intensive margin frictions combine to generate both left bunching and extensive margin responses, even among those with desired earnings near z^*. Other models of left bunching do not generate these local extensive margin responses, because they imply that the welfare cost of the kink is proportional to one's distance to z^*, and so extensive margin adjustment is not optimal.

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in Gelber et al. (2017), but has not been published previously. Gelber et al. (2021) considers extensive margin responses to *kinked* budget sets, and Kleven and Waseem (2013) considers *intensive* margin responses to notched budget sets.

[11] The probability here and in the following paragraphs is with respect to the distribution of fixed cost of working. When we say probability zero here, we mean there is zero probability that their fixed working cost is exactly equal to their utility gain from entering employment.

4 Data

We use data derived from the IRS population files. These collections of tax returns go back to 1999 and contain all information returns as well as income tax returns. We supplement the IRS files with birth and death information from Social Security's Death Master File. We start with a 100 percent extract of all people with a social security number, born between 1939 and 1953, limited to ages 60-64, with at least one year of positive earnings (necessary for defining our running variable). We focus on 1939-1953 birth cohorts because these are the cohorts for which we can construct a balanced panel of earnings between ages 60 and 64, i.e two years before and after age 62, when claiming Social Security is first possible.

The resulting sample, which we call the full sample, consists of 33.4 million people. In our main analyses, we limit the sample to people with no self-employment income at age 61. We limit the sample this way because self-employed people can more easily manipulate reported income, and we want to avoid confounding our estimates of labor supply behavior with income reporting behavior. The resulting main sample consists of 31 million people.

We construct several variables from these data, including age in each year as of December 31 and an indicator for being identified as female in the the Death Master File. We also observe several key outcomes related to retirement. In addition, we have several measures of annual income. Our primary measure is total W2 income, as reported across all employers. We measure self-employment earnings as total Medicare-taxable earnings reported on Schedule SE. We observe Old Age and Survivor's Insurance (OASI) income, and (separately) Social Security Disability Insurance (DI) income.

There are a number of notable strengths of our data set. First, our earnings measures are administratively collected and not subject to the type of reporting error found in survey data. Second, our primary earnings measure is simply W2 income (not including self-employment income), which is reported by a third party and cannot be manipulated by claiming deductions. Variation in this measure therefore likely reflects true earnings variation and not reporting effects. Third, our sample consists of a balanced panel of people *ever* in the tax system. We do not drop observations with zero income, for example, nor do we condition on filing an information return. We therefore do not select a sample on the basis of reported income. Of course our data also limitations. Like most administrative data sets in the US, we observe only what is reported to the administrator (in this case, IRS), and we do not observe total wealth and we lack many covariates such as education.

We report summary statistics on person-level variables in Table 1, and we report summary statistics of time-varying variables by age for the main sample in Table 2. Half the sample is identified as female, the average claim age is about 62.3,[12] and about a 8 percent of our main sample ever has self-employment income. Earnings and (especially) the probability of having any earnings fall with age. DI income is relatively rare, with 3–7 percent of the

[12] It is possible for a person to have Social Security income at ages younger than 62 because they may be claiming as a surviving beneficiary.

sample having any. OASI income is rare until age 62 and then becomes common; a quarter of the sample has some OASI income at age 62 and 43 percent has some at age 64.

5 Empirical Results

5.1 Left bunching is substantial

We begin our empirical analysis by documenting in Figure 4 left bunching at the Earnings Test Exempt Amount. The figure plots the distribution of income relative to the exempt amount, by age, for ages 60, 62, 63, and 64. As a comparison we overlay the age 61 earnings distribution in gray. At ages 60 and 61, before anyone is eligible for OASI, the earnings distribution is smooth and slightly upward sloping. The two earnings distributions are nearly identical, and no bunching is apparent.

There is clear excess mass around—and especially below—the exempt amount at ages 62, 63, and 64. Beginning about $4,000 below the exempt amount, the distribution starts to rise, relative to both its initial values and the age 61 level. The distribution then falls discontinuously above the exempt amount. There is clearly more mass just to the left of the exempt amount than just to the right. We note that, although the density drops off discontinuously above the exempt amount (especially at ages 63 and 64), there is otherwise not a strong trend in the density, and therefore it is unlikely that a downward sloping density drives the observed left bunching. Indeed the age 60 and 61 densities are actually slightly upward sloping over this range.

Quantifying left bunching—or right or total bunching—requires measuring excess mass relative to some counterfacutal density. Early approaches to measuring bunching calculated counterfatual densities by estimating a smooth polynomial using data away from the exempt amount, and interpolating near the exempt amount (Chetty et al. 2011*a*; Kleven and Waseem 2013; Kleven 2016). We show such a smooth fit as the black line in Figure 4. We exclude observations within $4,000 of the exempt amount. Given this counterfactual earnings distribution, it is straightforward to calculate left and right bunching as the actual fraction of observations in the excluded region (below or above the threshold), less the predicted value from the smooth fit. We report left and right bunching in Table 3. We estimate essentially zero left bunching at age 60, 1.8 percent at age 62, and over 4 percent at ages 63 and 64. We estimate zero or negative right bunching at all ages. Left bunching is statistically significant at ages 62-64. [13] Right bunching is near zero (and statistically insignificant), and significantly lower than left bunching.

Although it is standard in the literature to estimate a counterfactual density using polynomial interpolation, recent research has cautioned against it. Blomquist et al. (2021) point out that any interpolation or extrapolation ends up identifying bunching in part form functional form assumptions, and in general bunching amounts and preference parameters such

[13] We estimate standard errors using the bootstrap procedure of Chetty et al. (2011*b*), resampling residuals.

as elasticities are not identified from a single cross-section. Echoing this argument, Bertanha, McCallum and Seegert (2023) show how to use mild assumptions on the distribution of heterogeneity to restore identification. The problem both papers identify is that, in general, a single cross-section does not let us separate the distribution of heterogeneity from bunching responses except with some restrictions—we cannot be sure how much bunching would be present absent a kink.

An alternative to the polynomial method is to use data on earnings distributions absent a kink as a proxy for the counterfactual. In particular, we draw on the age 61 income distribution. We plot this distribution as gray circles in Figure 4. Our functional form assumptions appear to be innocuous: there is little slope, let alone nonlinearities, in the age 61 earnings distribution. When we calculate bunching using the age 61 earnings distribution as the counterfactual (last two columns of Table 3), we continue to find substantial left bunching at ages 62-64. We acknowledge that this counterfactual is only valid if underlying ability distributions do not change too much from year to year and if there are no extensive margin responses to the Earnings Tests—both assumptions that are likely to be violated in this context, at least to some extent. Nonetheless, we view this as a useful check on the functional form assumptions implicit in our polynomial approach. In addition, we are reassured by the fact the earnings distribution is largely constant from one year to the next, when comparing ages 60 and 61 in Panel (a) of Figure 4. Our identifying assumption, then, would be that in the absence of the Earnings Test, the distribution would be similar to the age 61 distribution. Overall, we find visually clear evidence that left bunching is substantial, especially relative to right bunching. Quantitatively, we estimate large amounts of left bunching and small amounts of right bunching across a range of possible counterfactual densities.

5.2 There is an extensive margin response at the kink

The results so far show clear left bunching, which is inconsistent with standard models of bunching, but could be rationalized either with tax bracket misperception, or with "strong" enough loss aversion, or a steeply downward sloping counterfactual earnings distribution, as shown in Section 3.3. The key to distinguishing these explanation is the extensive margin response: tax bracket misperception, in the presence of earnings frictions, implies that employment responds discontinuously to the perceived notch in the budget set, while loss aversion does not.[14]

We therefore investigate how employment at ages 62–64 varies with age 61 earnings. Figure 5 plots the probability of employment (i.e. positive earnings) at ages 62, 63, and 64, given age 61 distance to the exempt amount. The idea behind this plot is that earnings at age 61 are a good proxy for earnings at age 62 and beyond in the absence of the Earnings Test

[14]Standard models imply an employment response as well, but not a discontinuity, see Gelber et al. (2021), Gelber et al. (2022), and Appendix C.

kink (in part because not everyone can easily adjust their earnings from on year to the next, Gelber, Jones and Sacks (2020)). People with age 61 earnings just above the exempt amount are "treated" in the sense that they are subject to the Earnings Test if they do not adjust their earnings. People with age 61 earnings just below the exempt amount likely have similar employment propensities but are "untreated." Thus, this plot can give a clean indication of the effect of the Earnings Test on employment among people with age 61 earnings close to the exempt amount. A kink and a discontinuity are both evident in the plot, although the discontinuity appears small.

We quantify the discontinuity by estimating regression discontinuity models of the following form:

$$\mathbf{1}\left\{z_{i,a} > 0\right\} = \beta_0 + \beta_1(z_{i,61} - z^*) + \beta_2 \mathbf{1}\left\{z_{i,61} > z^*\right\} + \beta_3(z_{i,61} - z^*) \times \mathbf{1}\left\{z_{i,61} > z^*\right\} + \varepsilon_{i,a} \tag{2}$$

The outcome is an indicator for positive earnings at age a, and the running variable is age 61 earnings relative to the exempt amount, z^*. We estimate the model separately for ages 62, 63, 64, and 63-64 pooled, using using the Calonico, Cattaneo and Titiunik (2014) optimal bandwidth (hereafter the "CCT-optimal bandwidth"). We do not expect employment responses at age 62 because our employment outcome is an indicator for having no earnings for the entire year, and whole-year responses would not manifest until people have claimed OASI for an entire year, which is not possible at age 62. In general, we would expect the discontinuity to grow with age as OASI claiming increases.

Table 4 presents the results of our regression discontinuity specifictation in equation (2). At age 62, we estimate an insignificant discontinuity of -0.2 percentage points. This grows to -0.3 percentage points at ages 63 and 64, which is statistically significant at each age and when pooled. The estimated discontinuities are fairly similar across a range of specifications, which vary the degree of the polynomial (linear or quadratic), the kernel (uniform or triangular), and the inclusion of additional controls; see Appendix Table A.1. Thus, we find statistically significant discontinuities in employment. Consistent with fairly small discontinuities, the plots in Figure 5 show only slight drops in earnings above the exempt amount.

The extensive margin response we document here is distinct from prior evidence because the response here is a discontinuity, driven by people earning right at the exempt amount. We find a small but visible and statistically significant response. This discontinuity is notable because people earning exactly at the exempt amount do not face higher work disincentives than people earning just below the exempt amount, so in models without misperception, we would expect no discontinuity.[15] Prior work on the extensive margin response to the Earnings Test has looked at a broader population earning significantly farther above the exempt amount, and thus facing greater benefit reduction, and found correspondingly larger responses (Gruber and Orszag 2003; Gelber et al. 2021, 2022).

[15] We establish this result formally in Appendix C.

6 Misperception explains a meaningful share of left-bunching

We have shown that some amount of left bunching is due to bracket misperception, because bracket misperception predicts a downward discontinuity in employment at the exempt amount, but other models of left bunching do not. This evidence does not yet indicate how much left bunching is due to misperception. Careful quantification of the role of different factors in explaining left bunching would require specifying and estimating a rich structural model, a task beyond the scope of this paper. However, we provide here a calibration-based argument in two steps. First, we place a lower bound on the share of agents who misperceive the kink as a notch, and, secondly, we use this to establish a lower bound on the amount of left bunching due to bracket misperception. Even under conservative calibrations, implying a small rate of misperception, we find that bracket misperception drives a large a share of left bunching, because notches generate very large bunching amounts.

6.1 Model set-up

We consider a model in which a fraction π of the population misperceives the earnings test kink for a notch. Our goals are to place a lower bound on π and to use this bound to derive a lower bound on the share of left bunching from misperceivers. We build on the standard model of bunching (Saez 2010; Kleven 2016), but add intensive margin adjustment cost and an extensive margin response, as these elements are necessary for an extensive discontinuity. In this section we abstract from imperfect control of earnings for expositional purposes. Full details and derivations of our results are in provided Appendix C, and we summarize the main details here in the text.

Individuals derive utility from consumption c and earnings z, given ability n and a fixed cost of work q:

$$u(c, z; n) = v(c, z; n) - q_n \cdot \mathbf{1}\{z > 0\}. \tag{3}$$

The fixed cost of work generates non-trivial extensive margin responses (Cogan 1980; Gelber et al. 2021). We assume $q_n \sim G_n$, with G_n twice continuously differentiable. Denote v_0 as the outside value, utility received when not working. Then the probability of working is then:

$$\begin{aligned} \Pr(z > 0|n) &= \Pr(v(c, z; n) - q_n > v_0) \\ &= \Pr(q_n < v(c, z; n) - v_0) \\ &= G_n(\bar{q}_n) \\ \text{where: } \bar{q}_n &\equiv v(c, z; n) - v_0 \end{aligned} \tag{4}$$

In the absence of the earnings test, individuals face a constant linear tax τ and receive an annual Social Security benefit of B_0. Under bracket misperception, individuals make earnings choices as if the earnings test creates a notch in their budget set, which they perceive to be

$BRR \cdot B_0$. That is, we assume bracket misperception takes the form of believe that the benefit reduction rate applies to their benefit, once their earnings exceed z^*. We focus on this form because it is consistent with a psychology in which people are aware of a 50 percent benefit reduction. Other forms are possible and our reduced form results do not differentiate between alternative misperceptions that generate notches. The exact form of the misperception does not matter for bounding the share of bracket misperceivers, as we explain below, but it does matter for calculating the amount of left bunching due to misperceptions. We denote by $\tilde{z}_{n0}$ individuals optimal earnings in the absence of the earnings test, conditional on working. We index individuals by this earnings amount, since it is isomorphic to ability n. Earnings under the earnings test are z_{n1}. Upon facing the earnings test, individuals can maintain their earnings at $\tilde{z}_{n0}$, drop out of employment, or adjust to a positive earnings level at a cost of ϕ.

