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MEASURING “SCHMEDULING”

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ABSTRACT

What mental models do individuals use to approximate their tax schedule? Using an incentivized income-tax forecasting task, we estimate the prevalence of the “schmeduling” heuristics for constructing mental representations of nonlinear incentive schemes. We find evidence of widespread adoption of the “ironing” heuristic, which linearizes the tax schedule using one’s average tax rate. In our preferred specification, 43% of the population irons. We find no evidence of adoption of the “spotlighting” heuristic, which linearizes the tax schedule using one’s marginal tax rate. We show that the presence of ironing rationalizes a number of empirical patterns in individuals’ perceptions of tax liability across the income distribution. Furthermore, while our empirical framework accommodates a rich class of other misperceptions, we find that a simple model including only ironers and correct forecasters accurately predicts average underestimation of marginal tax rates. This paves the way for tractably incorporating tax misperceptions into standard analysis of income tax reforms. As an illustration, we show that ironing augments the benefits of progressive taxation in a standard model of earnings choice. We quantify these benefits in a calibrated model of the U.S. tax system.

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1 Introduction

Financial incentives often feature nonlinearities, leading to complex decision environments. Economic models of fully optimizing and fully informed decision-makers offer a rationale for this complexity: in the presence of information asymmetries, standard results in mechanism design show that the optimal incentive scheme is often nonlinear. In practice, however, understanding these incentives appears to be difficult for many decision-makers. For example, the challenge inherent in optimizing against a nonlinear price schedule is starkly apparent in insurance plan choice (Bhargava et al., 2017), cell-phone usage (Grubb and Osborne, 2015), and water and energy consumption (Carter and Milon, 2005; Ito, 2014). In the context of taxation, a growing literature documents behavior inconsistent with full optimization with respect to tax credits (Miller and Mumford, 2015; Feldman et al., 2016; Chetty and Saez, 2013; Chetty et al., 2013), and surveys of taxpayers document misunderstanding of features of the income tax schedule (reviewed in section 2.2).[1]

Accounting for these imperfections in individual decision-making necessarily complicates policy analysis, particularly because suboptimal responses can be widely varied. However, in cases where people rely on a small set of parsimoniously-modeled heuristics, it is conceptually possible to integrate such behaviors into a tractable framework for policy analysis. Implementing such a framework requires specifying the candidate models of individuals' imperfect reaction to incentives, measuring each model's propensity, and then integrating these models into an otherwise standard economic framework.

In this paper, we undertake this task for two potentially focal approaches to simplifying a nonlinear incentive schedule: the models of "ironing" and "spotlighting" discussed and popularized in Liebman and Zeckhauser's "Schmeduling" (2004). These models build on the wealth of evidence that individuals often simplify assessments by unduly relying on a small set of salient features (see, e.g., Tversky and Kahneman, 1974; Kahneman, 2000; Ariely, 2001). Given a nonlinear schedule, both heuristics construct mental models in which the schedule is linear. When applying the spotlighting heuristic, the individual assumes that the slope of the linearized schedule is equal to his marginal incentive. When applying the ironing heuristic, the individual assumes that the slope of the linearized schedule is equal to his average incentive. These heuristics—and in particular ironing—capture the pervasive difficulty of "thinking on the margin,"[2] and can be psychologically grounded in individuals' tendency to treat sample statistics as applicable beyond their own narrow domain (see, e.g., Fiedler and Juslin, 2006).

Due in part to their intuitive appeal, the schmeduling heuristics are often suggested as potential mechanisms underlying misoptimized responses to tax incentives (see, e.g., Congdon et al., 2009;

[1] Individuals also appear to incur large cognitive costs from complex tax filing (see, e.g., Benzarti, 2017; Aghion et al., 2017).

[2] The difficulty of thinking on the margin should be apparent to anyone who has taught undergraduate microeconomics classes. Beyond such anecdotes, this difficulty has been documented in high-stakes managerial decisions about product pricing (see, e.g., Altomonte et al., 2015).

Finkelstein, 2009; Chetty et al., 2009; Miller and Mumford, 2015; Rees-Jones and Taubinsky, 2018). But despite the frequent discussion of these heuristics in the behavioral public economics literature, few studies inform schmeduling's degree of empirical relevance as an account of tax perceptions. Evidence from lab behavior (de Bartolome, 1995) and from labor-supply responses to lump-sum transfers (Feldman et al., 2016) both suggest some uptake of the ironing heuristic. However, existing work on ironing does not inform its relative propensity amongst taxpayers or the portion of systematic misperceptions that it explains—both crucial questions for assessing the consequences of ironing for tax reform (Farhi and Gabaix, 2017). In the case of spotlighting, we know of no qualitative or quantitative tests in tax settings.

In this paper, we propose and implement a survey-experimental approach to identifying the propensity of the schmeduling heuristics. Existing methods to identify the use of the ironing heuristic from behavior (e.g., Ito, 2014) rely on rich quasi-experimental variation of the schedule that is unavailable for income taxes. Spotlighting is even more difficult to identify from behavior, since its adopters correctly assess marginal taxes. Existing survey approaches to assessing tax understanding generally assess knowledge of a few features of the tax schedule, such as average or marginal tax rates, which cannot firmly separate the use of these heuristics from other candidate forms of misunderstanding. The key innovation of our approach arises from the observation that direct elicitation of individuals' perceptions of broader regions of the tax schedule is extremely useful in identifying the schmeduling heuristics.

In section 2 we derive a series of distinguishing predictions that may be tested when perceptions of broader regions of the tax schedule are elicited. These predictions describe the biases that arise when forecasting one's own marginal tax rate, the steepness of the tax schedule over a broader region of incomes, the tax liabilities of the relatively rich and the relatively poor and, importantly, how all of these forecasts evolve with the respondent's own income. For example, the ironing heuristic leads individuals to overestimate the taxes paid by low income earners and underestimate the taxes paid by high income earners, though the overall perception of the tax burden on both the poor and the rich is increasing in individuals' incomes. Conversely, the spotlighting heuristic leads to average underestimation of all tax burdens, with perceptions of the taxes paid by the poor decreasing in respondents' incomes. Furthermore, we show that measurements of these kinds of perceptions allow the relative propensity of each schmeduling heuristic to be separately identified from a rich class of other candidate misunderstandings.

In section 3, we describe the design of our experiment. We deployed an incentivized tax-forecasting task to an approximately representative sample of 4,197 U.S. taxpayers. Respondents forecast the tax due by an example taxpayer constructed to be very similar to themselves. Forecasts are repeatedly elicited for different potential income amounts for the example taxpayer, facilitating inference on the structure of the schedule that the respondents believe is in place.

In section 4, we examine the basic structure of perceptions of the tax schedule. Consistent with prior work, we find that taxpayers underestimate the marginal tax rates that apply in their own tax brackets. Examining perceptions beyond the respondent's own bracket, we find a systematic tendency to overestimate the taxes paid by the comparatively poor, to a degree that becomes more severe as respondents' own income increases. Conversely, we find a systematic tendency to underestimate the taxes paid by the comparatively rich, to a degree that becomes less severe as respondents' own income increases. Taken together, these results are largely consistent with the predictions of ironing, are inconsistent with the predictions of spotlighting, and cannot be explained by a model in which taxpayers underestimate the progressivity of the tax schedule in a manner that is not shaped by the taxes that they pay themselves.

Motivated by these reduced-form results, we estimate a structural model of tax perceptions that embeds populations of ironers, spotlighters, correct forecasters, and a rich class of other candidate mistakes. We find that tax perceptions are best explained by a model with approximately 43% of filers adopting the ironing heuristic and no filers adopting the spotlighting heuristic. The remaining filers appear to overestimate taxes on most of the population by a relatively constant amount, and underestimate taxes applicable to the top 5 percent of the population. On average, these remaining filers have perceptions of marginal tax rates not far off from the truth.

Despite the many different ways in which taxpayers could misperceive taxes, we find that a model accounting for only our estimated rate of ironing is able to precisely explain the systematic underestimation of marginal tax rates in one's own tax bracket. This result holds not only when ironing propensity is estimated using our full sample of elicited perceptions, but also in an out-of-sample fit assessment that estimates schmeduling propensity while excluding forecasts from the respondent's own bracket. This validates our use of individuals' perceptions of broader regions of the tax schedule to help estimate the heuristic processes that govern more local perceptions. Furthermore, this suggests that a parsimonious two-type model of ironers and correct forecasters provides a satisfactory account of systematic marginal tax rate misperceptions.

We document the sensitivity of our estimates to a variety of sample restrictions. Our empirical results persist when analyzing taxpayers with comparatively high incentives for accurate tax knowledge, such as the employed, those who complete their returns without outside assistance, and those of comparatively high income. Our results persist among respondents who might be suspected to be debiased, such as those who complete our survey after tax day, those of comparatively high age (and thus comparatively high experience with the tax system), or those of comparatively high confidence in their answers. They are robust to alternative assumptions about respondents' ability to disentangle federal income taxes from other taxes that appear on pay stubs, such as state or FICA taxes. And they are robust to restrictions of the sample to those who do and do not perfectly resemble our hypothetical taxpayer. Across the restrictions we consider, the estimated subgroup propensity to iron ranges from 24% to 58%; indicating widespread and cross-group prevalence. Across these robustness checks we continue to find no evidence of spotlighting.

In section 5, we illustrate the implications of our findings for tax policy. We embed a population of ironers in an otherwise standard model of income taxation building on, e.g., Mirrlees (1971) and Saez (2001). In this model, ironing increases the welfare attained under a convex tax schedule, since reliance on this heuristic generates revenue in a progressive fashion. For the U.S. income tax system, our preferred estimates imply that the presence of ironing increases welfare by an amount equivalent to a 2.3% windfall in available government revenue—a quantitatively large effect both in absolute and relative terms.[3] Moving to analysis of policy reform, we find that ironing increases the welfare costs of moving toward a flat tax. Because ironers do not underestimate marginal tax rates in a flat tax system, moving to this system generates the additional cost of eliminating the welfare-enhancing mistakes created by ironing. Our preferred estimates suggest that ironing increases the welfare costs of moving from the U.S. tax schedule to a revenue-equivalent flat tax by 14%. Moving to analyses in the tradition of Saez (2001) (and their behavioral extensions in Farhi and Gabaix, 2017), we find that our estimated prevalence of ironing substantially increases the optimal top marginal tax rate.

Of course, predicting field behaviors from survey measurements of beliefs must be done with caution. In section 6, we conclude by highlighting what we view as the primary considerations of external validity when evaluating the implications of our results for policy analysis. To the extent that the expected utility model is an "as-if" depiction of more complex cognitive processes, inferring "unbiased" choices by replacing subjective beliefs with objective ones may be problematic (Bernheim and Taubinsky, 2018). Relatedly, and as with most other heuristics, the propensity to schmedule may be shaped by context, which may vary between our survey study and the income-generating decisions our work informs. We highlight the elements of our analysis that we view as most, and least, susceptible to external validity concerns, summarize the generalizable lessons for tax policy, and highlight productive paths for further research.