6.2 Bounding the misperception share from the extensive margin discontinuity

We use the extensive margin discontinuity to learn about the misperceiving share, denoted by π, because only misperceivers contribute to the extensive margin discontinuity. Actually estimating π requires a fully-specified structural model, beyond the scope of this paper. Instead we focus on placing a lower bound on π.

Consider individuals with $\tilde{z}_{n0} \approx z^* + dz$, for some small $dz > 0$, i.e. with desired earnings just above the exempt amount. These individual's extensive margin responses to the earnings test, relative to those just below z^*, determine the magnitude of the extensive margin discontinuity. An individual can react to a perceived kink at z^* in three ways: they can adjust to below the perceived notch (left bunching at z^*) at an adjustment cost of ϕ, they can continue to earn $z^* + dz$, or they can drop out of employment. As long as adjustment costs are smaller than the downward notch at z^*—the realistic case we will focus on in our calibration—they will always prefer adjusting to z^* to remain at $\tilde{z}_{n0}$. Remaining employed, however, now requires that they pay an adjustment cost, a utility loss of ϕ.

Thus the perceived notch creates an additional cost of working, but this cost is given by the cost of adjusting to z^*, not by the size of the notch.[16] This cost reduces the perceived returns to working—the average net-of-tax-and-transfer rate—from $(1-\tau)$ to $(1-\tau-\phi'/z^*)$, or a percent change of $(-\phi'/z^*)/(1-\tau)$, where $\phi' \equiv \phi/\lambda$ is the dollar equivalent of the utility cost of adjustment. Lower returns to working produce lower employment, with a magnitude that depends on the extensive margin elasticity, η, the elasticity of employment with respect to the average net of tax rate. Building on our results in Appendix C, the discontinuity in

[16] This is true for people with z_{n0} near z^*, for whom there is no first-order welfare cost of earning z^* instead of z_{n0}. For people with higher earnings, the imposed cost of work is larger, but those very close to z^* are relevant for the discontinuity. We return to the more general case below.

employment at z^* is therefore:

$$\hat{D} = \pi \cdot \eta \cdot \left(\frac{-\phi'/z^*}{1-\tau} \right) \cdot Pr(z_{n1} > 0 | \tilde{z}_{n0} = z^*). \tag{5}$$

We scale by π because only misperceivers contribute to a discontinuity in employment at z^*. Rearranging, we have an expression for the misperceiver share:

$$\pi = \frac{\hat{D}}{\eta \cdot Pr(z_{n1} > 0 | \tilde{z}_{n0} = z^*)} \left(\frac{-\phi'/z^*}{1-\tau} \right)^{-1}. \tag{6}$$

This expression is intuitive. A given discontinuity is generated by a misperceiving share π and by a response among misperceivers, equal to the elasticity times the percent change in the average net-of-tax-and-transfer rate. Therefore the amount of misperceivers is increasing in the observed discontinuity and decreasing in the extensive margin elasticity times the change in return to work. Notice also that this formula does not depend on bunching or intensive margin elasticities. We can learn about misperceiving shares without using information on left bunching.

Applying equation 6 requires information on an extensive margin discontinuity, taxes below z^*, the employment rate at z^*, an extensive margin elasticity, and an adjustment cost. We observe a discontinuity of about 0.0035 with a 95% confidence interval of (0.0007, 0.0052). We set $\tau = 0.25$ (accounting for payroll taxes and state and local taxes), and we observe in Figure 5 an employment rate of approximately 0.7. We lack any direct estimates of the extensive margin elasticity, so we turn to a bounding approach. Specifically, we recover π under a large value of η, 1.0. We view this as a conservative upper bound on η and, hence, a lower bound on π, because Chetty (2012) finds extensive margin elasticities around 0.25, and his confidence interval rule out extensive margin elasticities above 0.72. Although we do not estimate adjustment costs here, we can draw on previously estimated adjustment costs of \$280 for this population (in a framework that ignored misperception, Gelber, Jones and Sacks (2020)). We report results for this adjustment cost and for adjustment costs of \$160, representing one percent of earnings at the threshold (consistent with Chetty (2012)).

We report the implied misperception shares in Table 5. At our main estimate, we find misperception shares of 23-40 percent, depending on the assumed adjustment cost. At the lower bound of our 95% confidence interval, we still find shares of 5 to 8 percent. Even small extensive margin discontinuities are consistent with substantial misperception rates because misperception does not generate large extensive margin responses, as few misperceivers are on the margin of dropping out of employment.

6.3 Quantifying left bunching due to misperception

Next, we turn to quantifying the amount of left bunching from people who misperceive the exempt amount. Setting aside extensive margin responses for the moment, bunching with a notch is determined by an iso-utility condition: the marginal buncher, with earnings $z^* + \Delta z^N$, is indifferent between adjusting to the notch point or locating on the upper budget segment. Total bunching is therefore:

$$B^N = \int_{z^*}^{z^* + \triangle z^N} h_0(z) dz, \tag{7}$$

where h_0 is the density of earnings under a linear tax.[17] As was the case in our simulation in Section 3.3, we assume all of this bunching is left-bunching. The bunching amount can be calculated once one knows the location of the marginal buncher $z^* + \triangle z^N$, which depends on preference parameters such as intensive margin elasticities. Estimating these parameters is beyond the scope of this paper, and thus we turn to a bounding exercise.

As explained in Kleven and Waseem (2013), a notch creates a "dominated region" of earnings resulting in consumption below the level associated with the notch point. We refer to this region as $[z^*, z^* + \triangle z^D]$, and illustrate it in Figure 1. The dominated region is determined by the notched budget set alone, not preference parameters. Given our assumption about misperception, $\triangle z^D = (1 - BRR) B_0 / (1 - \tau)$. For any utility function, the marginal buncher, i.e. the agent with counterfactual earnings at $z^* + \triangle z^N$, always has earnings outside the dominated region, i.e. $\triangle z^N \geq \triangle z^D$. Therefore, in the absence of adjustment frictions and extensive margin responses, we have a lower bound on bunching in response to a notch that can be calculated without estimating any preference parameters:

$$\begin{aligned} B^N \geq & B^D \\ \equiv & \int_{z^*}^{z^* + \Delta z^D} h_0(z) dz \\ = & H_0(z^* + \Delta z^D) - H_0(z^*) \\ \approx & h_0(z^*) \Delta z^D \\ = & h_0(z^*) \frac{(1 - BRR) B_0}{1 - \tau} \end{aligned}$$

This bound ignores extensive margin responses, which tend to reduce bunching because some participants will prefer to dropping out to bunching. We now extend the model to account for extensive margin responses. Consider an agent with counterfactual earnings, in the absence of the Earnings Test, $\tilde{z}_{n0} \in [z^*, z^* + \triangle z^D]$. Denote $v(c_0(\tilde{z}_{n0}), \tilde{z}_{n0}; n)$ as utility, conditional on working and net of entry costs, q_n, for this agent, in the absence of the Earnings Test or perceived notch. Likewise, denote $v(c_1(z^*), z^*; n)$ as the corresponding utility level, net of adjustment costs, ϕ, and entry costs, q_n, if the agent were to bunch at z^* after the Earnings Test is introduced. We show in Appendix C.6 that, conditional on $\tilde{z}_{n0}$, the reduction in employment, i.e. the percent of agents that exit instead of bunching, will

[17] This density is in turn determined by the density of ability n.

be:

$$\begin{aligned}\frac{\triangle \Pr(z_{n1} > 0|\tilde{z}_{n0})}{\Pr(z_{n1} > 0|\tilde{z}_{n0})} =& \eta \cdot \left(\frac{-\phi'/z^* - \triangle_\lambda v(\tilde{z}_{n0})/z^*}{1-\tau}\right) \\ \text{where:}& \\ \phi' \equiv& \phi/\lambda \\ \triangle_\lambda v(\tilde{z}_{n0}) \equiv& \frac{v(c_0(\tilde{z}_{n0}), \tilde{z}_{n0}; n) - v(c_1(z^*), z^*; n)}{\lambda} > 0\end{aligned} \tag{8}$$

and λ is the marginal utility of consumption, thus converting utils into money metrics. Intuitively, the employment reduction equals the extensive margin elasticity multiplied by the effective percent change in the average net-of-tax-and-transfer rate.[18] To get the percent change for everyone in the dominated region, we integrate this expression over the range $[z^*, z^* + \triangle z^D]$.

Accounting for extensive margin responses, our lower bound on bunching from bracket misperceivers is:

$$\begin{aligned}\underline{B} =& \pi \cdot h_0(z^*)\triangle z^D \cdot \left(1 - \int_{z^*}^{z^*+\triangle z^D} \frac{\triangle \Pr(z_{n1} > 0|\tilde{z}_{n0})}{\Pr(z_{n1} > 0|\tilde{z}_{n0})} d\tilde{z}_{n0}\right) \\ =& \pi \cdot h_0(z^*)\frac{(1-BRR)B_0}{1-\tau} \cdot \left(1 - \int_{z^*}^{z^*+\triangle z^D} \eta \cdot \frac{-\phi'/z^* - \triangle_\lambda v(\tilde{z}_{n0})/z^*}{1-\tau} d\tilde{z}_{n0}\right)\end{aligned} \tag{9}$$

To implement this bound, we require knowledge of benefits B_0, an estimate of $h_0(z^*)$ (the density of earnings at z^*), as well as the average extensive margin response. We calculate the average $z^* + \Delta z^D$ amount among 63-64 year-olds in the 2020 release of Social Security's Benefit and Public Use file (U.S. Social Security Administration 2025), limiting the sample to people with age 61 earnings less than \$50,000 (for whom bunching is a realistic possibility).[19] This average is the appropriate way to account for heterogeneity (Kleven and Waseem 2013; Kleven 2016). Figure 4 indicates $h_0(z^*) \approx 0.02/\$500$. For the average extensive margin response, we calculate $\triangle_\lambda v(\tilde{z}_{n0})$ assuming a quasilinear utility function, and use the 2020 BEPUF, among people with earnings in the dominated region. We assume an extensive

[18] Compared to the employment reduction in equation (5), this expression features a larger reduction in the net-of-tax-and-transfer rate: $-\phi/z^* - \triangle_\lambda v(\tilde{z}_{n0})/z^*$, because this expression applies to agents throughout the dominated region, including those not near z^*. For those just above z^*, $\triangle_\lambda v(\tilde{z}_{n0}) = 0$, and we recover the earlier expression.

[19] We rely on these data because the tax data do not contain adequate benefit information. They contain information on benefits received, but these benefits are potentially reduced because of the earnings test. The relevant measure of b is the benefit in the absence of the earnings test. We calculate this in the BEPUF using the recorded primary insurance amount and adjusting for claim age. We calculate that on average, benefits are exhausted at an earnings level \$13,754 above the threshold for this sample, ignoring auxiliary beneficiaries. The 2020 BEPUF is a synthetic data set released by SSA, containing synthetic data representing a 10 percent sample of Social Security beneficiaries, as of December 2020. It is useful for us because it contains microdata on benefit amounts. It is limited because it contains synthetic data, based on draws from statistical distributions modeled on real values. As our interest is calculating an average of a function of benefit amounts, we believe this limitation is not substantial in our case.

margin elasticity of 1 (consistent with our approach for π) and an intensive margin elasticity of 0.25.[20]

We report the average extensive margin response and minimum bunching amount from bracket misperceivers in columns 2 and 3 of Table 5. The extensive margin response is about 8 percent regardless of adjustment cost. Our bounds on bunching are sensitive to the calibration parameters (the value of the extensive margin response and the intensive margin adjustment costs). At our lower bound, the minimum bunching amount from misperception is 1 to 3 percentage points. This number means that between 1 and 3 percent of our sample overall both left bunches and experiences bracket misperception. We find that misperception can explain a substantial share of overall left bunching, as overall left bunching is 1.8–6.2 percent.[21] First, tax bracket misperception produces a small discontinuity, since most people prefer to bunch than to drop out. Second, even a small misperception share can generate a large amount of bunching because notches produce very large bunching responses.

7 Adjusting elasticity estimation for misperception

When bunching is generated by bracket misperception, elasticity estimates that assume agents correctly perceive a kink will be biased. Here we provide a method to recover elasticity estimates in the presence of bracket misperception. Our method relies on four strong assumptions that are likely to be violated in practice, but we believe it provides a useful starting point for researchers looking to debias estimated elasticities. In the following example, we assume a standard kinked tax scheduled, with marginal tax rate τ below an earnings threshold z^* and a higher marginal tax rate of $\tau + d\tau$ thereafter. We assume that bracket misperception consists of perceiving a pure notch of of $d\tau \cdot z^*$ at z^*, with no change in the perceived marginal tax rate. Other forms of misperception are straightforward to accommodate.