While economists traditionally favor revealed-preference analysis, recent works have argued that direct belief elicitation serves a key function in economics: reported beliefs can often discriminate between models that are indistinguishable from observed behavior alone (Manski, 2004; Gennaioli et al., 2016). We contribute to two distinct lines of research applying this logic to questions in public economics. First, our paper contributes to the existing literature on direct elicitation of tax perceptions (e.g., Fujii and Hawley, 1988) in two ways. First, by providing more powered estimates of marginal tax rate underestimation using improved elicitation methods. Second, and perhaps most importantly, by leveraging elicited perceptions of taxes on incomes outside of one's bracket to identify the mechanisms driving tax rate misunderstanding. Additionally, we relate to a recent literature that elicits individual beliefs about, and preferences over, inequality (see, e.g., Cruces et al., 2013; Weinzierl, 2014; Kuziemko et al., 2015; Weinzierl, 2017; Alesina et al., 2018). This literature studies individual's preferences for redistribution and their determinants. In contrast,

[3]To illustrate, 2.3% of individual income tax return revenue in our year of study amounts to 32 billion dollars—approximately half of the cost of programs such as the Earned Income Tax Credit ($68 billion in 2014) or the child tax credit ($57 billion in 2014); for details and other useful benchmarks, see Congressional Budget Office (2013).

we study individuals' understanding of the economic incentives generated by the tax systems in place—a necessary component for the integration of misperceptions into optimal tax policy analysis (Farhi and Gabaix, 2017).[4]

2 "Schmeduling" and its Predictions

2.1 Definitions

Liebman and Zeckhauser (2004) propose two compelling heuristics for decision-making with a non-linear incentive schedule like the income tax. In summarizing these heuristics, we denote perceived income tax schedules by $\tilde{T}(z|z^*)$, and the true income tax schedules by $T(z)$. These report the tax due as a function of income (z), given the individual's chosen income (z^*).

Definition 1. The ironing heuristic arises when an individual uses the average price at the point where he consumes to forecast prices at other consumption levels. In the tax context, this corresponds to an individual knowing his average tax rate and applying that rate to any amount of income. Formally, $\tilde{T}_I(z|z^*) = \frac{T(z^*)}{z^*} \cdot z$.

As illustrated in Figure 1, use of the ironing heuristic corresponds to approximating the non-linear tax schedule with a secant line drawn through one's own position on the schedule and the origin. As noted in Liebman and Zeckhauser, the adoption of this heuristic can be rationalized given the manner in which tax information is often conveyed to taxpayers. Paystubs typically present one's gross earnings and the subtracted tax withholdings, making the average tax salient and leaving the marginal tax rate unknown. Furthermore, at the time of completion of annual tax returns, filers must calculate both their totally annual taxable income as well as the total annual tax due, again inviting assessment of the average tax rate. Taxpayers who find these numbers more accessible could conceivably adopt this forecasting rule as a time-saving heuristic, allowing them to approximate their own position on the schedule while accessing only a single, salient number. Despite its convenience, reliance on this heuristic would result in misoptimized labor supply choices on the intensive margin.

Definition 2. The spotlighting heuristic arises when an individual uses the local slope of his price schedule to forecast prices at non-local levels. In the tax context, this corresponds to an individual acting as if his own tax bracket extends to other regions of the tax schedule. Formally, $\tilde{T}_S(z|z^*) = T(z^*) + T'(z^*) \cdot (z - z^*)$.

As illustrated in Figure 1, use of the spotlighting heuristic corresponds to approximating the non-linear tax schedule with a tangent line drawn through one's own position on the schedule. Use of

[4] Kuziemko et al. (2015) have one question pertaining to perceptions of tax rates: whether the top income tax rates today are higher or lower than what they were in the 1950s and 1960s.

this heuristic can be rationalized by noticing that some individuals might take the time to learn their own local region of the tax schedule—for example, by noting their past-years' tax burden and by looking up their statutory marginal tax rate—but might mistakenly forecast these local parameters beyond the narrow region to which they apply. Compared to the ironing heuristic, the usage of the spotlighting heuristic is somewhat more cognitively demanding, as it is requires knowledge of two idiosyncractic parameters (one's tax burden and marginal tax rate) rather than just one (the average tax rate, in the case of ironing). Although this heuristic leads to (approximately) optimized labor supply choices on the intensive margin, it would lead to incorrect labor supply choices on the extensive margin.[5]

The structure of these heuristics can be founded in a recent psychological literature that likens human judgments to those of a "naive intuitive statistician" (Fiedler and Juslin, 2006). This literature argues that decision makers are often able to form reasonably accurate forecasts of simple sample properties, such as frequencies or averages (for early examples, see Spencer, 1961, 1963). However, they often fail to account for sampling biases or constraints in such judgments. As summarized in Juslin et al. (2007), "people tend spontaneously to assume that the samples they encounter are representative of the relevant populations." Both schmeduling heuristics may be considered specific examples of this general decision error. The decision-maker correctly assess the average tax rate over either all dollars earned that year (in the case of ironing) or over small changes to his own income (in the case of spotlighting), but then incorrectly applies this average as the range is changed in a manner rendering their previously considered sample nonrepresentative. While this psychological tendency is far broader than this application, the assessment presented here provides an examination of some of its specific consequences in policy domains.

2.2 Predictions of Schmeduling

We now formalize a series of predictions aimed at illustrating the features of tax perceptions that do, or do not, distinguish between these heuristics. In principle, the use of these heuristics can be examined at the individual level (related analyses will be presented in section 4.4). However, in practice, common imperfections in survey responses—such as measurement error or rounding heuristics—can substantially confound individual-level analyses. These issues lead us to formulate our predictions with respect to the average tax schedule perceived by a population of heuristic forecasters, under the assumption that such errors will "average out."

We first analyze predictions about the levels of misperceptions, and then analyze predictions about the slope of the misperceptions. We document these predictions for the empirically-relevant case of progressive—i.e., convex—tax schedules.

Prediction 1. Perceptions of taxes on low- and high-income filers.

[5] See, e.g., Saez (2002b) for a theory and quantification of the importance of extensive margin elasticities.

1-I: Ironers overestimate the taxes paid by low-income filers and underestimate the taxes paid by high-income filers.

1-S: Spotlighters underestimate the taxes paid by both low- and high-income filers.

The reasoning behind Prediction 1 is apparent in Figure 1. At the individual-level, ironers overestimate the taxes due for individuals with lower earnings than their own and underestimate the taxes due for individuals with higher earnings than their own. When averaging the perceived schedules of a population of ironers, this results in Prediction 1-I, with low- and high-income evaluated relative to an appropriately weighted average of the incomes of the tax forecasters. In contrast, the forecast corresponding to the spotlighting prediction is always below the true taxes due at the individual level, resulting in Prediction 1-S.

Prediction 2. Perceptions of taxes on low- and high-income filers, by own income.

2-I: Higher-income ironers exhibit more overestimation of the taxes paid by low-income filers and less underestimation of taxes paid by high-income filers.

2-S: Higher-income spotlighters exhibit more underestimation of the taxes paid by low-income filers and less underestimation of taxes paid by high-income filers.

The reasoning behind Prediction 2 is again apparent in Figure 1. As the ironer's income is increased, the slope of the secant line increases, directly leading to Prediction 2-I. As the spotlighter's income is increased, the tangent line rotates upward, leading to Prediction 2-S.

We now consider how the schmeduling heuristics influence perceptions of the steepness of the tax schedule, both locally and more globally.

Prediction 3. Perceptions of marginal tax rates (MTRs).

3-I: Ironers underestimate their own MTR.

3-S: Spotlighters correctly estimate their own MTR.

Claim 3-S follows immediately from the definition of spotlighting: by assumption, spotlighters know and apply their MTR. Turning to Prediction 3-I, we note that the definition of ironing does not fundamentally require underestimation of MTRs, but that this underestimation arises for progressive tax schedules, in which average tax rates (ATRs) are always lower than MTRs.

As a means of characterizing perceptions of the "steepness" of a broader region of the tax schedule, it is convenient to define the *perceived slope* over income range $[z_1, z_2]$ to be $\frac{\tilde{T}(z_2|z^*)-\tilde{T}(z_1|z^*)}{z_2-z_1}$, and the *actual slope* to be $\frac{T(z_2)-T(z_1)}{z_2-z_1}$.

Prediction 4. Perceived slope of tax schedule.

4-I: Consider income range $Z = [\underline{z}, \bar{z}]$ which satisfies $z_i^* \in Z$ for all individuals i. Evaluated over Z, ironers' perceived slope underestimates the actual slope.

4-S: Consider income range $Z = [\underline{z}, \bar{z}]$ which satisfies $z_i^* \in Z$ for all individuals i. There exists a threshold $z^\dagger \in Z$ such that spotlighters earning $z_i^* \leq z^\dagger$ underestimate the actual slope over Z, whereas spotlighters earning $z_i^* > z^\dagger$ overestimate the actual slope.

As illustrated in Figure 1, the use of the ironing heuristic results in a linear approximation to the schedule that ultimately is shallower than the schedule itself. Since the schedule is convex, treating ones' average tax rate as the relevant slope for higher income values will result in an approximate schedule that underestimates the highest taxes due, and concurrently is "flatter" than the true schedule. In contrast, spotlighters' perceptions of the average slope of the full tax schedule depend more critically on their own income. For lower-income individuals, one's own marginal tax rate can be lower than the average slope of the entire schedule. However, for sufficiently high-income individuals, this effect reverses, leading spotlighters to overestimate the average slope. This contrast is displayed in the two examples of Figure 1.

Moreover, because both marginal and average tax rates are rising with one's own income in a progressive tax system, the perceived slope over an income range will be increasing in the schmeduler's income:

Prediction 5. Perceived slope of tax schedule, by own income.

5-I: Ironers' perceived slope over income range Z is increasing in their earnings, z^*.

5-S: Spotlighters' perceived slope over income range Z is increasing in their earnings, z^*.

While Prediction 5 does not distinguish between the use of the two heuristics, it does clearly differentiate their use from correct forecasting, or from forecasting based on misperceptions of the schedule that are not tied to one's earnings.

Summary of Existing Survey Evidence: Perceptions of the income tax have long been of interest in public finance, with a literature on the survey measurement of these perceptions extending back at least to the 1960s. Table 1 provides a summary the relevant survey literature and indicates the schmeduling predictions that this these papers inform. The different objectives of these papers lead them to collect data of limited use in identifying the uptake of the schmeduling heuristics. For example, early papers in this literature (Enrick, 1963, 1964; Wagstaff, 1965) assess if taxpayers know the size of their own tax bill—a feature of tax perceptions for which ironing, spotlighting, and correct forecasting all make the same prediction.[6] Later papers became more interested in assessing taxpayers' understanding of their marginal tax rate, which permits an assessment of Prediction 3. The early works of Gensemer et al. (1965) and Brown (1969) document substantial misperceptions of

[6] For recent work further examining perceptions of average tax rates, see Ballard and Gupta (2018).

marginal tax rates, with Brown documenting a tendency towards marginal tax rate overestimation. Subsequent studies with substantially larger samples have found average underestimation (Lewis, 1978; Fujii and Hawley, 1988), consistent with Prediction 3-I and rejecting Prediction 3-S.[7] However, viewed in isolation, such findings do not clearly establish ironing as the mechanism driving this underestimation.

Fewer results are available to assist in assessing Predictions 1, 2, 4, or 5. Blaufus et al. (2015) ask a panel of German respondents about their perceptions of the taxes paid by those earning 10,000, 40,000, 300,000, or 2 million euros a year. They find evidence that the tax burden is overestimated at the bottom of the scale and underestimated at the top of the scale, consistent with Prediction I-1. Gideon (2017) finds that survey respondents tend to underestimate the top marginal tax rate, a feature that could lead to underestimation of taxes paid by the rich (as in 1-I) and could arise from an underestimation of slope of the full tax schedule (as in 4-I). Beyond results such as these, this literature's focus on perceptions of taxes at a smaller number of very specific, typically local points results in a general inability to test the nuanced predictions that firmly separate the schmeduling heuristics from other potential mechanisms. This motivates the design of our experiment, eliciting the key class of data absent from this work: perceptions of taxes over a broader variety of incomes, sampled with continuous support.

2.3 Identifying Schmeduling Propensities

Eliciting perceptions over a broader range of the tax schedule allows not only new reduced-form tests but, perhaps more importantly, identification of the mechanisms that are driving potential misperceptions. Formally, we characterize the average perceived tax schedule as a mixture model of forecasting types, given by

$$E[\tilde{T}(z|z^*)|z, z^*] = \gamma_I \tilde{T}_I(z|z^*) + \gamma_S \tilde{T}_S(z|z^*) + \sum_k \omega_k \tilde{T}_k(z) + (1 - \gamma_I - \gamma_s - \sum_k \omega_k) T(z). \tag{1}$$

In this model, γ_I denotes the fraction of individuals using the ironing heuristic and γ_S denotes the fraction of individuals using the spotlighting heuristic. Non-schmeduling taxpayers may hold alternative perceptions of the schedule (captured by the term $\sum_k \gamma_k \tilde{T}_k(z)$), with the remainder of taxpayers adopting the correct tax schedule. We aim to make minimal assumptions about the structure of the alternative misperceptions beyond explicitly specifying that they are not a function of earnings choice, and thus are not a function of either the individual's average or marginal tax rate. Misperceptions of this sort could correspond to, e.g., average overestimation of the tax burden or a general tendency to underestimate marginal tax rates. For example, $\tilde{T}_k$ could correspond to

[7] In more nuanced recent work, Gideon (2017) examines the accuracy of marginal tax rate perceptions across the income distribution. He finds average underestimation of marginal tax rates for respondents with gross income exceeding \$50,000, and average overestimation for those of lower income.

underestimation of all MTRs by 50%; that is, $\tilde{T}_k = t_0 + \frac{1}{2}T$, for some constant $t_0 \in \mathbb{R}$. Note that although we think it most psychologically natural to consider γ_I and γ_S as probabilities of pure ironing or spotlighting types, we could instead interpret these parameters as weights in a representative agent model of partial ironing and spotlighting.

To obtain intuition for the data requirements for identifying equation (1), consider first a dataset in which only perceptions of respondents' own MTR (i.e., $\frac{d}{dz}E[\tilde{T}(z|z^*)|z,z^*]|_{z=z^*}$) are measured. Such observations are plainly insufficient to separately identify γ_I, γ_S, and $\sum_k \omega_k \tilde{T}_{r,k}(z|\theta)$. To illustrate, note that correct average perceptions of MTRs could arise from correct tax forecasting, or from spotlighting, or from some individuals underestimating their own MTRs due to ironing while others over-estimate MTRs in a perfectly offsetting manner. As another example, consider a group of individuals facing an average tax rate of 10% and an MTR of 20%, but perceiving their MTR to be 15%. Such perceptions could be rationalized by a 50-50 mixture of correct forecasters and ironers. However, they could also be rationalized by a 50-50 mixture of correct forecasters and individuals who simply underestimate *all* MTRs by half; or by a 3:1 mixture of correct forecasters and individuals who underestimate *all* MTRs by 75%.

This indeterminacy may be resolved by directly eliciting beliefs about $\tilde{T}(z|z^*)$ across a joint distribution of (z, z^*) spanning the relevant range of each variable's support. With such data, the analyst has access to the empirical moment $\frac{d}{dz}E[\tilde{T}(z|z^*)|z,z^*]$ not only at only points where $z = z^*$, but rather for all relevant combinations of (z, z^*). This, in turn, provides access to $\frac{d^2}{dzdz^*}E[\tilde{T}(z|z^*)|z,z^*]$—i.e., the rate of change of MTR perceptions as respondents' own income changes. Since both models of schmeduling offer different, full accounts of the structure of this cross derivative, and since either correct forecasting or our position-independent alternatives require that this second derivative be zero at all points, this proves sufficient to identify both γ_I and γ_s. Conditional on such estimates, the average of all other perceived schedules is identified by the "residual" structure of $E[\tilde{T}(z|z^*)|z,z^*]$ unexplained by the estimated schmeduling propensity. This illustrates the identifying power of tax perceptions elicited over a broader support of (z, z^*), and motivates our design of an experiment capturing such perceptions.

3 Experimental Design

We administered our experiment during the tax season of 2015. From March 15th through May 17th, respondents were recruited for a brief[8] web survey hosted on the Qualtrics platform, with recruitment targeting similar sample sizes in all weeks of this sampling window. Subject recruitment was managed by ClearVoice Research, a market research company that maintains a large, national population of respondents willing to take brief online surveys.[9] Respondents were recruited based

[8]Median completion time: 16 minutes. Interquartile range: 11-25 minutes.

[9]For other economic research making use of the ClearVoice panel, see Benjamin et al. (2014) or Taubinsky and Rees-Jones (Forthcoming).

on demographic data previously provided to ClearVoice, allowing us to generate a sample with demographics that approximate the national age, income, and gender distribution found in the U.S. census records (for tabulations of demographics in our sample and the census, see Appendix Table A1).

3.1 Experimental Protocol

The Qualtrics survey featured four modules. Screenshots of the full experiment are available in the Survey Appendix; we summarize the contents here.

Introductory Module: The first module elicited basic information about respondents' tax filing behavior, allowing us to construct a similar hypothetical tax filer in the forecasting module. Respondents were asked if they had already filed their tax return; who completed (or would complete) that tax return; their filing status; their exemptions claimed; if they claimed the standard or itemized deduction; their total income; if they filed each of schedule B through F; if they used TurboTax or similar software; if they or their spouse were born before January 2, 1950; and if they claimed the Earned Income Tax Credit.[10] Additionally, respondents were asked their degree of confidence in the key parameters determining their tax: their filing status, their exemptions, their deduction status, and their income. Confidence in these parameters was high. Given ratings options of "very confident," "somewhat confident," and "not confident at all," 96% of respondents were "very confident" in their filing status; 89% of respondents were "very confident" in their number of exemptions; 90% of respondents were "very confident" in their deduction status; 71% of respondents were "very confident" that their total income reported was within $1,000 of being correct.

Forecasting Module: The key questions for our empirical analysis were contained in the forecasting module. Respondents were presented with a variant of the following prompt, describing a hypothetical taxpayer whose filing behavior was very similar to their own:[11]

> This next group of questions is about Fred, a hypothetical taxpayer who is very similar to you. Fred is your age, and has a lifestyle similar to yours. Fred filed his 2014 Federal Tax Return claiming [own exemptions] exemption(s) and [own status] filing status, like you did. Fred also claimed the standard deduction, like you did.[12] However, Fred's tax computation is particularly simple, since all of his taxable income comes from his annual salary. He has no other sources of taxable income, and is not claiming additional credits or deductions.
>
> For the following questions, we will ask you to estimate the total federal income tax

[10]Respondents who claimed the Earned Income Tax Credit completed an additional brief battery of questions regarding their understanding of this tax provision.

[11]For respondents who had not yet completed their tax return, the verb tense was changed from past to future as appropriate.

[12]For filers not claiming the standard deduction, this sentence read: "Unlike you, Fred claimed the standard deduction."

> Fred would have to pay for different levels of total income. To help motivate careful thought about these questions, we are providing a monetary reward for correct answers. At the end of the survey, one of these questions will be chosen at random. If your answer to that question is within $100 of the correct answer, $1 will be added to your survey compensation.

Following this preamble, respondents made 16 forecasts of taxes due under different amounts of income, given the following prompt:

> If Fred's total income for the year were $[X], the total federal income tax that he has to pay would be:

The amounts of income substituted into the prompt above were drawn according to three sampling schemes. Ten forecasts were drawn from the "mid-range sampling distribution." This is a range of income values spanning all but the top of the national income distribution, sampling uniformly from $0 up to a point partially through the fourth tax bracket. This sampling pattern differs by filing status, leading us to present estimates separately by filing status in some of our analysis. Four forecasts were drawn uniformly from the "high-income sampling distribution," starting from the top of the mid-range income distribution and ranging to approximately $500,000. We call the sample of all 14 points the "full sampling distribution." Finally, two draws were included that guarantee the presence of some forecasts "close" to the respondent's own income. One draw substituted the respondent's own reported income for X above, while the second applied that income plus a random perturbation taking a value between 0 and 1,000.[13] When assessing respondents' knowledge of the tax schedule local to their own income, we will restrict data to the "local distribution" consisting of these two forecasts as well as any of the random forecasts that happen to fall in the respondent's own tax bracket. However, when we are not assessing questions about local tax perceptions, we exclude these two forecasts to preserve a random sampling structure.

Miscellaneous Questions: After the forecasting task, respondents faced a brief battery of miscellaneous questions. These included an elicitation of the salience of their income tax, assessments of their health and savings behaviors, an elicitation of their elasticity of charitable giving, the "big three" financial literacy questions of Lusardi and Mitchell (2014), an attention check, and a test of knowledge of their sales tax rate.

Incentives: On the final screen, one of the respondents' 16 tax forecasts was randomly selected for incentivization. They were told the correct answer, reminded of their own answer, and awarded the bonus payment if their response was within $100 of the truth.

[13] This value fell within the respondent's own tax bracket for all but 89 respondents.

3.2 Sample for Analysis and Dataset Preparation

Over the course of our sampling period, we collected 4,828 complete responses. We exclude responses according to several criteria. First, we exclude 5 responses with missing data on one or more of the tax forecasts. Second, we exclude 73 responses from individuals forecasting either 0 tax or 100% tax for all forecasts, as we believe this reporting pattern indicates either misunderstanding of the prompt or represents an attempt to quickly click through the survey without meaningfully responding to questions. Third, we restrict our sample to individuals reporting income ranging from zero to $250,000, excluding 117 respondents whose self-reported incomes are outside the typical range of the panel. Finally, we exclude 436 respondents who failed the attention check included in the miscellaneous questions module. To limit the influence of extreme tax forecasts, we conduct a rolling Winsorization of tax forecasts to the 1st and 99th percentile values in each $10,000 income bin.

This set of restrictions results in a final sample of 4,197 respondents, and a total of 58,758 forecasts of tax liability for randomly drawn incomes. In section 4.4, we analyze the robustness of our empirical results to these dataset construction decisions.

4 An Empirical Assessment of Tax Misperceptions

4.1 Reduced-Form Tests of Schmeduling

Systematic Over- and Under-Estimation (Schmeduling Predictions 1 and 2): To present an initial, non-parametric summary of income tax perceptions, Figure 2 plots a kernel-smoothed estimate of average perceived tax schedules. Since schedules are filing-status specific, we present estimates separately for the two largest filing-status groups: single and married filing jointly. The top panels present estimates restricted to the data from the ten income draws of the mid-range sampling distribution. The lower plots extend the support to include the four income draws from the high-income sampling distribution.

The top two panels illustrate two important features of perceived tax schedules. First, on average, the perceived tax schedule is qualitatively similar to the true tax schedule, though it displays some systematic error. For example, over the mid-range sampling range, respondents overestimate the tax burden by $679 (clustered s.e.: $185) on average, or 3.2 percentage points (clustered s.e.: 0.003pp) in effective tax rates. Standard errors are clustered at the respondent level.