Our first assumption is that there is a known fraction π of the population that misperceives the kink for a notch. In the absence of other frictions—our second assumption—overall bunching is:

$$B = \pi \int_{z^*}^{z^*+\triangle z^N} h_0^N(z)dz + (1-\pi)\int_{z^*}^{z^*+\triangle z^K} h_0^K(z)dz, \tag{10}$$

where $z^* + \triangle z^N$ is the counterfactual earnings of the marginal buncher among misperceivers and $z^* + \triangle z^K$ is the cutoff among non-misperceivers, and h_0^N and h_0^K are the corresponding counterfactual earnings distributions. As both cutoff earnings levels depend on the intensive margin elasticity, this expression gives us a way to recover elasticities from bunching, given π and an observed amount of bunching, B.

[20] Further details regarding the calculation of $\triangle_\lambda v(\tilde{z}_{n0})$ under quasilinearity are provided in Appendix C.6.

[21] In fact at our point estimates, left bunching is more than fully explained by misperception. However given the uncertainty in our estimates, we cannot reject that left bunching is fully (and not more than fully) explained by bracket misperception. To see this, note that delta-method type arguments imply that the standard error on $\underline{B}$ is proportional to the standard error on our estimated discontinuity.

To make progress, we invoke our third assumption, that misperceivers and and non-misperceivers have the same earnings distribution and utility function, and that utility function is iso-elastic and quasi linear, $v(c, z; n) = c - (n/(1 + 1/\varepsilon)) \cdot (z/n)^{1+1/\varepsilon}$. Then cutoff earnings levels for non-misperceivers is the standard expression (Saez 2010):

$$z^* + \triangle z^K = z^* \left(\frac{1-\tau}{1-\tau-d\tau} \right)^{\epsilon}.$$

The cutoff earnings level for misperceivers is defined implicitly by an indifference condition for the marginal buncher, who is indifferent between bunching at z^*, or remaining at their initial earnings level (Kleven and Waseem 2013). That condition can be written as:

$$u\left((1-\tau)z^*, z^*; n^* + \triangle n^N\right) = u\left((1-\tau)(z^* + \triangle z^N) - d\tau z^*, z^* + \triangle z^N; n^* + \triangle n^N\right).$$

where $n^* + \triangle n^N = (z^* + \triangle z^N)/(1-\tau)^{\varepsilon}$. We can solve for $\triangle z^N$ using numerical methods. This gives us both $\triangle z^K$ and $\triangle z^N$ as functions of ε. Our fourth and final assumption is that the distribution H_0, and by extension, the density $h_0(z)$, is known or can be estimated. With these assumptions, we can recover ε by numerically finding the value of ε that makes equation (10) hold.

We illustrate the approach in Table 6. Each row in the table corresponds to a differently sized kink. We assume that the analyst observes a bunching amount that corresponds to a frictionless, optimizing elasticity of 0.25.[22] We report the corrected elasticity assuming misperception shares of 5 and 10 percent. The bias can be large even for small π, it is increasing in π, and at least in this example, it is decreasing in $d\tau$.[23]

8 Conclusion

Using administrative data on earnings, we perform a systematic exploration of the puzzling left bunching phenomenon that has been noted across a number of economic contexts. In our setting—the kink created by the Social Security Earnings Test—we find that left bunching cannot be explained through standard reactions to incentives. Instead, we find that tax bracket misperception explain the data well, accounting for both the intensive and extensive margin responses. We have shown several patterns that are consistent with a model of tax bracket misperception at this kink: the existence of left bunching, the observation of left bunching even with an earnings distribution that is nearly flat, and the downward discontinuity in employment at the exempt amount.

[22] In each scenario, we set the lower tax rate to 10 percent and the threshold to $20,000, and we assume a uniform counterfactual earnings density of 0.0004 (roughly our empirical value).

[23] This exercise abstracts from the frictions that generate diffuse bunching. In that case, more attention must be paid to fact that bunching to the right of the kink will be combined with missing mass from misperceivers, confounding estimation. One approach to overcome that is to specify the share, θ, of kink bunchers that left bunch, and then use only observed left-bunching to recover the elasticities with a slightly amended formula: $B_L = \pi B^N + (1-\pi) \cdot \theta \cdot B^K$.

Our findings have two key implications. First, for Social Security claimaints, the misperception of the Earnings Test can be a costly one. For one, the true policy features a notch with a discontinuous *increase* in Social Security benefits at the exempt amount equal to 0.55 percent of benefits after reaching Normal Retirement Age. Beneficiaries are therefore leaving substantial "money on the table" by locating just below the exempt amount. Thus, tax bracket misperception that we document is a misperception of the true benefit schedule in two senses, first a kink in current benefits is misconstrued as a notch, and second, an actual upward notch in benefits is apparently overlooked by the majority of claimants who bunch. These misperceptions may affect estimates of elasticities based on bunching in response to the AET (e.g. Gelber, Jones and Sacks 2020; Gelber et al. 2021), but may be less of a concern for estimates that rely on more general variation in incentives away from the kink (Gelber et al. 2022, e.g.).

Second, to the extent that tax bracket misperception also explains left bunching in other contexts, this has wide-ranging implications for our understanding of elasticities as they have been estimated from bunching at kinks. As explained in Kleven (2016), the implied elasticity for a given amount of bunching in response to a notch is much smaller than the same amount of bunching in the presence of a kink. These estimates are typically used to evaluate the efficiency costs of various taxes and implicit taxes, and also are used to derive optimal tax and transfer systems. It is therefore important that estimates appropriately consider the underlying model of behavior. Such a model should involve several factors. First, it will be necessary to estimate the fraction of the population that misperceives the kink as a notch, and the complementary fraction that correctly perceives the kink. In principle, each of these two groups could exhibit different elasticities, which could also be estimated. Moreover, within the misperceiving group, some individuals may be inert to the notch as in Kleven and Waseem (2013), and this fraction could also be estimated. Developing a model that could credibly estimate all of these parameters—given enough empirical moments—will be a worthy challenge for future work. Another challenge for future work will be to explore the reasons why, as discussed above, left bunching appears clear in many circumstances, but bunching appears relatively symmetric in others. As a step in that direction, Anagol et al. (2025), find that the use of professional tax preparers may be negatively correlated with notch-like behavior in the presence of a kink.

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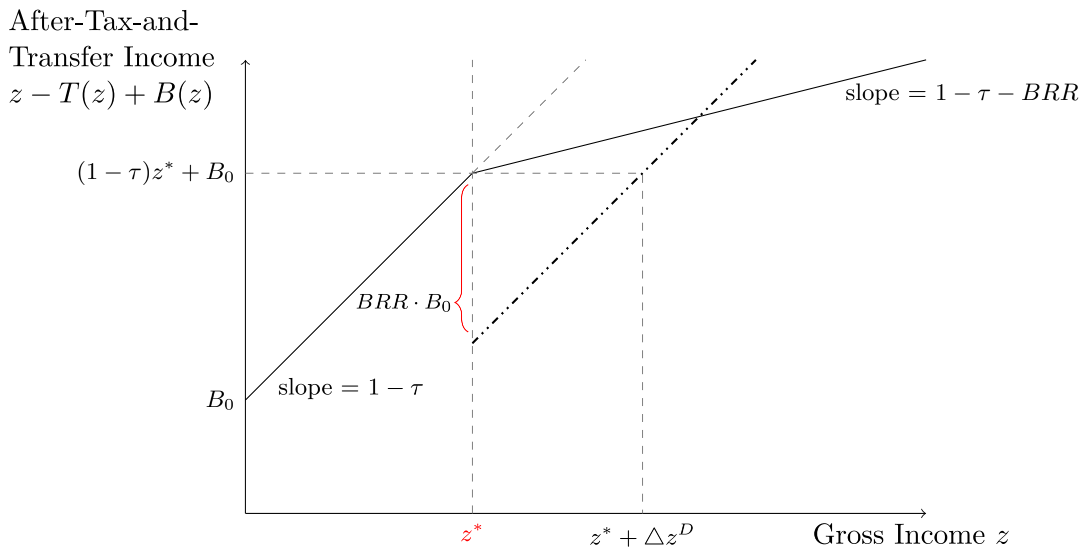
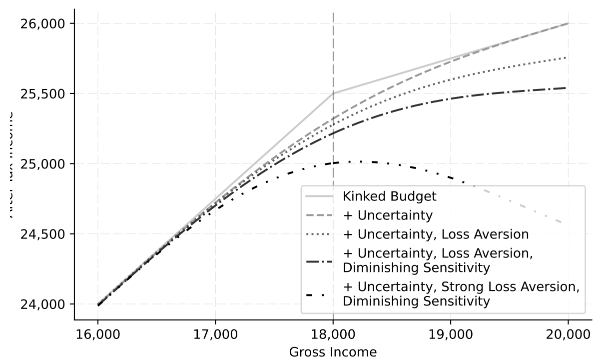
Figure 1: Budget set created by the earnings test, with and without misperception

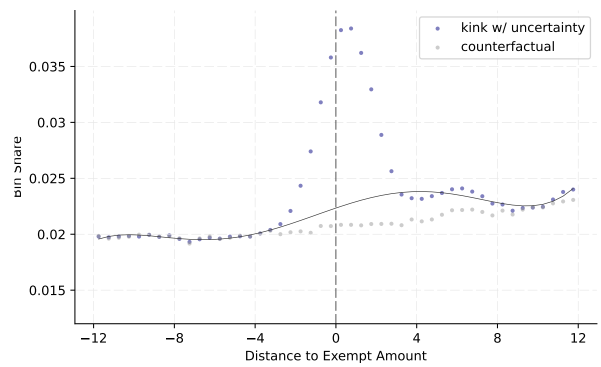


Notes: Figure plots after-taxes-and-transfer income against gross income, under the earnings test, not counting long-run changes from actuarial adjustment or benefit reduction. The dash-dotted line depicts a misperceived notch, instead of a kink. The dominated region is also highlighted.

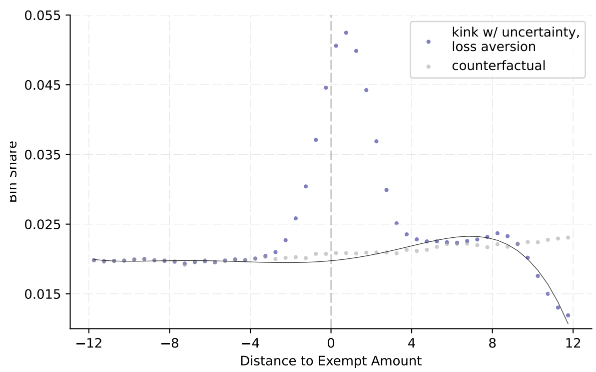
Figure 2: Models that do and do not predict left bunching



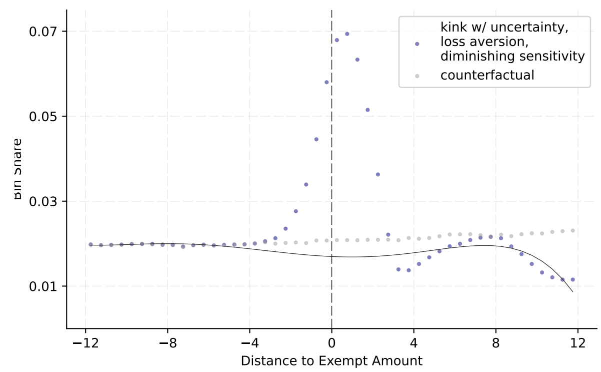
(a) Nominal and Effective Budget Sets



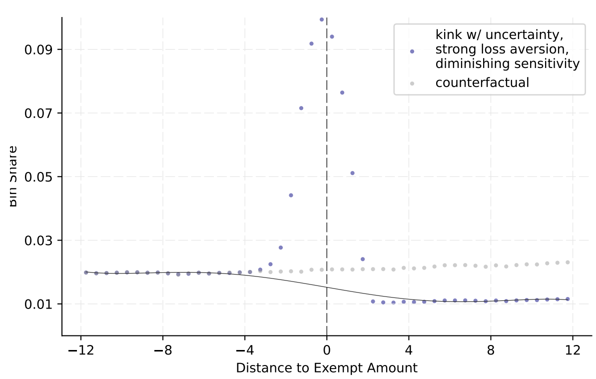
(b) Kink + Uncertainty



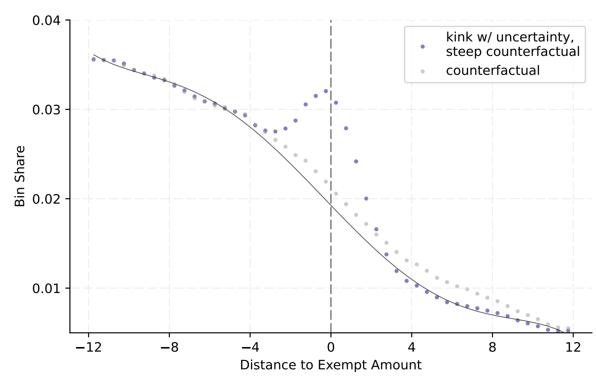
(c) Kink + Loss Aversion



(d) Kink + Diminishing Sensitivity



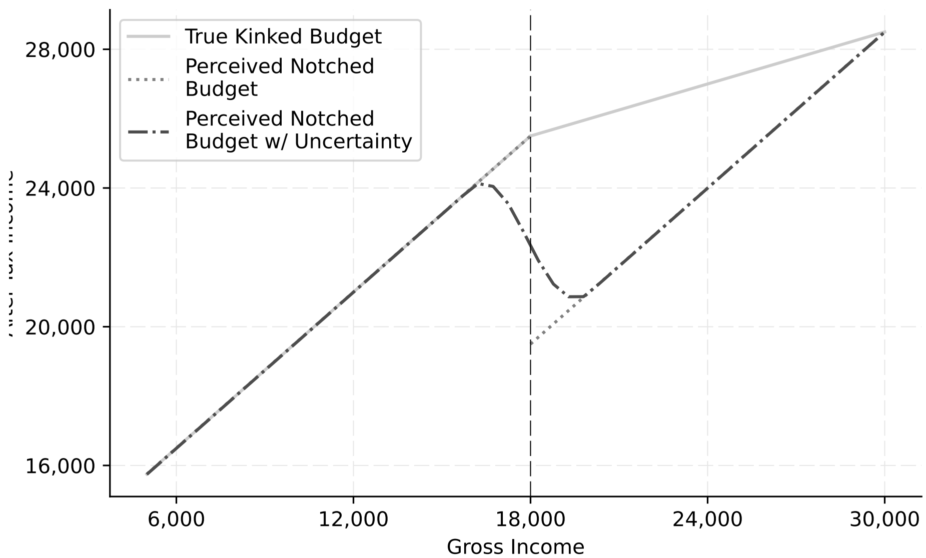
(e) Kink + Strong Loss Aversion + Diminishing Sensitivity



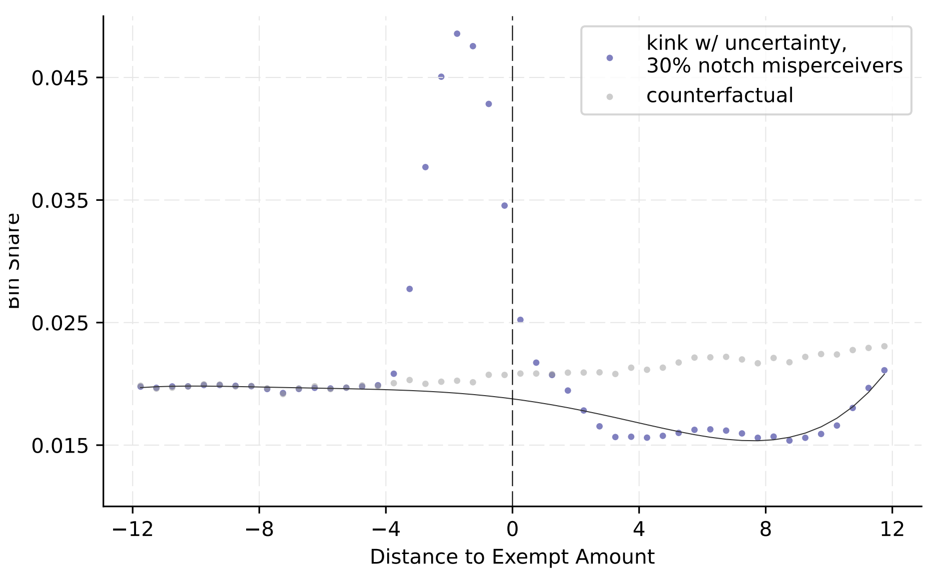
(f) Kink + Downward Sloping Earnings

Notes: Panel (a) plots the nominal budget with a kink created by the Earnings Test, along with four effective budget sets under different scenarios. Panels (b) through (e) plot the earnings distribution under each of the four effective budget sets. Panel (f) plots the earnings distribution under the same scenario as panel (b), but with a downward sloping counterfactual distribution. Each earnings distribution includes 50% of agents who remain at their counterfactual earnings due to frictions.

Figure 3: Left bunching from tax bracket misperception



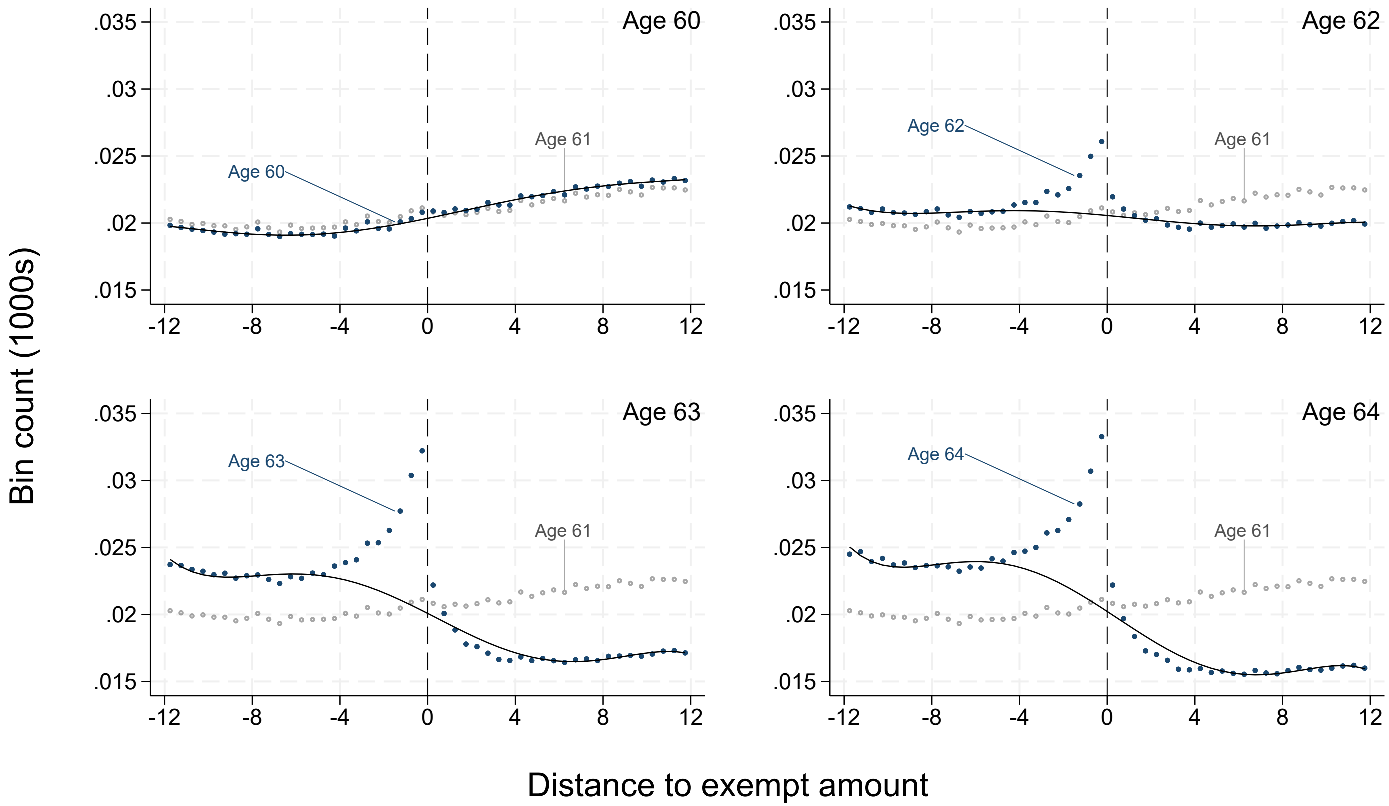
(a) Effective budget set under notch misperception



(b) Earnings distribution with mix of kink and notch bunching

Notes: Panel (a) plots the nominal budget with a kink created by the Earnings Test, along with an alternative budget set featuring a notch, and the corresponding effective budget set, incorporating uncertainty, under the notched budget set. Panel (b) plots the earning distribution from a sample that includes 30% of agents who perceive a notch and respond, 20% who perceive a kink and respond, and 50% who remain at their counterfactual earnings level due to frictions.

Figure 4: Distribution of earnings relative to exempt amount, by age



Notes: Figure plots the number of observations in each bin of earnings (relative to the exempt amount), by age. Sample is anyone born 1939-1954 with a Social Security number and in the tax system in 1999-2018, and no age 61 self-employment income. The gray dots show the number of observations at age 61. The smooth black line is a degree 5 fit estimated using all data from the indicated age except in the range (-4000, 4000).

Figure 5: Discontinuity in probability of having earnings

Notes: Figure plots the probability of having non-zero earnings at the indicated ages, given age 61 earnings relative to exempt amount. Sample is anyone born 1939-1954 with a Social Security number, and no age 61 self-employment income.

Table 1: Person-level summary statistics

	Sample	
	Full	Main
Female	0.490	0.500
Year of birth	1947.4	1947.4
Claim age	62.3	62.3
Retirement age	60.0	60.0
Ever had SE earnings	0.142	0.076
N people	33,408,559	31,013,086

Notes: Full sample is anyone born 1939-1954 with a Social Security number, and at least one year of positive earnings age 60–64. Main sample conditions on no self-employment income at age 61. Claim age is the youngest age at which we observe non-zero OASI or DI income (our interested in OASI income but the tax do not distinguish the two). Retire age is the youngest age at which we observe a disbursement from a tax-advantaged retirement account.

Table 2: Summary statistics by age, main sample

	Age				
	60	61	62	63	64
Earnings:					
Mean (if> 0)	57,200	56,300	54,500	52,900	51,800
Pr(> 0)	0.925	0.877	0.821	0.735	0.666
OASI Income:					
Mean (if> 0)	7,100	11,600	7,100	13,100	14,000
Pr(> 0)	0.018	0.027	0.257	0.378	0.431
DI Income:					
Mean (if> 0)	16,200	17,000	17,300	17,900	17,800
Pr(> 0)	0.028	0.040	0.055	0.064	0.070
Earnings Test Exempt Amount (Mean)	15,800	15,900	16,000	16,200	16,200
N obs	31,013,086	31,013,086	31,013,086	31,013,086	31,013,086

Notes: Sample is anyone born 1939-1954 with a Social Security number, at least one year of positive earnings age 60–64, and no self-employment income at age 61. All dollar amounts are 2018 real and rounded to $100 to avoid disclosing individual taxpayer incomes. Earnings are Medicare-covered only.

Table 3: Excess mass around the exempt amount, by age, main sample

	(1)	(2)	(3)	(4)
	Counterfactual			
	Smooth quintic		Age 61	
Age:	Left Bunching	Right Bunching	Left Bunching	Right Bunching
60	0.001	0.001	0.000	0.000
	(0.001)	(0.001)	(0.006)	(0.006)
62	0.018	0.001	0.025	-0.006
	(0.001)	(0.001)	(0.006)	(0.006)
63	0.043	-0.001	0.056	-0.022
	(0.001)	(0.001)	(0.006)	(0.006)
64	0.045	-0.003	0.062	-0.026
	(0.001)	(0.002)	(0.006)	(0.006)

Notes: Sample is anyone born 1939-1954 with a Social Security number, at least one year of positive earnings age 60-64, and no self-employment income at age 61. Excess probabilities in a given bin are calculated as the actual bin probability less the counterfactual probability. Left and right excesses are the total excess amounts between [-4000, 0) and [0, 4000). We consider two counterfactuals: the fit from a smooth quintic (estimated using data from (-12000, 12000) but excluding the range (-4000, 4000)), and the age 61 earnings distribution. Standard errors in parentheses. In columns (1) and (2) these are obtained via the bootstrap (1000 iterations, resampling residuals); in columns (3) and (4), they are obtained in the standard way for the difference in proportions.

Table 4: RD estimates of discontinuity in employment at ages 62–64, given age 61 distance

	(1)	(2)	(3)	(4)
	Age			
	62	63	64	Pooled: 63–64
Discontinuity	-0.0023	-0.0034	-0.0033	-0.0035
	(0.0013)	(0.0014)	(0.0015)	(0.0014)
CCT Bandwidth	1,666	2,323	2,528	2,313
N obs	1,092,458	1,515,514	1,655,257	3,018,180

Notes: Sample is anyone born 1944–1951 with a Social Security number and in the tax system in 1999–2018, and no age 61 self-employment income. Table reports estimates from a linear RD regression of an indicator for positive earnings at the indicated outcome age on age 61 distance to the exempt amount. Robust standard errors in parentheses (clustered on individual in column (4)). We use the CCT bandwidth.