Second, and perhaps more importantly, these plots also demonstrate that the sign of the average misperception depends on the amount of income that is being taxed. In both plots, the average perceived tax schedule appears more linear than the true schedule, with a tendency towards overestimation of the tax burden for low amounts of income and underestimation of the tax burden for high amounts of income. In the lower two plots of Figure 2, which present analyses including the high-income sampling distribution, this underestimation of taxes on high incomes becomes even more pronounced. This pattern indicates a general underappreciation of the degree of progressivity in the current U.S. tax code. The qualitative patterns of these results provide a test of Prediction 1, formally rejecting the predictions made by the spotlighting model (1-S) while remaining consistent with the predictions made by the ironing model (1-I).

Turning to an assessment of Prediction 2, we next explore the differences in perceived schedules as a function of respondents' own income. Figure 3 summarizes the average bias in forecasts as a function of the true tax due, and plots this bias conditional on respondent's own income quartile. We present fitted values from the regression model:

$$(\tilde{T} - T)_{i,f} = \sum_{b,q}\sum \alpha_{b,q} * I(\text{income}_f \in \text{bin}_b) * I(\text{income}_i \in \text{quartile}_q) + \epsilon_{i,f}.$$

In this regression, we predict the difference between the perceived tax ($\tilde{T}$) and the true tax (T) for person i's assessment of Fred scenario f. We estimate the average of this forecast error in \$5,000 bins (denoted b), estimated separately by the income quartile of the respondent (denoted q).[14] As seen in this figure, the primary pattern described above—overestimation of low tax burdens and underestimation of high tax burdens—persists across all four income groups. Despite this consistent pattern, tax perceptions are significantly different across income quartiles. Wald tests reject joint equality in all pairwise comparisons of the income-quartile-specific estimates of α (all p-values $<$0.014). An important feature revealed in the plots is that the "crossing point" where overestimation turns to underestimation occurs at higher income values for higher income respondents. These patterns are consistent with the predictions of ironing (2-I), and are broadly inconsistent with the predictions of spotlighting (2-S).

Perceived Slope of Tax Schedules (Schmeduling Predictions 3-5): Figures 2 and 3 suggest underestimation of the slope of the tax schedule. This is visually apparent in the "flattening" of the estimated schedules in Figure 2, and in the negative slope of the bias functions in Figure 3. We now turn to a statistical assessment of this underestimation, and use our results to assess Predictions 3-5.

To formally test for underestimation of the slope of the tax schedule, we estimate fixed-effect OLS regression models of the form $\tilde{T}_{i,f} = \beta T_{i,f} + \nu_i + \epsilon_{i,f}$. The object of interest in this analysis is β, which measures the scaling of the tax schedule implicit in the respondents' forecasts. By including respondent-specific fixed effects (ν_i) we identify β from the effective slope of the tax schedule reported within-subject. We test the null hypothesis of $\beta = 1$, the value that would be estimated if respondents indicated a rate-of-increase of taxes consistent with the true tax schedule. An estimated value over 1 would indicate an implicit steepening of the schedule, and an estimated value under 1 would indicate an implicit flattening. Results of this analysis are presented in Table 2.

[14] Note that the estimation sample is restricted to cases with tax burdens in the range [0,55000).

In the first panel of Table 2, we restrict the estimation sample to the "local distribution," consisting only of the two locally sampled income draws and any of the randomly sampled income values that happen to fall in the respondent's own tax bracket. Beliefs in this region of the tax schedule directly reveal whether taxpayers correctly perceive the marginal tax rates that they face, and thus allow the assessment of Prediction 3. We find that people underestimate the marginal tax rates in their own tax-bracket ($\beta = 0.81$, clustered s.e.=0.043), consistent with the prediction of ironing (3-I) and inconsistent with the prediction of spotlighting (3-S). The 2nd-5th columns of the table provide estimates of this same parameter when the sample is restricted to respondents in each of the four income quartiles. Across these estimates, we find that underestimation remains statistically detectable for respondents in the top two income quartiles. For respondents in the bottom two income quartiles the standard errors of these estimates are sufficiently large that we can reject neither correct perception, nor substantial underestimation (or overestimation) of their MTRs.

The second panel of Table 2 presents estimates of β derived from the 10 random draws of the mid-range sampling distributions. As in the local analysis, we find substantial and statistically significant underestimation of the steepness of the tax schedule ($\beta = 0.82$, clustered s.e.=0.013). In contrast to the local analysis, we find that this underestimation persists among all four income quartiles, with the null hypothesis of $\beta = 1$ rejected at at least the 1% level for each estimate. The degree of underestimation is most severe among the lowest-income respondents: estimates range from 0.70 (clustered s.e.=0.029) for the lowest-income respondents to 0.94 (clustered s.e.=0.023) for the highest-income respondents. These results provide an investigation of Predictions 4 and 5, and again refute the predictions of the spotlighting model while supporting the predictions of the ironing model.

The third panel estimates β using data from the full sampling distribution. Results are congruent with those generated from only the mid-range sampling distribution. Underestimation of the slope of the tax schedule persists, and indeed is more severe ($\beta = 0.62$, clustered s.e.=0.010). As in the second panel, we find that all four income quartiles underestimate the average slope of the tax schedule, with the difference again increasing in the respondent's own income.

Summary: Assessing the five predictions articulated in section 2, we find no support for the predictions of the spotlighting model and consistent support for the predictions of the ironing model.

4.2 Disentangling Heuristic Use

While the reduced-form results support the presence of ironing and provide little evidence of spotlighting, these analyses do not address three questions of primary interest. First, how much of the apparent under-appreciation of progressivity can be attributed to ironing? Second, even if they are not prevalent, are there any spotlighters in the population? Third, are there features of average tax perceptions that schmeduling fails to capture? We address these questions with a mixture-model approach to estimating the propensity of each heuristic.

Estimating Heuristic Propensity: To provide quantitative estimates of the propensity of heuristic use, we estimate the structural model in equation (1). We present results from two estimating equations:

$$\tilde{T}_{f,i} = (1 - \gamma_I - \gamma_S)T(z_{f,i}) + \gamma_I \tilde{T}_I(z_{f,i}|z_i^*) + \gamma_S \tilde{T}_S(z_{f,i}|z_i^*) + \epsilon_{f,i} \tag{2}$$

$$\tilde{T}_{f,i} = (1 - \gamma_I - \gamma_S)(T(z_{f,i}) + r(T(z_{f,i}))) + \gamma_I \tilde{T}_I(z_{f,i}|z_i^*) + \gamma_S \tilde{T}_S(z_{f,i}|z_i^*) + \epsilon_{f,i} \tag{3}$$

In these equations, $\tilde{T}_{f,i}$ denotes the forecasts of the taxes due by the hypothetical taxpayer. Individual respondents are indexed by i, and iterations of the hypothetical taxpayer question are indexed by f. We model tax forecasts as a convex combination of three possible models of tax perceptions. We include the ironing and spotlighting forecasts as defined above, each evaluated at the hypothetical income assigned to Fred ($z_{f,i}$), but using the average tax rate or marginal tax rate determined by the respondents' own income (z_i^*). In equation (2), we estimate a model in which aggregate tax forecasts are formed by a mixture of these two heuristics and the true tax liability ($T(z_{f,i})$). In equation (3), this latter term is augmented to $T(z_{f,i}) + r(T(z_{f,i}))$, denoting the true tax due plus a *residual misperception function*. By including this term and estimating it with a flexible functional form, we can separately identify our candidate heuristics from general misperceptions of the tax schedule not attributed to the models defined above. In the estimates we present below, we model the residual misperception function as a fifth order polynomial.

Table 3 presents non-linear least squares estimates of these models. Columns 1 and 3 present estimates of equation 2. Columns 2 and 4 present estimates of equation 3, integrating the residual misperception function into the analysis. Standard errors are clustered at the respondent level. Column 4 is our preferred specification because it utilizes all randomly sampled data and includes the residual misperception function.

The first two columns, which estimate the model from the mid-range sampling distribution, show a substantial weight on the ironing heuristic. In column 1, the point estimate implies 21% weight on the ironing heuristic. However, the point estimate on the spotlighting forecast is negative 9%—outside the range of valid probability values, and marginally significantly so. We view the estimation of invalid probabilities for heuristic propensity as evidence of model mispecification, and a demonstration of the difficulty of inference in this setting when non-income-dependent misperceptions are not accommodated.[15] Illustrating that point, when the residual misperception function is included in this estimation in column 2, weight on the spotlighting heuristics becomes statistically

[15]To rationalize this result and illustrate the confound introduced by excluding controls for residual misperceptions, recall that we found systematic overestimation of the taxes due across the mid-range income distribution. Quantitatively, this overestimation cannot be generated by ironing. But because the spotlighting heuristic generates underestimation of taxes due outside of one's own bracket, placing negative weight on this heuristic is a simple way for the model to approximate our finding of systematic overestimation of tax levels.

indistinguishable from zero, while weight on the ironing heuristic increases to 29%. The contrast of columns 1 and 2 demonstrates the importance of allowing for residual misperceptions when estimating the propensity of these heuristics: since these heuristics can change the level of aggregate tax forecasts, their identification can be confounded with level effects when residual misperception is not accommodated.

In columns 3 and 4, we repeat the estimation exercise of columns 1 and 2 using the full sampling distribution. In these specifications, we again find substantial weight on the ironing forecast and effectively zero weight on the spotlighting forecast. In the fourth column, which includes a residual misperception function and utilizes all randomly-sampled forecasts, we estimate an ironing propensity of 43% (clustered s.e.=9.5%) and a spotlighting propensity indistinguishable from zero (-2%, clustered s.e.=7.6%). This estimated ironing propensity is somewhat larger than, but statistically indistinguishable from, the estimate of 29% derived from mid-range forecasts. In sum, this analysis strongly supports the presence of a large subpopulation of ironers and provides no evidence supporting the presence of spotlighters.

Interpreting Residual Misperceptions: The estimates of our mixture model suggest that reliance on the ironing heuristic is common, but not universal. We now turn to characterizing the residual misperceptions held by those who do not iron.

Figure 4 plots the estimates of the residual misperception function generated in the regressions of Table 3. The top panel presents the estimates generated from the mid-range sampling distribution. Residual misperceptions over the mid-range sampling distribution are characterized by a reasonably uniform overestimation of taxes due. The bottom panel presents the estimates incorporating the high-income sampling distribution. We again observe relatively stable overestimation over comparatively low tax bills. However this eventually transitions to (statistically insignificant) underestimation of higher tax burdens. Taken at face value, the initial upward slope of residual misperceptions implies overestimation of the MTRs associated with comparatively small tax bills. The gradual downward slope that follows implies modest underestimation of the MTRs associated with large tax bills.

It is noteworthy that this simple representation of residual misperceptions arises despite its specification as a fifth-order polynomial. Our estimation procedure is capable of detecting substantial nonlinearity in residual misperceptions if they are present, but these analyses suggest that the misperceptions that remain are comparatively simple in structure. Because the residual is so simple in structure, our estimated heuristic propensities are insensitive to the parameterization of the residual misperception function. Reestimating equation 3 with the residual misperception function specified as any polynomial of orders 1 through 10 results in estimated heuristic propensities within two percentage points of the estimates reported in Table 3 (see Appendix Table A2). Estimates change more meaningfully when misperceptions are not included or are assumed to be constant, but these results suggest that a first-order polynomial is sufficient to remove the confounding influence of residual factors.