Table 5: Bracket misperception generates substantial left bunching despite small extensive margin responses

		(1)	(2)	(3)
Extensive margin Discontinuity	Adjustment cost	Misperception share	Extensive margin response	Minimum bunching from misperception
-0.0007	160	0.080	0.086	0.03
-0.0007	280	0.046	0.076	0.01
-0.0035	160	0.399	0.086	0.13
-0.0035	280	0.228	0.076	0.07

Notes: Table reports the implied share of the population with bracket misperception (column 1), the extensive margin response among misperceivers in the dominated region (column 2), and a lower bound on bunching among mispercievers (column 3). Overall bunching is 0.04-0.05. The rows differ in the assumed discontinuity and adjustment cost. -0.0007 is the lower bound of our 95% confidence interval and -0.0035 is our estimate. We additionally set the extensive margin elasticity at 1 (an upper bound that yields a lower bound on misperceiving share π), and the intensive margin elasticity at 0.25. See Section 6 for details.

Table 6: Illustration of recovering elasticities under misperception

	(1)	(2)	(3)	(4)
			Corrected elasticity	
Upper tax rate	Observed bunching	Naive elaticity	$\pi = 0.05$	$\pi = 0.10$
0.15	0.01	0.25	0.05	0.00
0.20	0.02	0.25	0.11	0.03
0.30	0.05	0.25	0.16	0.09

Notes: Table reports the structural intensive margin elasticities implied by a given tax system, bunching amount, and misperception share π. In all rows the lower tax rate is 0.10, the kink point is $z^* = \$20,000$, and the counterfactual density is 0.02/500. The bunching amount in all cases corresponds to an elasticity of 0.25 in the absence of misperceptions or other frictions.

Appendix A Appendix Exhibits

Table A.1: Robustness of discontinuity in employment at ages 62-64, given age 61 distance

Outcome age	62 (1)	63 (2)	64 (3)	Pool 63-64 (4)
A. Baseline (linear RD, no controls, uniform kernel)				
Discontinuity	-0.0023	-0.0034	-0.0033	-0.0035
	(0.0013)	(0.0014)	(0.0015)	(0.0014)
BW	1,666	2,323	2,528	2,313
N	1,092,458	1,515,514	1,655,257	3,018,180
B. Quadratic-uniform (no controls)				
Discontinuity	-0.0023	-0.0032	-0.0033	-0.0040
	(0.0014)	(0.0016)	(0.0020)	(0.0017)
BW	3,269	4,137	3,114	3,389
N	2,135,015	2,696,465	2,035,139	4,427,816
C. Linear-triangular (no controls)				
Discontinuity	-0.0018	-0.0037	-0.0036	-0.0037
	(0.0013)	(0.0014)	(0.0014)	(0.0014)
BW	2,029	2,894	3,465	2,787
N	1,328,404	1,892,831	2,262,486	3,642,832
D.Quadratic-triangular (no controls)				
Discontinuity	-0.0023	-0.0036	-0.0037	-0.0039
	(0.0013)	(0.0016)	(0.0019)	(0.0016)
BW	4,186	4,904	3,865	4,183
N	2,727,812	3,197,894	2,521,079	5,452,604
E. Controls (linear, uniform)				
Discontinuity	-0.0010	-0.0018	-0.0029	-0.0023
	(0.0012)	(0.0013)	(0.0013)	(0.0012)
BW	2,029	2,894	3,465	2,787
N	1,328,404	1,892,831	2,262,486	3,642,832

Notes: See notes to Table 4; panel A. is identical to the results there. The remaining panels vary the RD especification, changing the degree (linear or quadratic) and kernel (uniform or triangular), or including controls. The controls are indicators for birth year, sex, and age 61 earnings exactly at the exempt amount.

Appendix B Numerical Simulations

B.1 Simulation details

We model a set of N agents, each who are faced with the static optimization problem of choosing a target level of earnings, z_{targ}, which maximizes expected utility:

$$
\begin{aligned}
z_{\text{targ}} =& \underset{z}{\operatorname{argmax}} \int u\left(\hat{c}(z+\epsilon), z\right) + r\left(u\left(\hat{c}(z+\epsilon), z\right) - u\left(c_0(z+\epsilon), z\right)\right) f\left(\epsilon\right) d\epsilon \\
\text{where: } & \hat{c}\left(z\right) = z - T\left(z\right) + \hat{B}\left(z\right) \\
& c_0 = z - T(z) + B_0 \\
& r(x) = \begin{cases} \lambda_G x^{\alpha_G} & \text{if } x \geq 0 \\ -\lambda_L (-x)^{\alpha_L} & \text{if } x < 0 \end{cases}
\end{aligned} \tag{B.1}
$$

The agent may thus operate under potential misperceptions of the benefit formula when $\hat{B}(\cdot) \neq B(z)$ and reference dependence when either $\lambda_j \neq 0$ for $j \in \{G, L\}$. Realized earnings will then be $z_{\text{targ}} + \epsilon$, where $\epsilon \sim F(\cdot)$, a continuous, symmetric, and mean zero distribution.

The utility function, $u(\cdot)$ takes the following functional form:

$$
u(c, z; n) = \frac{c^{1-\gamma}}{1-\gamma} - \frac{n^{1-\gamma}}{1+1/\varepsilon}\left(\frac{z}{n}\right)^{1+1/\varepsilon}
$$

The parameter γ governs risk aversion, while the parameter n indexes heterogeneity in labor supply. In the case of no taxes or transfers, i.e. $T(z) = B(z) = 0$, and no uncertainty, the optimal earnings level is $z = n$. We therefore interpret n as a measure of "ability." We use a value of $\gamma = 1$, in which case we have a natural log functional form for the consumption component of utility. In order to ensure that realized earnings never reaches a negative value, which is incompatible with a the natural log, we draw the income errors, ϵ, from a Beta distribution with pdf:

$$
\begin{aligned}
f(\epsilon) =& \frac{(\epsilon + 4,000)^{\alpha-1}(4,000-\epsilon)^{\beta-1}}{(8,000)^{\alpha+\beta-1}\mathrm{B}(\alpha,\beta)} \\
\text{where: } & \mathrm{B}(\alpha,\beta) = \frac{\Gamma(\alpha)\Gamma(\beta)}{\Gamma(\alpha+\beta)} \\
& \alpha = \beta = 2.25
\end{aligned}
$$

where B is the Beta function, and Γ is the gamma function. The parameters of the Beta distribution are chosen to match an empirical feature of our data: diffuse bunching appears to spread about \$4,000 in either direction from the kink. The error term ϵ is bounded between -4,000 and 4,000, is single peaked at zero, and is symmetrically distributed.

Following Saez (1999), we can solve (B.1), by reframing the optimization problem in terms of an effective budget set, $\tilde{T}(z)$, as follows:

$$z_{\text{targ}} = \underset{z}{\operatorname{argmax}}\ u(z - \tilde{T}(z), z)$$

where:

$$u(z - \tilde{T}(z), z) \equiv \int \left(u\left(\hat{c}(z+\epsilon), z\right) + r\left(u\left(\hat{c}(z+\epsilon), z\right) - u\left(c_0(z+\epsilon), z\right)\right)\right) f(\epsilon)\, d\epsilon, \qquad \text{(B.2)}$$

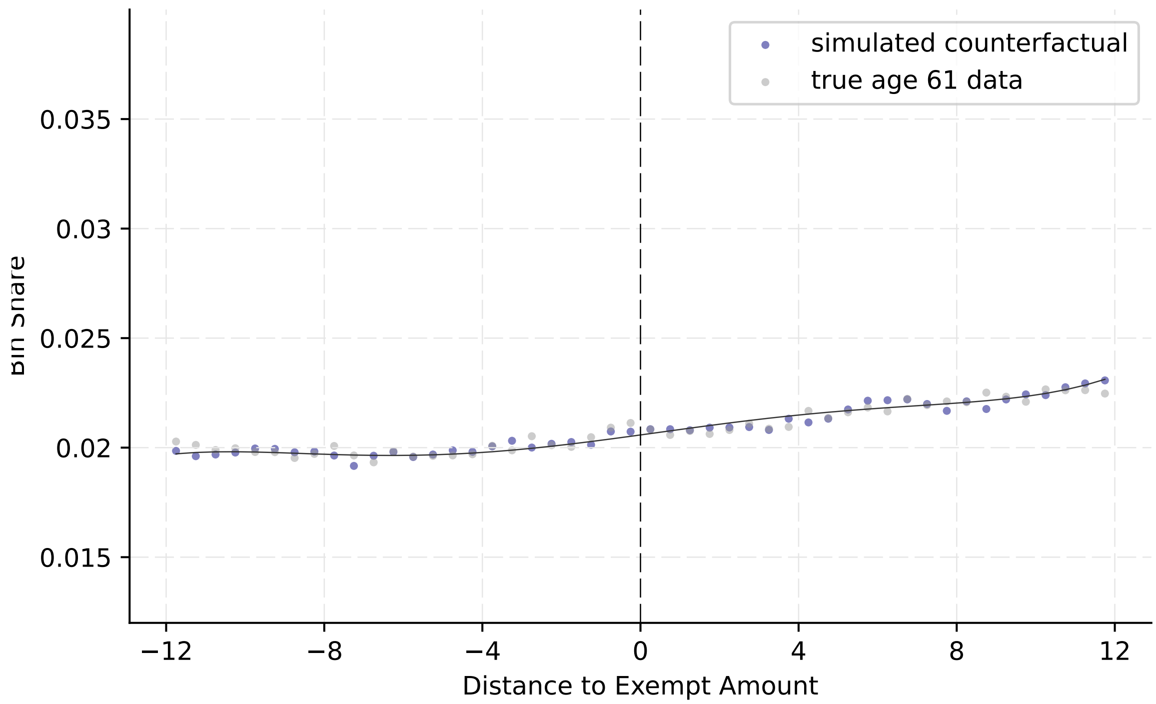
An agent with standard preferences, no uncertainty, and no reference dependence, facing the effective budget set $\tilde{T}(z)$, will choose the same z_{targ} as the agent in the more general problem. In order to calculate $\tilde{T}(z)$, one must evaluate integrals over the distribution of earnings errors ϵ. To evaluate these integrals, we simulate 1,000 draws from the distribution $F(\epsilon)$, calculate utility at each draw, and take the average.

For each agent with ability parameter n, we partition a common earnings range $[z_{min}, z_{max}]$ at key earnings levels, such as the location of the kink, and the nonconvex kink created when benefit claw-back is exhausted, or the location of the perceived notch. And then, within each interval, we search for an interior solution that satisfies the first-order condition for the effective budget set: $(1 - \tilde{T}'(z))u_c + u_z \equiv 0$. In the case of kinked budget sets, we can use a standard root-finding routine, i.e. Brent's method, to find the solution, after deriving an analytical expression for $\tilde{T}'(z)$. However, in the case of a notch, the analytical expression for $\tilde{T}'(z)$ is not valid, because the marginal tax rate is not well-defined at a notch. However, we can still calculate $\tilde{T}(z)$ and numerically calculate its derivative in this case. We compare utility at any interior solutions to utility at each of the boundaries of the intervals, which may serve as corner solutions.

We calibrate our distribution of potential earnings, n, so that realized earnings, $z_{\text{targ}} + \epsilon$, from a simulation with no Earnings Test kink and a locally constant marginal tax rate of 0.25 will closely match the empirical distribution of earnings from our Age 61 sample. In particular, we draw a uniform distribution of abilities, n, between \$12,000 below the kink and \$12,000 above the kink. We then solve for realized earnings, in the absence of a kink, producing a series $z(n)$. We then approximate the inverse of this relationship, $n^{-1}(z)$, by regressing n on z using a degree-5 polynomial. Next, we feed the empirical age 61 distribution, z_{61}, into this polynomial, resulting in a distribution of abilities, $\hat{n}_{61} = n^{-1}(z_{61})$. Finally, we simulate optimal target earnings for 2,500 agents in the absence of an Earnings Test kink and draw 400 realized earnings for each agent. Figure B.1 compares the resulting, simulated earnings distribution to the actual data. We use this initial earnings distribution as one potential empirical counterfactual with which to calculate bunching.

Armed with a distribution of abilities, n, we next simulate target earnings for 2,500 agents, under various preference, perception, and budget set combinations. In each case, we draw another 400 earnings errors, to generate a distribution of 1,000,000 earnings realizations, and plot the resulting distributions in Figures 2 and 3. As noted in the main text, in each

Figure B.1: Simulated versus actual earnings distribution



Notes: Figure shows the simulated counterfactual earnings distribution underlying all of our simulations, as compared to the actual distribution of earnings at 61 in our data.

simulation, we assume that half of agents are inert and remain at their counterfactual earnings level. The remaining half optimize according to the specifics of each scenario.

After we have simulated an earnings distribution, we calculate left and right bunching. We calculate this in two ways. First, just using the ex-post simulation data, we calculate bunching by estimating a counterfactual earnings distribution using a quintic polynomial, using data outside of an excluded region of \$4,000 to either side of the exempt amount. We then calculate bunching difference between the simulated distribution and this counterfactual polynomial, within the region of \$4,000 to either side of the exempt amount. This is the same method used on our real data in the text. Second, we compare the ex-post earning distribution to the counterfactual distribution mentioned above, taking the difference between the two within the region of \$4,000 to either side of the exempt amount. Table B.2 below reports the calculated bunching amounts under each simulation:

B.2 Bunching to the right under uncertainty

We plot the effective budget set, $\tilde{T}(z)$, under different scenarios in Figures 2a and 3a. The features of the effective budget set implied by $\tilde{T}(\cdot)$ provide intuition for a consistent result in our simulations: uncertainty tends to lead to bunching that peaks to the right of the actual kink. This result has been previously explained in Saez (1999). We reproduce the logic here.