Care is needed in interpreting our estimates of residual misperceptions. When designing our estimation strategy, this component was included to capture any apparent non-schmeduling misperceptions, either real or spurious. As examples of the latter category, note that a spurious appearance of misunderstanding of progressivity could arise under certain structures of nonclassical measurement error. Similarly, apparent forecasting bias may arise if respondents improperly treat our survey questions as if they ask about a tax filer more complex than the one considered. Similar bias would arise if respondents integrate tax burden from non-federal sources, such as state or FICA taxes. It is a crucial feature of our approach that such confounds result in perturbations of the form modeled by our residual misperception function, and thus are controlled for in a manner that removes their influence from the estimates of the schmeduling heuristics' propensity. However, interpretation of residual misperception function must be conducted under the caveat that its shape may be influenced by such non-externally-valid features. Consequently, out-of-sample predictive power of this component of the mixture model may fail.

Summary: When estimating our structural model of misperceptions, we find evidence or widespread adoption of the ironing heuristic and no evidence of usage of the spotlighting heuristic. Our preferred specification implies 43% weight on ironing, no weight on spotlighting, and residual over-estimation of tax burdens that stays fairly constant throughout the income distribution but eventually turns to underestimation for very high incomes.

4.3 Ironing Explains Estimates of MTR Misperceptions

Our approach to estimating heuristic propensity relies on forecasts of taxes due over a wide range of incomes. While such data is useful for identification, optimal response to tax policy is often contingent only on "local" knowledge of the tax schedule; specifically, knowledge of one's own MTR. Because individuals have more reason to learn about taxes on incomes close to their own, a reasonable reader may worry that models estimated using tax forecasts over a wide range of income provide a misleading depiction of MTR misperceptions. In this subsection, we thus assess the degree to which our estimated model accounts for these local perceptions, and evaluate goodness of fit when the predictions are only based on our estimates of ironing propensity.

To address these questions, we assess the ability of our estimated model to fit the model-free estimate of own-bracket MTR underestimation reported in Table 2. We do this both by estimating our model using the full sample of income draws, and also using only the income draws that only lie outside of the respondent's tax bracket.

As repeated in the first column of Table 4, we found that perceptions of the slope of respondents' own tax bracket was scaled by a factor of 0.81, indicating an average underestimation of MTRs. In column 2, we reestimate this regression while replacing respondents' actual forecasts with the forecasts predicted by the preferred specification of our model. We find a resulting scaling parameter of 0.86, quantitatively similar to (and statistically indistinguishable from) the model-free baseline.

To what degree do the different components of the mixture model contribute to this fit? Moving across columns 2 through 4, we progressively remove model components and reassess the fit to MTR perceptions. In column 3, we replace our MTR forecasts with those based on the estimated ironing propensity and residual misperception function, but setting the propensity for spotlighting equal to zero. We find that this has no meaningful effect on the resulting scaling parameter, consistent with the statistical insignificance of our estimate of spotlighting's propensity. In column 4, we further restrict the model to remove the influence of the residual misperception function: we forecast MTRs based on a 43% propensity to use the ironing heuristic, with remaining weight placed on the true tax forecast. In this analysis, we find that the resulting scaling of MTRs precisely matches that in the model free baseline, with a statistically insignificant difference of less than one percentage point. In summary, accounting for ironing alone allows a quantitatively precise forecast of MTR perceptions.

The comparisons conducted above help assess the fit of our estimated model. However, this test of fit is explicitly within-sample: forecasts of taxes due in one's own bracket are used both for the estimation of the model and in the model-free validation. To provide a more stringent test of our model's ability to capture MTR perceptions, we construct an analogous out-of-sample test of fit. We reestimate our model while excluding all data from respondents' own tax brackets.[16] We then use the estimated model to forecast tax perceptions within respondents' own brackets, and again compare the scaling. As shown in columns 5-7, this analysis yields results nearly identical to those in the within-sample exercise. Importantly, a simple model consisting of only ironers and correct forecasters predicts the scaling of MTRs to within a percentage point.

Summary: A simple mixture model of ironers and correct forecasters accurately predicts MTR misperceptions.

4.4 Heterogeneity and Robustness

Individual-Level Estimates: The results of Table 3 suggest that aggregate tax misperceptions can be rationalized by placing significant weight on the ironing forecast. This is perhaps most naturally interpreted through a heterogeneous model in which some individuals have accurate beliefs (or accurate beliefs up to the perturbation of the residual misperception function) and some individuals employ the ironing heuristic. In such a model, our estimated coefficients may be interpreted as the propensity of use for each of the candidate forecasting rules. However, in principle our results could alternatively be rationalized by a homogeneous decision rule that places some weight on the truth and some weight on the ironing heuristic. While we believe that such a model would be difficult

[16] Compared to column 4 of Table 3, this restriction results in extremely similar estimates of heuristic propensity. We estimate an ironing propensity of 0.46 (clustered s.e.= 0.101) and a spotlighting propensity -0.04 (clustered s.e. = 0.079), and thus see differences of no more than 0.03 from the values in our preferred specification.

to psychologically motivate, we present individual-level estimates of our model to help rule out this possibility.

To begin, we estimate equation 2 at the individual level for each of the 3,552 respondents facing a non-zero tax rate.[17] Figure 5 plots a kernel-density estimate of the distribution of estimated individual classifications. In general, this distribution is quite diffuse. This is to be expected, since estimating two parameters from only 14 tax forecasts would lead to a distribution of point-estimates that is a convolution of both the true parameters and individual estimation error. Notice, however, that the resulting estimates yield a sharply bimodal distribution. As illustrated in the figure, the peaks of this distribution correspond to the parameter values describing those relying fully on the ironing forecast and those relying fully on the correct tax forecast. Consistent with earlier analyses, no excess mass is seen at the parameter values corresponding to full reliance on the spotlighting forecast. While this analysis cannot rule out the existence of some intermediate cases, this distribution is consistent with a substantial population of pure ironers, in the sense intended by Liebman and Zeckhauser's (2004) presentation of the heuristic.[18]

We can also perform the same estimation exercise while restricting individual-level parameter estimates to valid probabilities. To do so, we evaluate equation 2 over a grid of probability values, and assign individuals to the grid point that minimizes the mean squared error of their forecasts. We again see strong support for the existence of pure types: 33% of respondents are classified as "true tax" forecasters, 33% are classified as pure ironing forecasters, 2% are classified as pure spotlighters, and the remainder are estimated at intermediate values. Similar results are obtained by repeating the analog of this exercise that applies the model and data restrictions of each column of Table 3 (all such analyses are reported in Appendix Tables A3-A6).

Persistence of Heuristic Use Among Subgroups: While tax knowledge is important to all people for, e.g., determining which policies and politicians to support or for budgeting spending, economic analyses often hinge on knowledge among specific groups. Groups of particular interest include the rich (in models of redistribution), workers (in models of labor-supply), or individuals completing their own tax returns (in models of compliance). Figure 6 presents estimates of ironing and spotlighting propensity created by applying our primary regression specification to various sample splits of interest. We continue to estimate prevalent ironing among both above- and below-median income respondents (41% vs 24%), the employed and the unemployed (35% vs 53%), those

[17] Notice that for individuals facing zero tax, the ironing and spotlighting heuristics yield the same forecast, and are thus not separately identified.

[18] Similar figures can be generated estimating equation 3, and by restricting the estimation sample to only the mid-range income distribution. In Appendix Figure A1, we reproduce Figure 5 while applying the restrictions for each of the columns in Table 3. Since we cannot estimate residual misperceptions at the individual level, we use the estimated residual misperception function from the analysis of Table 3. Across all specifications, we continue to find a large mass at $\gamma_I = 1, \gamma_S = 0$, indicating that our inference about the existence of pure ironers is not confounded by the residual misperception function. However, when residual misperceptions are included, the density around $\gamma_I = 0, \gamma_S = 0$ is reduced by approximately half. This can be rationalized by interpreting the residual misperception function not as a literal forecasting rule by a pure "type," but as an approximation to heterogeneous remaining misperceptions beyond the heuristics we study.

who completed their own tax return and those who did not (31% vs 58%), and those who use tax preparation software and those who do not (42% vs 43%). Furthermore, we find substantial prevalence of the ironing heuristic among both financially literate and financially illiterate tax filers, as classified by whether they do or do not correctly answer all of the "Big Three" financial literacy measures (35% vs 36%). We find that adoption of ironing persists among those who completed the survey before or after tax day (34% vs 52%) and among both above- and below-median age respondents (34% vs 55%), suggesting that the misperceptions we document are neither temporarily eliminated by the experience of completing a tax return nor permanently eliminated by the cumulative experience with tax payments incurred over a lifetime. Finally, adoption of ironing persists among those with above- and below-median rates of indicating confidence in their given forecast (32% vs 49%).

Across these sample splits, the propensity to iron is statistically significantly different from zero at least at the 5% α-level in all but one case.[19] The propensity to spotlight is statistically insignificant, evaluated at the 10% α-level, across all sample splits.

Inclusion of Other Taxes: In practice, the federal income tax is not the only tax on income; for most respondents, state taxes and FICA taxes also apply. Our experimental exercise specifically asked respondents to make forecasts about their federal income tax. However, a confused respondent could make forecasts that incorporate additional tax components. Since the inclusion of these extra taxes increases both the aggregate MTR and ATR, the presence of confusion of this sort would render our estimates of the degree of underestimation of the steepness of the tax schedule conservative. Thus, this confusion cannot account for our central reduce-form results. Moreover, this confusion could not account for our reduced-form evidence of ironing, since it would not explain why a respondent's estimate of Fred's tax liability is increasing in his own income.

In principle, such confusion could affect point estimates of ironing propensity. To examine the sensitivity of estimates to these concerns, we reestimate our primary heuristic model presented in Table 3 under three alternative assumptions: that the true tax, ATR, and MTR are all based on an aggregate tax schedule that additionally includes FICA tax, state tax, or both.[20]

Results are presented the top panel of Figure 7. We find that our conclusions regarding heuristic propensity are broadly similar across these alternative specifications. Estimated rates of ironing range from 37% to 55% across these specifications, whereas spotlighting is indistinguishable from

[19] The ironing propensity estimate of 0.24 among below-median income respondents has a clustered standard error of 0.231, generating an extremely large confidence interval including zero. This unusually large standard error is generated in this analysis due to multicolinearity: since average tax rates and marginal tax rates are nearly identical for low income filers, with their difference increasing in income on a convex tax schedule, the ironing and spotlighting predictions become highly correlated (ρ=0.91) if attention is restricted to low income respondents. The resulting correlation of the ironing and spotlighting forecasts significantly limits the statistical power of our approach.

[20] We approximate state tax liability by applying the state's single or married-filing-jointly schedule to the federal adjusted gross income. Note that across states there are often small differences in the calculation of the tax base, which we necessarily abstract from due to data limitations. In analysis including state tax approximations, we exclude 34 respondents that we are unable to match to a state.

zero (or marginally significantly negative in one case). The minimal influence of these alternative assumptions demonstrates an advantage of our empirical approach. The apparent misperception of tax amounts that would result from the contraindicated inclusion of additional taxes takes a form that can be approximated by the residual misperception function. Absent the presence of a residual misperception function, this type of confusion could be incorrectly attributed to heuristic forecasting. With a residual misperception function included, this class of forecasting errors is correctly classified as alternative phenomena, resulting in similar schmeduling propensity estimates.

Similarity of Actual and Hypothetical Tax Filers: Our experiment focused on a hypothetical taxpayer constructed to approximate the respondent. While the hypothetical taxpayer had the same filing status and number of exemptions as the respondent, he was built with intentionally simple taxable behavior: only wage income, and no additional schedules, credits, or deductions. This design element resolves an important difficulty present in other surveys of tax knowledge: uncertainty about the complete details shaping the respondents' own tax liability. While this design eliminates the measurement error inherent from that lack of knowledge, and thus allows us to incentivize experimental forecasts, it has one undesirable feature: respondents with filing behavior more complex than pure wage income are making forecasts regarding a tax schedule that imperfectly approximates their own. Our description of Fred precisely matches the returns submitted by 1,357 (32%) of our respondents, and the remaining 2,840 respondents have some element of their tax return—such as schedule B-F, an itemized deduction, or a claim to the EITC—that renders the approximation imperfect. In Figure 7, we conduct our main analysis restricted to each group of respondents. Both demonstrate substantial ironing (dissimilar filers: 34%; similar filers: 57%), and statistically insignificant spotlighting.

Importance of Data Restrictions: While most of our data restrictions described in section 3.2 are standard and affect few responses, two decisions may be contentious. First, note that we exclude 436 respondents (9% of our initial sample) who failed the attention check included in the miscellaneous questions module. As illustrated in Figure 7, reincluding these respondents has little effect on our estimated heuristic propensities. While this exclusion has little effect on the final results, we implement it as a matter of principle. Prior to running analyses, we worried that forecasts of respondents that do not carefully read instructions would necessarily be imperfect, and that the imperfection resulting from their inattention would not generate an externally valid measurement of the misperceptions of interest.

Second, we employ a Winsorization strategy as a means of controlling extreme forecasts. When deploying a unconstrained-response survey to thousands of respondents, at least a small number of wildly unreasonable forecasts are to be expected. To present an illustrative example, one respondent indicated that the tax due for an income of $823 is $96,321, when in fact it is zero. Even if most respondents have reasonably accurate tax perceptions, a small number of such extreme forecasts can significantly impact both parameter estimates and power. Furthermore, we believe the extremity of such forecasts does not approximate any externally valid forecasting problem, but rather is an indication of unusual confusion or experimental noncompliance. This motivated our choice to Winsorize tax forecasts at the 1st and 99th percentile forecasts within each \$10,000 bin. As we demonstrate in Figure 7, alternative means of Winsorization have little impact on our quantitative estimates. Furthermore, our basic results persist even with the complete omission of outlier control, although estimates become notably less precise.

5 Welfare Implications of Ironing

In this section, we illustrate the potential for our estimated propensity of ironing to meaningfully influence welfare calculations. We consider a standard model of intensive -margin earnings decisions and distortionary taxation and calibrate the consequences of ironing's presence. To keep exposition concise, we briefly provide intuition for the important theoretical consequences and we focus attention on quantitative estimates corresponding to our preferred model specification. In Appendix B, we provide formal analysis that corresponds to the theoretical claims summarized here.

5.1 Model and Assumptions

Economic Setting: Individuals have a utility function $U(c, l)$, where c is consumption and l is labor. Individuals produce $z = wl$ units of income for every l units of labor, where the wage w is drawn from an atomless distribution F. The government cannot observe earnings potential w, and is thus restricted to setting taxes $T(z)$ as a function of earnings z. More generally, and as in Feldstein (1995; 1999), this model serves as a model of taxable income choice. This encompasses, for example, decisions over tax-preferred activities such as charitable contributions.[21]

Optimizing individuals choose $z^* \in \text{argmax}\{U(z-T(z), z/w)\}$. Ironers choose $z^* \in \text{argmax}\{U(z-A(z^*)z, z/w)\}$, where $A(z^*) = T(z^*)/z^*$ is the average tax rate. Notice that for ironers, z^* is a fixed point of a decision process in which misperceptions are possibly shaped by z^*, while at the same time z^* is a perceived optimum given those misperceptions.[22] In Appendix B.1 we provide existence and uniqueness results, as well as basic comparative statics for this solution concept, which have been implicitly assumed by Liebman and Zeckhauser (2004).

The social welfare function is given by

[21] See Chetty (2009) for some exceptions to this generalization, and Slemrod and Kopczuk (2002) for discussion of its impact on the interpretation of labor-supply elasticity.

[22] Farhi and Gabaix (2017) implicitly use this solution concept in their study of optimal income taxation. In Appendix B we formalize the solution concept and characterize existence or uniqueness for the types of misperceptions that we estimate. The solution concept may be reformulated as a special-case of Berk-Nash equilibrium (Esponda and Pouzo, 2016) and, as such, can be microfounded as a steady state of a dynamic process in which individuals follow a myopic best-response strategy while learning through a misspecified model. To formally embed our model in the Berk-Nash framework, we must re-interpret $\tilde{T}(z|z^*)$ as the mean of the individual's belief, while allowing the individual to have a sufficiently diffuse prior so that no outcomes are "surprises." See also Gabaix (2014) for a general approach to modeling boundedly rational misperceptions of incentive schemes.

$$\int U(z^*(w,1_\gamma) - T(z^*(w,1_\gamma)), z^*(w,1_\gamma)/w)dH + \lambda \int T(z^*(w,1_\gamma))dH, \tag{4}$$

subject to $\int T(z^*(w,1_\gamma))dH \geq 0$, where $1_\gamma \in \{0,1\}$ is an indicator for ironing, H is the joint distribution over wage and ironing types, and λ is the marginal value of public funds. Denote the social marginal welfare weight at the current tax system by $g(w,1_\gamma) = U'_c/\lambda$.

Assumptions for Numerical Results: We parameterize individual utility according to the functional form $U(z) = log(z - T(z) - \frac{(z/w)^{1+k}}{1+k})$, a commonly used specification in optimal tax studies (e.g., Atkinson 1990; Diamond 1998; Saez 2001). In this model, assuming correct tax perceptions, the structural labor supply elasticity is determined by $\frac{1}{k}$. When tax rates are misperceived, the elasticity with respect to wages must be scaled by the term $\frac{1-\tilde{T}'}{1-T'}$, which takes an average value of 1.02 in our data—thus, while the formal calculation of elasticity is not identical, quantitatively the difference is negligible. In simulations, we will vary the parameter k across values from 2 to 5, capturing elasticities ranging from approximately 0.2 to 0.8. In a recent meta-analysis of labor-supply elasticity estimates, Chetty et al. (2011) report microeconomic estimates ranging from 0.26 to 0.82 (across different labor supply elasticity concepts and methods of inference), with a preferred estimate of the intensive-margin Hicksian elasticity of 0.33. Our range of k values approximately spans this range, and $k = 3$ approximately corresponds to Chetty et al.'s preferred estimate.

Contingent on these parameters, we calculate the wage parameter that rationalizes reported earnings for each individual in the dataset. An individual's wage parameter can be calculated according to the equation $w = (\frac{z^k}{1-\tilde{T}'})^{\frac{1}{1+k}}$. Since this calculation depends on the individual's perceived marginal tax rate $\tilde{T}$, we calculate this value both under the assumption of ironing and under the assumption of correct forecasting.

When considering the consequences of a policy reform, we forecast the aggregate consequences of the individual reactions implied by the specified utility model and individual utility parameters. We forecast each individual's predicted response contingent on being an ironer or a correct forecaster, applying the relevant estimated wage parameter in each case. We aggregate these individual responses by assuming that behavior is determined by the ironing model with probability $\gamma = 0.43$, consistent with our estimate from our preferred regression model, and otherwise determined by the correct forecasting model.

5.2 Results

Implication 1: Government revenue increases due to ironing, and this revenue is raised progressively. Thus, ironing increases social welfare. When the tax schedule is progressive, marginal tax rates will be higher than average tax rates, and thus ironing will lead to underestimation of marginal tax rates. As established in de Bartolome (1995) for a linear income tax, and in Liebman and Zeckhauser (2004) and Appendix B more generally, this implies that labor earnings and thus government revenue will increase in the presence of ironers. Numerically, we find that under the U.S. tax schedule, our estimates of ironing propensity lead to a 1.6-3.7% increase in government revenue (reported in column 2 of Table 5), depending on the labor supply elasticity. For our preferred elasticity of $\frac{1}{3}$, the revenue gain is 2.2%.

While ironing raises revenue, it also generates individual misoptimization and therefore imposes costs on the affected individuals. Which individuals bear those costs significantly influences social welfare. In general, the cost of the mistake of ironing is proportional to a financial loss of $T'(z) - A(z)$, the difference between the marginal and average tax rates. To the extent that the difference between the marginal and average tax rate will increase with earned income, the financial burden of misoptimization will fall on the higher income individuals. For example, while the lowest income individuals will not misoptimize at all, the wedge will be substantial for the highest income individuals of our sample.

Figure 8 illustrates the estimated burden of misoptimization across different income levels, taking as given the structure of the U.S. income tax code and our estimates of ironing propensity. For each individual, we first calculate the compensating variation of ironing: that is, the amount of money that the individual would have to receive to be as well off ironing as he would be if he optimized with correct forecasts. We then plot the average compensating variation for each level of earnings, expressed in a money metric on the left y-axis and normalized by the (population wide) average of revenue generated by ironing on the right y-axis. This figure illustrates that the individual cost of misoptimization induced by ironing is increasing in income, and is generally well below the average revenue generated by its presence, suggesting the potential to exploit this bias and redistribute the extra government revenue it provides in a welfare-enhancing manner. In short, the burden of ironing is starkly progressive.

The first two observations—that ironing counteracts the distortionary effects of taxation by raising earnings, and that it increases government revenue in a progressive fashion—lead to the implication that ironing leads to progressive revenue collection, which will typically be welfare-improving.

To quantify the magnitude of welfare improvement from the current propensity of ironing, columns 3-5 of Table 5 present estimates of the fraction of current government revenue the social planner would pay to avoid reducing the rate of ironing from 43% to 0%. Calculating social welfare requires specifying the value of public funds, λ. In our preferred specification, we adopt the standard assumption that λ is equal to the average marginal utility of consumption in the population.[23] To illustrate the sensitivity of results to that assumption, we additionally present results for a "low λ" regime (in which we set λ to be equal to the 50th percentile of marginal utilities in our population) and a "high λ" regime (in which we set λ to be equal to the 90th percentile of marginal utilities in our population). Across different assumed elasticities and values of public funds, we find

[23] When calculating this average, we assume an income floor of \$6,000 to approximate the provision of social insurance that is outside of our current model.

that the improvement to social welfare realized from the presence of ironing is valued equivalently to an unfunded increase in government spending ranging from 1.4% to 3.6%, with 2.3% corresponding to our preferred specification. As compared to the raw increase in government revenue presented in column 2, this indicates that the welfare costs of individual misoptimization have a minimal offsetting effect to the additional spending funded by ironing.

Implication 2: Ironing increases the welfare benefits of progressive taxation. As we have already shown, ironing results in progressive revenue generation when the income tax schedule is itself progressive. Note, however, that the presence of ironing becomes irrelevant under linear, "flat" taxes, since such systems equate marginal and average tax rates. In effect, then, a tax simplification scheme that bring the tax schedule closer to a flat tax will reduce the socially beneficial influence of this bias. In other words, tax simplification, in addition to changing material incentives, can indirectly generate a type of debiasing.

To illustrate this numerically for the U.S. income tax system, we consider the welfare effects of moving to a flat tax. We constrain the marginal tax rate of the flat tax to be such that the amount of revenue raised would be identical in the absence of substitution to or from leisure: 11.06%.[24] As shown in columns 2 and 3 of Table 6, perfect tax forecasters on average increase their labor in response to this tax reform, leading to a 2.1-5.3% increase in tax revenue. However, because this reform leads to a less progressive tax system, and because we have assumed a social welfare function valuing redistribution, the reform leads to a substantial reduction in welfare. Quantitatively, this welfare loss is equivalent to a loss of 9.9-12.9% of government revenue under the current income tax system.