For the purposes of this argument, we present results for the case with no reference dependence. First, we rewrite the utility function as the sum of two separable components:

$$u(c, z) = U(c) + m(z)$$

where $U(c)$ captures the consumption component and $m(z)$ captures the component related to earnings and labor supply. Since the second component is not effected by the error shock to income, ϵ, we can simplify (B.2) as follows:

$$\begin{aligned}
u\left(z - \tilde{T}(z), z\right) &\equiv \int u\left(\hat{c}(z+\epsilon), z\right) f\left(\epsilon\right) d\epsilon \\
\Rightarrow U\left(z - \tilde{T}(z)\right) + m(z) &= \int \left(U\left(\hat{c}(z+\epsilon)\right) + m(z)\right) f\left(\epsilon\right) d\epsilon \\
&= \int U\left(\hat{c}(z+\epsilon)\right) f\left(\epsilon\right) d\epsilon + m(z) \\
\Rightarrow U\left(z - \tilde{T}(z)\right) &= \int U\left(\hat{c}(z+\epsilon)\right) f\left(\epsilon\right) d\epsilon \\
\Rightarrow z - \tilde{T}(z) =& U^{-1}\left(\int U\left(\hat{c}(z+\epsilon)\right) f\left(\epsilon\right) d\epsilon\right) \\
&= U^{-1}\left(\int U\left(z + \epsilon - T(z+\epsilon) + \hat{B}(z+\epsilon)\right) f\left(\epsilon\right) d\epsilon\right)
\end{aligned}$$

where in the fourth line, we used the fact that $m(z)$ is not a function of the error and can pass through the integral, and in the last line, we used the definition of $\hat{c}(z)$. Differentiating

Table B.2: Simulated Right and Left Bunching

	(1)	(2)	(3)	(4)
	Counterfactual			
	Smooth quintic		Simulation Based	
Simulation:	Left Bunching	Right Bunching	Left Bunching	Right Bunching
Kink w/ Uncertainty	0.03	0.06	0.04	0.08
Kink w/ Uncertainty, Loss Aversion	0.07	0.15	0.8	0.15
Kink w/ Uncertainty, Loss Aversion, Diminishing Sensitivity	0.11	0.20	0.09	0.17
Kink w/ Uncertainty, Strong Loss Aversion, Diminishing Sensitivity	0.26	0.18	0.24	0.12
Kink w/ Uncertainty, Downward Sloping Ability Distribution	0.04	0.04	0.03	0.02
Kink w/ Uncertainty, 30% Notch Misperceivers	0.15	0.01	0.14	-0.01

Notes: Table reports left and right bunching under various simulations described in Section 3.3. In each case, a share of agents, 50 percent, are inert, and remain at their counterfactual earnings level. The "smooth quintic" counterfactual is calculated by estimating a fifth-degree polynomial using data outside of an excluded region. The "simulation based" counterfactual is take from simulation of the same agents, in the absence of any kink or perceived notch.

both sides by z, we have:

$$1 - \tilde{T}'(z) = \int \left(1 - T'(z+\epsilon) + \hat{B}'(z+\epsilon)\right) \omega(z,\epsilon) f(\epsilon)\, d\epsilon$$
$$\text{where: } \omega(z,\epsilon) = \frac{U'\left(z+\epsilon - T(z+\epsilon) + B(z+\epsilon)\right)}{U'\left(z - \tilde{T}(z)\right)}$$

This expression reveals that the net-of-tax rate under the effective budget set is a weighted average of net-of-tax and benefit reduction rates at different earnings levels, with weights proportional to the density $f(\epsilon)$ and to a ratio of marginal utilities. Because marginal utility is higher at lower earnings levels, the weight on the net-of-tax rate at those levels is higher. As can be seen in Figure 2a, the effective budget set is smoothed version of the kinked one, and the rise in marginal tax rates at the kink is delayed and more gradual, pushing the inflection point at which the marginal tax rate increases to the right of the nominal kink. Thus, our approach to modeling the uncertainty that leads to diffuse bunching tends to push bunching to the right of the kink, all things equal. Note, however, that in the presence of a notch, this analytical result is not well-behaved: the derivative of the benefits function is not defined at the notch, and is everywhere else positive. In the case of a notch, then, we calculate $\tilde{T}(z)$ and evaluate its derivative numerically.

B.3 Comparison to Anagol et al. (2025)

Our approach to modeling diffuse bunching shares similarities with that of Anagol et al. (2025). In their setting, individuals choose a target level of earnings, z_{targ}, and then are faced with a sparse menu of earnings options: $\{z_{\text{targ}} + \epsilon_1, z_{\text{targ}} + \epsilon_2, \ldots, z_{\text{targ}} + \epsilon_m\}$. The agent then chooses the earnings level from this set that maximizes utility. In our model, agents choose a target level of earnings, and then must choose from a sparse menu with only one entry: $z_{\text{targ}} + \epsilon$. Anagol et al. (2025) show that including even a few more options in the sparse menu, which relaxes frictions somewhat, can lead to significantly different results. However, both our model and theirs do not predict left-bunching in the presence of a kink, they both do predict left-bunching in the presence of a notch or a misperceived notch, and they also both result in agents locating in the dominated region of a notch.

There are additional differences between our modeling approaches. In our case, the agent chooses the target level of earnings with the anticipation that they will then be assigned earnings from the sparse menu. Anagol et al. (2025) instead model the agents choice of the target earnings without anticipation of the resulting sparse menu. The upshot of this difference is that agents in our model err to the left of a notch due to the possibility that their earnings may drift into the dominated region once frictions are realized, which results in bunching that peaks to the right of the threshold. And in the presence of a kink, bunching peaks to the right of the kink, because the jump in marginal tax rates is more gradual. However, under their preferred distribution of earnings shocks, $F(\epsilon)$, which they refer to as "uniform sparsity", the choice of the target distribution becomes irrelevant.

A second difference is that in our model, the frictions that lead to a different realization of earnings only matter for consumption. The disutility of earnings supply is determined by the target earnings, whereas in Anagol et al. (2025), the sparse menu constrains both consumption and earnings disutility. The models therefore imply different underlying mechanisms for the friction. In our case, one might imagine that hours of labor are fixed, but bonuses, or tips, or some other uncertain component of compensation may vary, while in the case of Anagol et al. (2025), one might have in mind a lumpy menu of hours and/or salaries that prevent precise choice in earnings and effort.

Interestingly, both approaches were originally considered by Saez (1999) as a means of modeling diffuse bunching at tax kink points in the U.S. tax code.

Appendix C Modeling Extensive margin responses

We show that the combination of a (real or perceived) notch in the budget set, along with intensive margin adjustment frictions, results in a downward discontinuity in the extensive margin, i.e. a discontinuous drop in employment. A kink, however, does not produces a similar discontinuity, even in the presence of loss aversion.[1]

Following previous work on employment responses to kinks or notches (*e.g.* Hausman, Hausman and Holl (1981); Saez (2010); Kleven and Waseem (2013)), we continue to model utility as a function of consumption and earnings, $u(c, z; n)$, where the partial effect of an increase in z on utility is negative as it requires effort to increase earnings, and the partial effect of an increase in c on utility is positive. Our index of "ability" is n; the marginal rate of substitution of c for z is decreasing in n at all levels of c and z.[2] We assume $u(\cdot)$ is a function of class C^2. As in Saez (2010) and much subsequent literature, we model the determination of earnings, rather than hours worked, as earnings (but not hours worked) are observed in many administrative datasets.

Throughout, we make use of a potential outcomes framework (Rubin 1974). We index two potential states of the world by $j \in \{0, 1\}$. The tax schedule $T_j(z)$ denotes tax liability in state j, the benefit schedule $B_j(z)$, and z denotes pre-tax earnings. We assume that individuals maximize utility subject to a static budget constraint:

$$c_{nj} = z_{nj} - T_j(z_{nj}) + B_j(z_{nj}) \tag{C.3}$$

where z_{nj} is realized earnings for an individual with ability n in state j. In all states, the tax schedule is proportional: $T_0(z) = T_1(z) = \tau z$. In state 0 benefits are constant $B_0(z) = B_0$,

[1] This material builds on results in the working paper Gelber et al. (2017). We also rely on results on extensive margin responses to kinks published in Gelber et al. (2021). The material on extensive margin responses to notches has not been previously published.

[2] This implies a standard single-crossing property assumed in these models, which generates rank preservation in earnings, conditional on earning a positive amount.

and thus the effective marginal tax rate is constant at τ. Alternatively, in the case of a kink, in state 1 the tax and transfer schedule exhibits a change in slope at z^* due to benefit reduction: $B(z) = \max(0, B_0 - BRR(z - z^*) \cdot \mathbf{1}\{z > z^*\})$, where BRR is the benefit reduction rate. The effective marginal tax rate now increases discontinuously at z^*, due to benefit reduction. Once benefits are fully clawed back, the schedule returns to the initial marginal tax rate. In the case of a notch, the tax schedule in state 0 is the same, but now, in state 1, the tax and transfer schedule exhibits an discontinuous drop in after-tax-and-transfer income at z^*. Benefits under the notched schedule takes the form: $B_1(z) = B_0 \cdot (1 - BRR \cdot \mathbf{1}\{z > z^*\})$. That is, we have a "pure notch", which is a level shift in the tax and transfer schedule at z^*. At an interior solution, the first-order condition, $(1 - T_j'(z) + B_j'(z))u_c + u_z \equiv 0$, implicitly defines the earnings supply function (we suppress subscripts here as shorthand).

C.1 Intensive Margin Responses

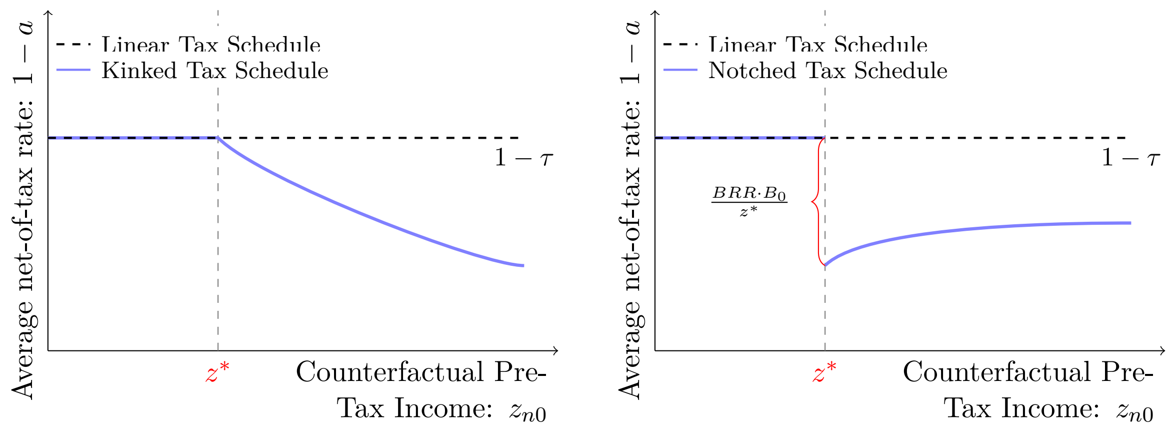
Given this setup, we briefly review the intensive margin effect of a kink or notch. As shown in Saez (2010), a kinked budget set leads to a discontinuity in the earnings density at the kink due to intensive margin responses. Assuming a smooth distribution of ability n, a range of individuals who would earn between z^* and $z^* + \triangle z^K$ in state 0 will respond in state 1 by reducing earnings to the kink at z^*. This is referred to as "bunching" at the kink. The reduction in earnings $\triangle z^K$ of the "marginal buncher"—i.e. the buncher who earns the most, $z^* + \triangle z^K$, in state 0—can be related to the size of the change in the effective marginal tax rate at the kink, BRR, in order to estimate an intensive margin elasticity (Saez 2010).

In the case of a notched budget set, intensive margin responses are analyzed in (Kleven and Waseem 2013). Those who would earn between $z^*$and $z^* + \triangle z^N$ in state 0 bunch at z^* in state 1. Of particular interest is a "dominated region" of earnings where after-tax earnings are lower than they are at the notch, z^*. This region is illustrated in Figure 1. Within this region, one can increase consumption and reduce labor supply by moving to z^*. This region lies between z^* and $z^* + \triangle z^D$, where $\triangle z^D \equiv (1 - BRR)B_0/(1 - \tau)$. Note that this region is a subset of the entire bunching region: $\triangle z^D < \triangle z^N$. In state 1, in the absence of adjustment frictions, no one will locate in the strictly dominated region above the notch. However, in the presence of adjustment frictions, there may be "inert" individuals who remain in the dominated region rather than bunching. In this case, the amount of bunching in combination with the share of earners remaining in the dominated region can be used to estimate a structural intensive margin elasticity.