Turning to the estimates accounting for ironing in columns 4 and 5, we see that the revenue benefits of the flat tax are dampened by the less elastic response of ironers. This lower revenue, combined with the fact that ironing amplifies the decrease in a progressivity generated by the flat tax, results in a more severe welfare loss than would be obtained under the assumption of perfect tax perceptions. The welfare losses range from 12.3-13.8%. In our preferred specification, the welfare loss associated with moving to a flat tax is 14% higher when the effects of ironing are incorporated.

Another simple way to analyze the impact of ironing on the benefits of progressivity is to analyze the optimal top marginal tax rate. Saez (2002b) shows that the top marginal tax rate $\bar{\tau}$ satisfies $\frac{\bar{\tau}}{1-\bar{\tau}} = \frac{1-\bar{g}}{a\bar{\varepsilon}}$ where $\bar{g}$ is the average social marginal welfare weight on the top income earners, $\bar{\varepsilon}$ is the structural elasticity, and a is the pareto parameter of the income distribution.[25] In the presence of ironing, the top marginal tax rate satisfies $\frac{\bar{\tau}}{1-\bar{\tau}} = \frac{1-\bar{g}}{[(1-\bar{\gamma}_I)a+\bar{\gamma}_I]\bar{\varepsilon}}$, where $\bar{\gamma}_I$ is the propensity to iron amongst high income earners.[26] Since the pareto parameter $a > 1$, the optimal top marginal tax

[24] Similar results obtain if we instead constrain the flat tax rate to raise the same amount of revenue after accounting for substitution effects (see Appendix C).

[25] For simplicity we consider the case where there are no income effects on labor supply.

[26] See Appendix B.3 for a derivation.

rate is higher in the presence of ironing. For a pareto parameter $a = 2$ estimated by Saez (2002b), for example, $\frac{\bar{\tau}}{1-\bar{\tau}}$ is 27% higher with 43% propensity to iron as opposed to 0%.

Our analysis of tax schedule design highlights the importance of establishing the mechanisms underlying misperceptions of marginal tax rates. Based on our estimated model, we are able to forecast the changes to misperceptions (and the behaviors they dictate) after reforms to the tax schedule—a task for which reduced-form estimates of MTR perceptions are insufficient.

5.3 Interpretation and Caveats

Across these two classes of analyses—examining the welfare impact of introducing ironing under our current tax system, and examining the impact of ironing on a flat-tax reform—we find evidence that this bias serves a useful role for the social planner.[27] The presence of ironing permits additional progressive revenue collection than would be possible if the tax system were perfectly understood. Accommodating this feature therefore becomes both conceptually and quantitatively important in the welfare analysis of redistributive tax policy.

We wish to caution readers against two implications one might erroneously draw from these results. First, since this heuristic use is beneficial in our model, one might infer that we endorse further obfuscation of the tax system with the goal of raising the population's use of heuristics. Note that the standard model of earnings choice that we have adopted abstracts entirely from political economy issues, which would be critically important in assessing such a proposed reform. We believe that there are meaningful, and potentially dramatic, costs associated with a populace coming to believe that a tax system is actively designed to mislead. Any policy recommendations on optimal obfuscation must derive from a model which incorporates those costs, which we do not.

As a second note of caution, we emphasize that our finding that heuristic use improves social welfare is specific to domain that we study: misperceptions of the tax rates of the federal income tax schedule for wage income. We have abstracted from misunderstanding regarding various other components of the schedule. For the wealthy, optimal decision making might additionally rely on knowledge of the alternative minimum tax or the estate tax.[28] For the comparatively low income, misunderstanding of the interaction of the tax schedule with assistance programs may generate additional misperceptions (Romich, 2006), and failure to optimize along these dimensions may be especially costly (Currie, 2006).[29] However, the likely presence of these other mistakes does not limit the validity of our specific claim: that ironing of the federal income tax schedule leads to progressive revenue collection and amplifies the benefits of progressivity.

[27] For other examples in which behavioral biases improve social welfare see Handel (2013); Handel and Kolstad (2015); Spinnewijn (2017); Handel et al. (forthcoming); Mullainathan et al. (2012).

[28] See Kuziemko et al. (2015) for documentation of misunderstanding of the estate tax.

[29] Concretely, a substantial literature documents misunderstanding specifically of the Earned Income Tax Credit (see, e.g., Liebman, 1998; Romich and Weisner, 2000; Chetty et al., 2013).

5.4 Summary of Additional Results

In Appendix C, we support the implications of our simulation results in a formal theoretical framework. We first provide an instructive step-by-step analysis of a two-bracket model in Appendix B.2, which elucidates the mathematical intuition behind our primary claims. We then generalize this in Appendix B.3, which provides formulas for the behavioral and welfare effects of raising tax rates on earners with incomes above a threshold. In Appendix B.3.3, we use that formula to calculate the top marginal tax rate, and in Appendix B.3.4 we use the formula to calculate the optimal income tax in a heterogeneous population of ironers. Our formula subsumes that of Liebman and Zeckhauser (2004) for the case of a population of only ironers, and complements the Farhi and Gabaix (2015) formula for the case of homogeneous partial ironers.

In Appendix C, we provide a series of robustness checks on our simulation results. We demonstrate that our highlighted implications still hold under weaker assumptions on the social planner's preference for redistribution, under different derivations of the flat-tax rate, and under different corrections for the absence of extremely high-income filers in our sample.

6 Discussion

A large and growing literature in behavioral economics shows that people rely on heuristics when facing complex incentives. We contribute to this literature by studying misperceptions of income taxes—a notoriously complex set of incentives with active public debate promoting simplification. We show that much of the systematic misperceptions of the income tax can be explained by widespread adoption of a single, simple heuristic: ironing. The ability to account for misperceptions with a single parsimonious model allows rigorous analysis of questions about tax reform. We provide such an illustrative analysis, which shows the welfare effects of ironing to be positive and economically significant.

Moving beyond applications specific to the design of optimal tax policy, we highlight that our empirical estimates are relevant for broader classes of tax incentives. When analyzing decisions to adopt tax-preferred behaviors, to invest in human capital in the hopes of raising future wages, or to make financial investments that will only accrue at a future date, our results provides a unique view into the tax perceptions that could shape such decisions.

Of course, we urge both caution and further research before utilizing our experimental estimates to assess the welfare consequences of real tax reforms. When implementing our survey experiment, we devoted significant effort and resources to recruiting a broad and diverse subject population. We aimed to make our forecasting task as natural as possible despite the somewhat unusual task of having to predict taxes for incomes significantly different from one's own. However, as with any study other than a natural experiment, important external-validity concerns remain. We discuss our two main concerns below.

First, as with all heuristics, we expect ironing to be most prevalent for "quick" decisions that are made without substantial external advice; e.g., whether to work an extra shift or to make a tax-deductable charitable contribution. When individuals rely on expert advice, we expect the ironing heuristic to be less relevant. Moreover, to the extent that heuristic use is a deliberate means of reducing cognitive costs, it may be less frequent in high stakes labor-supply decisions than it is in our survey experiment. At the same time, a countervailing force is that in practice, the decisions that rely on correct forecasts of tax rates involve many other dimensions that all require careful consideration; this additional complexity may leave little mental bandwidth for tax forecasting. For example, an individual choosing between two different jobs may, rightly or wrongly, be less concerned with correctly considering after-tax salaries than with workplace culture or livability of the different cities.

While further study of the elasticity of ironing propensity with respect to stakes is needed, some insights may be gleaned from research on analogous research on other heuristics. For example, while the mental accounting, narrow bracketing, and representativeness heuristics were originally documented in unincentivized survey studies, they have since been documented to play an important role in important field behaviors—e.g., in the marginal propensity to consume out of the supplemental nutrition assistance program in the U.S. (Hastings and Shapiro, forthcoming), take up of long-term care insurance (Gottlieb and Mitchell, 2015), and the link between analysts' earnings-growth forecasts and stock returns (Bordalo et al., 2017). Camerer and Hogarth (1999) provide a systematic analysis of whether incentives affect heuristic use in experiments, and find no evidence in support of this possibility. While some reservation is needed in assuming that field behavior will be governed by these heuristics, this existing literature strongly supports the possibility.

We are less reserved about our qualitative findings than we are about our point estimates. In particular, we do not see a clear reason for why our findings about the relative unimportance of residual misperceptions beyond ironing should be reversed when stakes are increased. Thus, our conclusion that ironing provides a parsimonious account of MTR underestimation seems less sensitive to concerns about external validity.

A second concern is that the population used in our study is likely non-representative. Despite matching the U.S. population on several key observable demographics, unobserved characteristics could influence selection into our online survey platform. Moreover, what matters most for economic efficiency and welfare are the misperceptions of those who are actually marginal to the tax reforms in question. While we have shown that our results are robust to a variety of sample restrictions, further work is likely needed to validate robustness of our results for marginal populations of interest. However, were heuristics and biases besides ironing present in the general population of interest, they would be found in subsamples such as ours as well; as such, we do not view these issues as a hindrance to a demonstration of ironing's comparative importance.

These results build towards a reasonably comprehensive account of income-tax-schedule misunderstanding that is much needed in the behavioral public finance literature. Recent work—perhaps most notably Farhi and Gabaix (2017)—has provided a comprehensive theoretical foundation for incorporating general biases into standard models of optimal income taxation. These results provide significant guidance on policy design with behavioral agents, but require the analyst to have significant knowledge of the structure of population misperceptions.[30] As illustrated in Section 5, our results are easily integrated into frameworks such as these, and in combination with their theoretical advances may broadly inform tax policy design.

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[30]In the language of Handel and Schwartzstein (2018), these types of analyses also underscore that knowledge of mechanisms can be crucial even for evaluating allocation policies and not just mechanism policies.