C.2 Extensive Margin Responses

In addition to the intensive margin response, individuals may also respond at the extensive margin. In the model of a kink briefly, preferences and budget sets are convex, which restricts a small tax change only to affect the choice between zero and infinitesimally small earnings supply (e.g. Kleven and Kreiner (2005)). To capture the realistic pattern of potential entry

Figure C.2: Extensive Margin Incentives



(a) Kinked Tax Schedule

(b) Notched Tax Schedule

Notes: The figures show the ANTR (y-axes) as a function of before-tax income (x-axes). In both panels, incentives under a linear tax schedule in which the ANTR is equal to $1-\tau$ everywhere are represented by a dashed line. In Panel A, incentives under a kinked tax schedule in which the ANTR is equal to $1-\tau$ below the kink point z^*, and $1-\tau-BRR\cdot B_0\cdot(z-z^*)/z$ above z^*, are represented by a solid line. In Panel B, incentives under a notched tax schedule in which the ANTR is $1-\tau$ below z^* and $1-\tau-BRR\cdot B_0/z$ above z^* are likewise represented by a solid line. Panel A shows that under a kink, the slope of this graph discontinuously decreases at the kink point z^*, due to the imposition of the marginal tax on earnings above z^*. Panel B shows that under an notch, the ANTR discontinuously drops at z^* . $1-a$ is defined as the average net-of-tax-and-trasnfer rate, i.e. $1-a=1-\left[(T(z)+B(z))-(T(0)+B(0))\right]/z$.

to or exit from non-trivial levels of earnings, we introduce a fixed cost of employment (Cogan 1980; Eissa, Kleven and Kreiner 2008). Utility is now given by:

$$u\left(c_{nj},z_{nj};n\right)=v\left(c_{nj},z_{nj};n\right)-q_{nj}\cdot 1\left\{z_{nj}>0\right\} \tag{C.4}$$

where $j\in\{0,1\}$ indexes the state of the world, and the state-specific, additively separable fixed cost of employment, q_{nj}, is drawn from a distribution with CDF $G\left(q|\,n\right)$ and pdf $g\left(q|\,n\right)$. If an agent does not work, they receive a reservation level of utility of $u\left(c^0,0;n\right)=v^0$ in either state of the world.[3,4]

We pay special attention to whether or not the individual locates at a corner, i.e. $z_{nj}=0$. Let $\tilde{z}_{nj}$ denote the optimal level of earnings in state j conditional on working. This is chosen

[3]Without loss of generality, the outside option, v^0, does not vary with n or j. This is because cross-sectional and state-specific variation in the outside option is not separately identified from the fixed cost of entry q_{nj}. We therefore collapse all such variation into the fixed cost of entry.

[4]Writing the fixed cost q as separable from v, as in (C.4) above, simplifies the exposition. Without loss of generality, this model is equivalent to a model in which these are not separable *per se*, and instead we express utility simply as $v\left(c,z;n\right)$. Letting c_n^0 be consumption when not working, we can then posit a discontinuity in $v\left(c,z;n\right)$ at the boundary of the support of z that reflects the fixed cost. Thus, we can define a fixed cost q_n as: $q_n\equiv\lim_{z->0^+}\left[v\left(c_n^0,0;n\right)-v\left(c_n^0,z,n\right)\right]$.

by maximizing $u(c, z; n)$ subject to (C.3). The individual works in state j if:

$$v(\tilde{z}_{nj} - T_j(\tilde{z}_{nj}) + B_j(\tilde{z}_{nj}), \tilde{z}_{nj}; n) - q_{nj} > v^0 \tag{C.5}$$

Our key behavioral response of interest is the extensive margin response to the presence of a kink or notch. Here we define an individual's type by their optimal interior earnings conditional on working in state 0, i.e. $\tilde{z}_{n0}$. (We will often refer to $\tilde{z}_{n0}$ as "counterfactual" or "desired" earnings.) An isomorphism exists between this earnings amount and ability n, and for empirical purposes using an earnings amount is natural to implement. The probability of working in state j conditional on type $\tilde{z}_{n0}$ is:

$$\begin{aligned}\Pr\left(z_{nj} > 0 \middle| \tilde{z}_{n0}\right) =& \Pr\left(q_{nj} \leq v(\tilde{z}_{nj} - T_j(\tilde{z}_{nj}) + B_j(\tilde{z}_{nj}), \tilde{z}_{nj}; n) - v^0 \middle| \tilde{z}_{n0}\right) \\ =& G\left(\overline{q}_{nj} \middle| n\right)\end{aligned} \tag{C.6}$$

where:

$$\overline{q}_{nj} \equiv v(\tilde{z}_{nj} - T_j(\tilde{z}_{nj}) + B_j(\tilde{z}_{nj}), \tilde{z}_{nj}; n) - v^0 \tag{C.7}$$

is the critical value for the fixed cost of employment that leaves the agent indifferent between working and not working. We allow the $G(\cdot)$ function to vary across individuals so that we have two sources of heterogeneity: (1) preferences captured by the $v(\cdot)$ function pin down intensive margin heterogeneity but also affect the extensive margin through $\overline{q}_{n1}$, and (2) the unrestricted heterogeneity in the $G(\cdot)$ function allows for differences in extensive margin responses independent of the $v(\cdot)$ function.[5] We make a number of assumptions regarding smoothness in heterogeneity. First, we assume that $G(q_{nj}|n)$ is continuous. Second, we assume that the partial derivative of $G(q_{nj}|n)$ with respect to q_{nj}, $g(q_{nj}|n)$, is continuous in q_{nj} and n. Third, we similarly assume that the partial derivative of $G(q_{nj}|n)$ with respect to n, $\partial G(q_{nj}|n)/\partial n$, is continuous in q_{nj} and n. Finally, we assume that the CDF of n is continuously differentiable.

C.3 Visualizing Incentives with a Kink or Notch

To demonstrate the impact of a kink or notch on the decision to work, we illustrate the extensive margin incentives created by a kink or notch in Figure C.2. Here we plot desired earnings on the x axis, i.e. earnings in state 0, and the average net of tax and transfer rate:

$$\begin{aligned}\text{ANTR} \equiv& 1 - \frac{[T(z) - B(z)] - [T(0) - B(0)]}{z} \\ =& 1 - a\end{aligned}$$

[5] If extensive margin responses were instead only driven by the value function $v(\cdot)$, we might generate unexpected predictions or restrictions on the employment function. For example, if $G(\cdot)$ were homogeneous in our model, we would necessarily require that labor force participation be upward sloping as a function of $\tilde{z}_{n0}$.

The ANTR measures the share of pre-tax income that is kept after taxes when working and earning z. With a linear tax schedule, the ANTR is constant at $1-\tau$. With a kinked tax schedule, the ANTR decreases above z^*, and the slope of the ANTR decreases discontinuously at z^*. With a notched schedule, the level of the ANTR discontinuously decreases at z^*.

C.4 Employment Probability with Unconstrained Intensive Margin Responses

We begin by considering the standard context in which individuals are free to adjust their earnings anywhere on the intensive margin. In other words, individuals' earnings, conditional on having positive earnings $\tilde{z}_{nj}$, may differ across the two tax schedules, and earnings choices are subject to no constraints other than the budget constraint $c = z - T(z) + B(z)$. Let the employment function in state 1, conditional on counterfactual, interior earnings in state 0, be $\Pr(z_{n1} > 0|\, \tilde{z}_{n0})$. This is the probability of having non-zero earnings in state 1 as a function of the level of earnings in state 0. We have shown that $\Pr(z_{n1} > 0|\, \tilde{z}_{n0}) = G(\overline{q}_{n1}|\, n)$. We now focus, in particular, on how this function behaves in the neighborhood of $\tilde{z}_{n0} = z^*$.

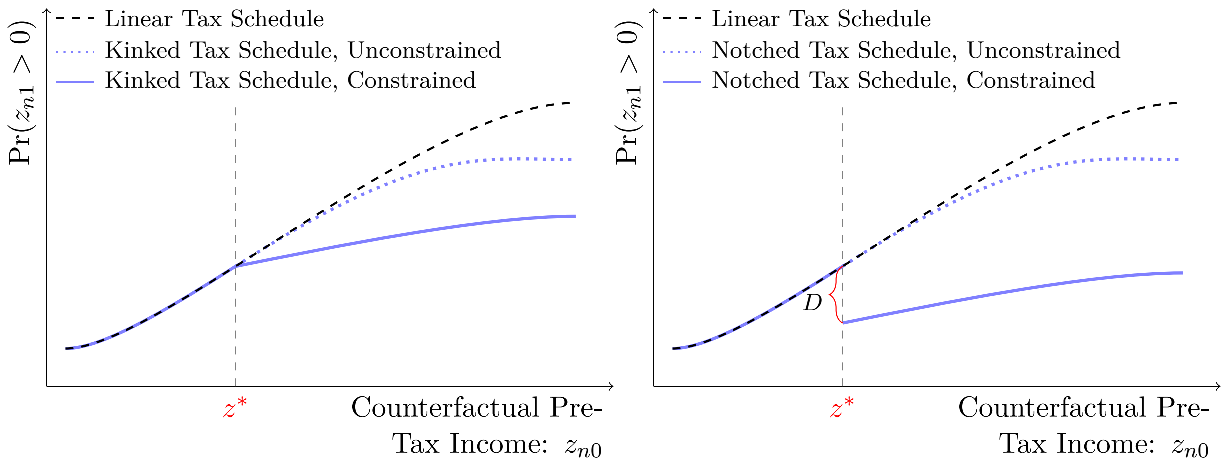
Proposition 1. *If the individuals can freely adjust their earnings on the intensive margin, then the employment probability, as a function of earnings in state* 0*, will be continuous at* z^**, in the presence of either a kink or notch:*

$$\lim_{\tilde{z}_{n0}\to z^{*+}} \Pr(z_{n1} > 0|\, \tilde{z}_{n0}) = \lim_{\tilde{z}_{n0}\to z^{*-}} \Pr(z_{n1} > 0|\, \tilde{z}_{n0}).$$

To prove this, recall from Section C.1 that under both a kink and a notch, the optimal earnings, conditional on positive earnings, $\tilde{z}_{n1}$ converges to z^* as we approach the type with counterfactual earnings $\tilde{z}_{n0} = z^*$ from the left. Likewise, under either budget set, a continuum of agents with $\tilde{z}_{n0} > z^*$ will respond to the kink or notch by moving to z^*. Thus, optimal earnings also converge to z^* when approaching the type with $\tilde{z}_{n0} = z^*$ from the right. It follows that the critical value for entry costs, $\bar{q}$ will also be continuous in $\tilde{z}_{n0}$ at z^*, and thus so will the employment probability.

Figure C.3, Panels (a) and (b), illustrate this result. The x-axis measures counterfactual earnings in state 0 conditional on having positive earnings, *i.e.* $\tilde{z}_{n0}$. The y-axis plots an illustrative employment rate. The dashed line represents a continuous relationship between the employment rate in state 0 under a linear tax schedule, i.e. $\Pr(z_{n0} > 0|\, \tilde{z}_{n0})$, and earnings conditional on having positive earnings, i.e. $\tilde{z}_{n0}$. The dotted line plots the employment rate in state 1 under a either a kinked tax schedule or a notched schedule, $\Pr(z_{n1} > 0|\, \tilde{z}_{n0})$, again relative to the x-axis of $\tilde{z}_{n0}$. In this case, we assume that individuals are unrestricted in their earnings choices. We see that the employment function is unchanged at counterfactual earnings levels below z^*, as the tax schedule remains the same in the two states. Above z^* we see a gradual decrease in the probability of positive earnings in state 1 relative to state 0, due to the decrease in the ANTR (Figure C.2). Nonetheless, neither the kink in Panel (a)

Figure C.3: Extensive Margin Responses by State 0 Counterfactual Earnings



(a) Kinked Tax Schedule

(b) Notched Tax Schedule

Notes: The figures illustrate features of the model described in Appendix C. The x-axes show desired income if employed on a linear budget set in state 0, *i.e.* $\tilde{z}_0$. The y-axes show a hypothetical probability of employment, under three scenarios: a linear schedule in state 0 (dashed line); a kinked or notched tax schedule in state 1 when individuals can make intensive margin adjustments (dotted line); and a kinked (Panel A) or notched (Panel B) tax schedule in state 1 when individuals cannot make intensive margin adjustments (solid line). D refers to the discontinuity at the exempt amount under a notch.

nor the notch in Panel (b) translate into a discontinuity in the employment rate. Intuitively, the ability to adjust on the intensive margin smooths the changes in after-tax income that would occur if agents were to remain at their counterfactual earnings level. While we have not explicitly stated as such, we note that this result holds as well for preferences with loss aversion over benefits, so long as the gain-loss utility component is continuous at the reference benefit.

C.5 Employment Probability with a Constrained Intensive Margin Responses

We now add an additional feature to the model, an intensive margin friction to adjusting earnings. Numerous papers have found evidence for such restrictions on labor supply or earnings, for example due to constraints on hours or earnings choices, or fixed costs of adjustment that would prevent adjustment to the kink for those in this region (e.g. Dickens and Lundberg (1985); Chetty et al. (2011*b*); Gelber, Jones and Sacks (2020)). Modeling and estimating frictions that could give rise to such restrictions is the focus of other work (Gelber, Jones and Sacks 2020). Here we do not take a stand on what specific process gives rise to such restrictions. We model the intensive margin friction as a fixed utility cost ϕ of changing earnings, conditional on having positive earnings, to any earnings level other than the counterfactual $\tilde{z}_{n0}$. That is,

$$u\left(c_{nj}, z_{nj}; n\right) = v\left(c_{nj}, z_{nj}; n\right) - q_{nj} \cdot 1\left\{z_{nj} > 0\right\} - \phi \cdot \mathbf{1}\left\{z_{nj} \neq z_{n0}\right\} \tag{C.8}$$

In the case of a kink, we still predict a continuous employment rate at z^*:

Proposition 2. *If individuals face a fixed cost of adjusting earnings on the intensive margin, i.e. a utility cost of ϕ if $\tilde{z}_{n1} \neq \tilde{z}_{n0}$, the employment probability, as a function of earnings in state 0, will remain continuous at z^* in the presence of a kink:*

$$\lim_{\tilde{z}_{n0} \to z^{*+}} \Pr\left(z_{n1} > 0 \middle| \tilde{z}_{n0}\right) = \lim_{\tilde{z}_{n0} \to z^{*-}} \Pr\left(z_{n1} > 0 \middle| \tilde{z}_{n0}\right).$$

We can show this result in two simple steps. First, note that the among the set of people who would bunch under no intensive margin frictions (i.e. $\tilde{z}_{n0} \in [z^*, z^* + \triangle z^K]$), the utility gain from moving to z^* vanishes as we get arbitrarily close to the type with $\tilde{z}_{n0} = z^*$ from the right. At some point, then, as we approach $\tilde{z}_{n0} = z^*$ from the right, the adjustment cost, ϕ, will begin to exceed the utility gain, and a set of agents will remain at their counterfactual earnings, $\tilde{z}_{n0}$. Second, it will still be the case, since utility for these agents converges to the utility received at z^*, that the critical value determining entry and exit, $\bar{q}$, will converge to same limit as the critical value for those initially earning just below z^*, yielding a continuous employment rate.

Returning to Figure C.3, Panel (a), the solid line depicts the relationship between counterfactual earnings in state 0 and the probability of positive earnings when a kink is present in state 1 and there is a fixed cost of adjustment on the intensive margin. The slope of the employment rate now discontinuously changes at z^*, where the ANTR also changes slope (see Gelber et al. (2021) for an extended discussion), but the *level* of the employment rate is still continuous at z^*. We note again that this result holds as well for preferences with loss aversion over benefits, so long as the gain-loss utility component is continuous at the reference benefit.

We now turn to the case of a notch. In this final case, we do observe a discontinuity in the employment rate at z^*:

Proposition 3. *If individuals face a fixed cost of adjust earnings on the intensive margin, i.e. a utility cost of ϕ if $\tilde{z}_{n1} \neq \tilde{z}_{n0}$, the employment probability, as a function of earnings in state 0, will now exhibit a discontinuity at z^* in the presence of a sufficiently large notch:*

$$\begin{aligned}\lim_{\tilde{z}_{n0} \to z^{*+}} \Pr\left(z_{n1} > 0 \middle| \tilde{z}_{n0}\right) - \lim_{\tilde{z}_{n0} \to z^{*-}} \Pr\left(z_{n1} > 0 \middle| \tilde{z}_{n0}\right) =& G(\bar{q}_{n^*0} - \phi | n^*) - G(\bar{q}_{n^*0} | n^*) \\ \approx& \eta \cdot \left(\frac{-\phi'/z^*}{1-a}\right) \Pr\left(z_{n1} > 0 | \tilde{z}_{n^*0}\right),\end{aligned}$$

where n^* denotes the agent for whom $\tilde{z}_{n0} = z^*$, the final line follows from a first-order approximations of $G(\cdot)$, $\phi' \equiv \phi/\lambda_{n^*0}$ is the utility cost of adjustment scaled by the marginal utility of consumption, i.e. the dollar equivalent, η is the extensive margin elasticity, and $1-a$ is the average net-of-tax-and-transfer rate at z^*.

To show this result, first note that the critical value for entry costs converges to $\bar{q}_{n^*0}$ as we approach $\tilde{z}_{n0} = z^*$ from the left, and thus, the employment probability converges to $G(\bar{q}_{n^*0}|n^*)$. Now consider agents just to the right of z^* in the absence of the notch. Unlike the case of the kink, these agents face a first-order utility loss should they not move to z^*, and this utility cost does not vanish as we get arbitarily close to z^*. If the utility cost exceeds the intensive margin adjustment cost, ϕ, the these agents will pay the cost and move to z^*. It is in this sense that we need a "sufficiently large" notch. Formally, for a notch in benefits of $-dB$, we require:

$$u(z^* - T_1(z^*) + B_0, z^*; n^*) - u(z^* - T_1(z^*) + B_0 - dB, z^*; n^*) > \phi \tag{C.9}$$

In words, the utility gain from bunching must exceed the cost of adjustment, which is likely the case if agents perceive a notch equal to a 50 percent reduction in Social Security benefits. Once agents just to the right of the z^* bunch, they receive the same utility as those just to the left of the notch, save for the additional utility cost of adjustment that is incurred. Thus, the critical value for entry cost for the bunchers will be lower, at $\bar{q}_{n^*0} - \phi$, which results in a employment probability of $G(\bar{q}_{n^*0} - \phi|n^*)$. Finally, to show the final expression in terms of an extensive margin elasticity, note:

$$\begin{aligned} \eta \equiv& \frac{\partial \Pr(z > 0|\tilde{z}_{n0})}{\partial(1-a)} \frac{1-a}{\Pr(z > 0|\tilde{z}_{n0})} \\ =& g(\bar{q}) \frac{\partial \bar{q}}{\partial(1-a)} \frac{1-a}{\Pr(z > 0|\tilde{z}_{n0})} \\ =& g(\bar{q}) \cdot \lambda z \cdot \frac{1-a}{\Pr(z > 0|\tilde{z}_{n0})} \end{aligned} \tag{C.10}$$

where λ is the marginal utility of consumption, and in the last line, we used the fact that:

$$\begin{aligned} \bar{q} =& v(c(z), z; n) - v^0 \\ =& v((1-a)z, z; n) - v^0 \\ \Rightarrow \frac{\partial \bar{q}}{\partial(1-a)} =& z \cdot v'((1-a)z, z; n) \\ =& \lambda z \end{aligned}$$

and in the third line, behavioral responses to the change in $(1-a)$ cancel out, due to the envelope theorem.

Next, we use a first-order approximation for $G(\cdot)$:

$$\begin{aligned} G(\bar{q}_{n^*0}-\phi|n^*)-G(\bar{q}_{n^*0}|n^*) \approx & g(\bar{q}_{n^*0}|n^*)\cdot(\bar{q}_{n^*0}-\phi-\bar{q}_{n^*0}) \\ =& -\phi\cdot g(\bar{q}_{n^*0}|n^*) \\ =& \eta\cdot\left(\frac{-\phi/\lambda_{n^*0}z^*}{1-a}\right)\cdot\Pr\left(z_{n1}>0|\tilde{z}_{n^*0}\right) \\ =& \eta\cdot\left(\frac{-\phi'/z^*}{1-a}\right)\cdot\Pr\left(z_{n1}>0|\tilde{z}_{n^*0}\right) \end{aligned}$$

where in the second-to-last line we used the expression for η derived above. In words, the discontinuity equals the elasticity of employment with respect to the net-of-tax-and-transfer rate times the percent change in the effective net-of-tax-and-transfer rate, multiplied by the baseline employment rate. The discontinuity in this case is illustrated in the solid line in Figure C.3, Panel (b). The solid line shows a discontinuity in the level of employment at z^*, in the case of a kink, driven by the discontinuity in the ANTR in Figure C.2. Intuitively, adjustment frictions mean that the intensive margin responses that were previously done to smooth out the nonlinearity now have first-order costs, even for very small adjustments.

C.6 Deriving equation (8)

Consider an agent with counterfactual earnings, in the absence of the Earnings Test, $\tilde{z}_{n0}\in[z^*,z^*+\triangle z^D]$. Denote $v(c_0(\tilde{z}_{n0}),\tilde{z}_{n0};n)$ as utility, conditional on working and net of entry costs, q_n, for this agent, in the absence of the Earnings Test or perceived notch. Likewise, denote $v(c_1(z^*),z^*;n)$ as the corresponding utility level, net of adjustment costs, ϕ, and entry costs, q_n, if the agent were to bunch at z^* after the Earnings Test is introduced. The change in the probability of positive earnings for this agent will be:

$$\begin{aligned} \triangle\Pr(z>0|\tilde{z}_{n0}) =& G(\bar{q}_{n1}|n)-G(\bar{q}_{n0}|n) \\ =& G(v(c_1(z^*),z^*;n)-\phi-v_0|n)-G(v(c_0(\tilde{z}_{n0}),\tilde{z}_{n0};n)-v_0|n) \\ \approx& g(\bar{q}_{n1}|n)\cdot(v(c_1(z^*),z^*;n)-\phi-v(c_0(\tilde{z}_{n0}),\tilde{z}_{n0};n)) \\ =& g(\bar{q}_{n1}|n)\cdot(-\phi-(v(c_0(\tilde{z}_{n0}),\tilde{z}_{n0};n)-v(c_1(z^*),z^*;n))) \\ =& \eta\cdot\left(\frac{-\phi-(v(c_0(\tilde{z}_{n0}),\tilde{z}_{n0};n)-v(c_1(z^*),z^*;n))}{(1-\tau)\lambda z^*}\right)\cdot\Pr(z>0|\tilde{z}_{n0}) \\ =& \eta\cdot\left(\frac{-\phi'/z^*-\triangle_\lambda v(\tilde{z}_{n0})/z^*}{1-\tau}\right)\cdot\Pr(z>0|\tilde{z}_{n0}) \end{aligned}$$

It follows that the percent change in employment will be:

$$\frac{\triangle\Pr(z>0|\tilde{z}_{n0})}{\Pr(z>0|\tilde{z}_{n0})}=\eta\cdot\left(\frac{-\phi'/z^*-\triangle_\lambda v(\tilde{z}_{n0})/z^*}{1-\tau}\right)$$

Note, we know that $\triangle_\lambda v(\tilde{z}_{n0})>0$, because both $\tilde{z}_{n0}$ and z^*, and their corresponding consumption levels, are in the choice set of the agent facing a linear tax of τ, and the former is chosen over the latter to maximize utility.

In order to calculate this change, we must place some structure on the utility function. We assume utility if working follows a constant-elasticity, quasi-linear form:

$$v(c, z; n) = c - \frac{n}{1 + 1/\varepsilon} \left(\frac{z}{n}\right)^{1+1/\varepsilon}, \tag{C.11}$$

where ε is the intensive margin elasticity. This form implies that $\tilde{z}_{n0} = n(1-\tau)^{\varepsilon}$, and utility at optimal earnings (absent the earnings test) is:

$$\begin{aligned} u_0(\tilde{z}_{n0}) =& v\left(c_0(\tilde{z}_{n0}), \tilde{z}_{n0}; n\right) - \phi - q_n \\ =& B_0 + (1-\tau)\tilde{z}_{n0} - \frac{n}{1+1/\varepsilon}\left(\frac{\tilde{z}_{n0}}{n}\right)^{1+1/\varepsilon} - q_n \\ =& B_0 + (1-\tau)\tilde{z}_{n0} - \frac{\tilde{z}_{n0}/(1-\tau)^{\varepsilon}}{1+1/\varepsilon}\left(\frac{\tilde{z}_{n0}}{\tilde{z}_{n0}/(1-\tau)^{\varepsilon}}\right)^{1+1/\varepsilon} - q_n \\ =& B_0 + \frac{(1-\tau)\tilde{z}_{n0}}{1+\varepsilon} - q_n \end{aligned}$$

where in the second line we substituted for n using $\tilde{z}_{n0} = n(1-\tau)^{\epsilon}$.

And for the set of earners for whom it would be optimal to bunch, were they to keep working, utility in the presence of the notch would be:

$$\begin{aligned} u_1(\tilde{z}_{n0}) =& v\left(c_1(z^*), z^*; n\right) - \phi - q_n \\ =& B_0 + (1-\tau)z^* - \frac{n}{1+1/\varepsilon}\left(\frac{z^*}{n}\right)^{1+1/\varepsilon} - \phi - q_n \\ =& B_0 + (1-\tau)z^* - \frac{\tilde{z}_{n0}/(1-\tau)^{\varepsilon}}{1+1/\varepsilon}\left(\frac{z^*}{\tilde{z}_{n0}/(1-\tau)^{\varepsilon}}\right)^{1+1/\varepsilon} - \phi - q_n \end{aligned}$$

These expressions can be plugged into the formula for the percent change in the employment probability. Note, in the case of quasilinear utility, we have $\lambda = 1$.