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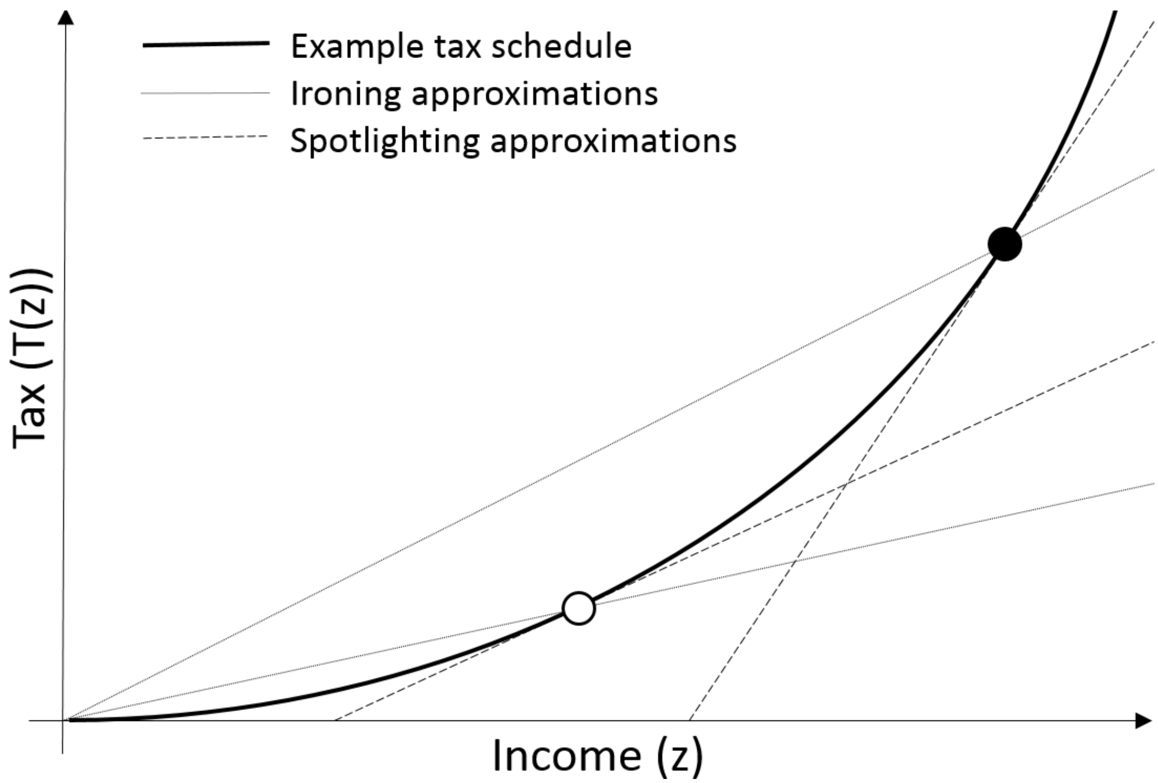
Figure 1: Ironing and Spotlighting Heuristics

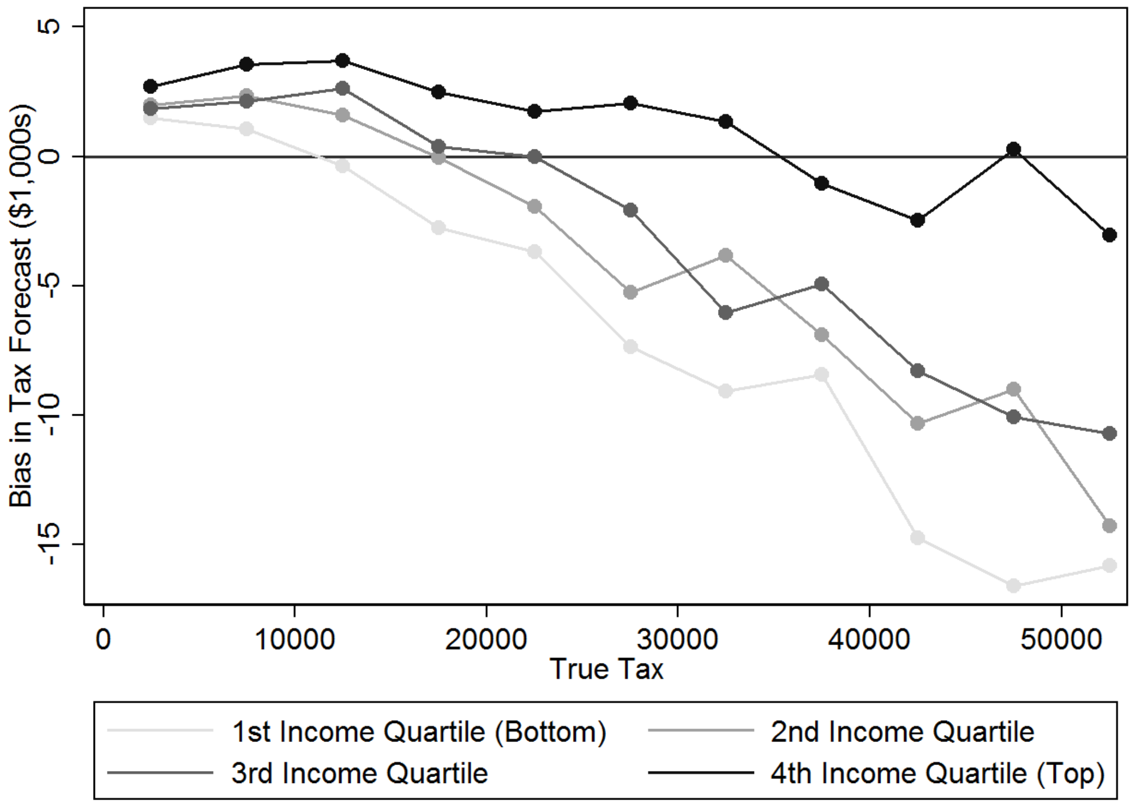


Notes: This figure presents an illustration of the ironing and spotlighting heuristics applied to a convex tax schedule. Taxpayers applying these heuristics approximate the schedule with linear forecasts that depend on their own position. We present two example positions, one with high income (the black dot) and one with comparatively low income (the white dot). Under the ironing heuristic, the taxpayer forecasts by applying his average tax rate at all points, resulting in the observed secant lines. Under the spotlighting heuristic, the taxpayer forecasts by applying his marginal tax rate to the change in income that would occur, resulting in the observed tangent lines.

Figure 2: Local-Polynomial Approximations of the Perceived Tax Schedule

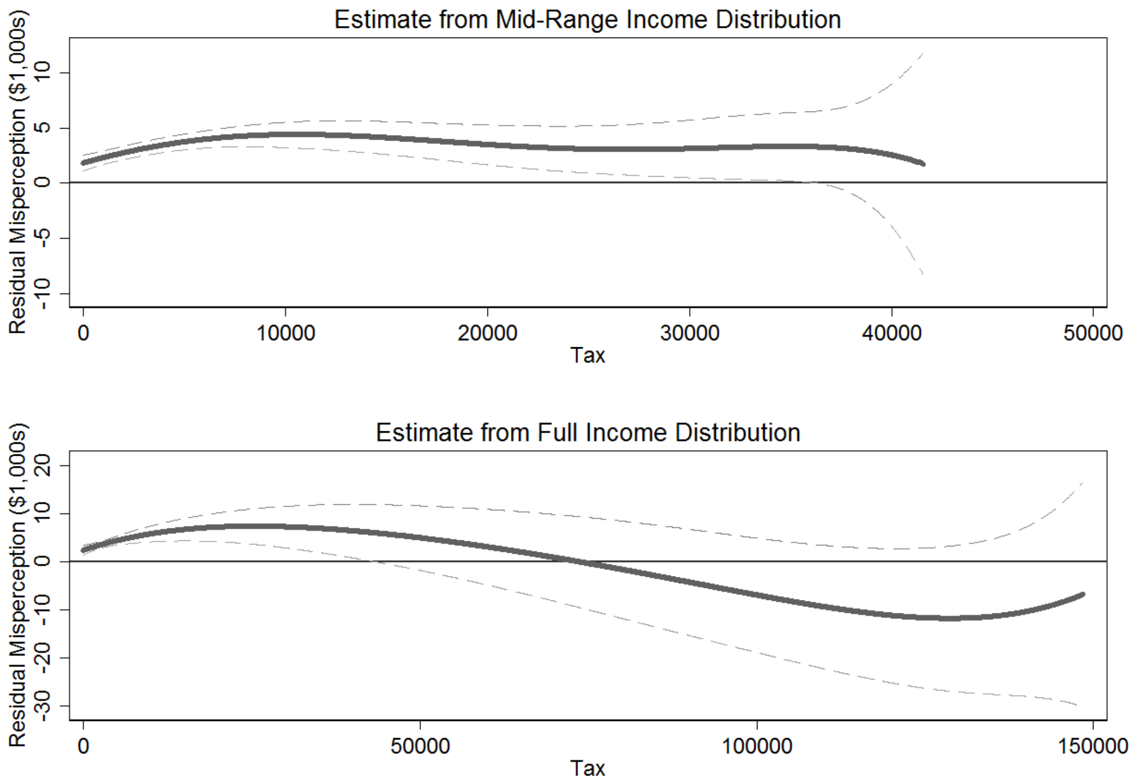
Notes: This figure presents local-polynomial approximations of the perceived relationship between the income earned and taxes owed. Results are plotted separately for single and married-filing-jointly tax filers, as incomes considered in the forecasting task were drawn from filing-status-specific distributions. The first row of figures presents estimates derived from only mid-range forecasts, while row two presents estimates derived from the full sampling distribution. Bandwidth: 10,000. Degree of polynomial: 2. Kernel: Epanechnikov.

Figure 3: Bias in Tax Perceptions, by Respondents' Income Quartile



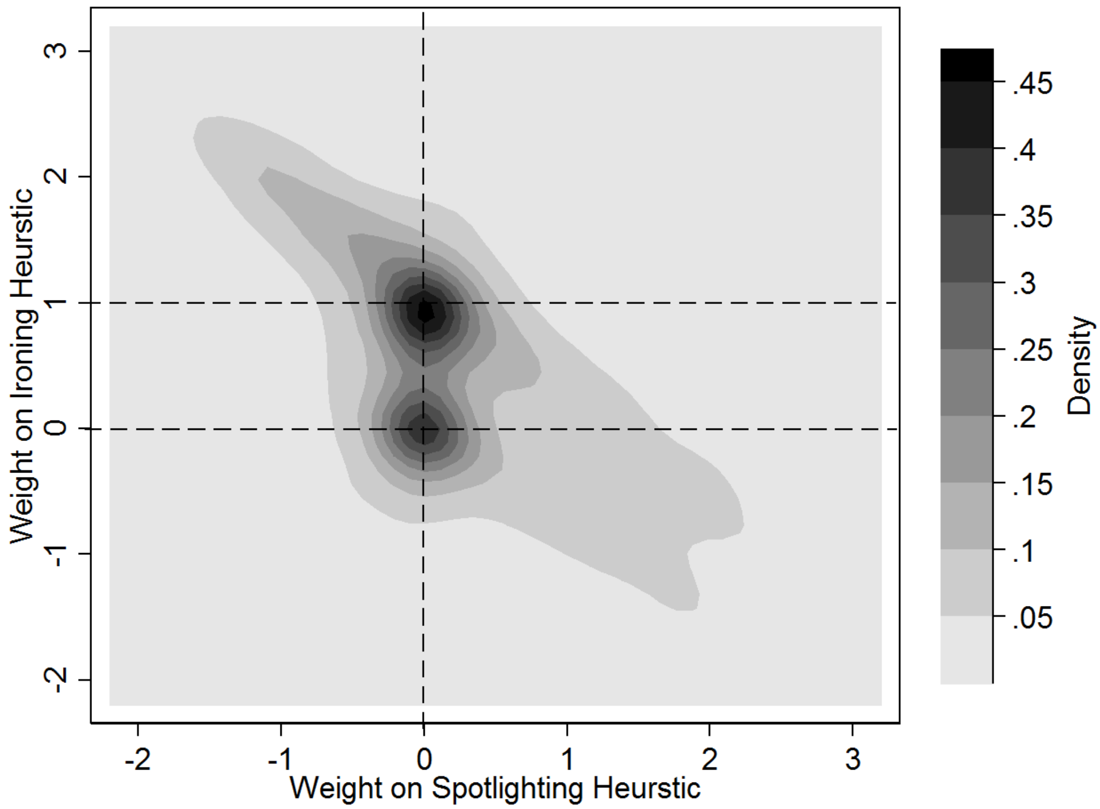
Notes: This figure plots the average bias in tax forecasts as a function of the true tax owed by the hypothetical tax payer. To explore how misperceptions of the tax schedule vary depending on the forecasters' own income, we plot this relationship separately by the income quartile of the respondent. Presented are the estimated coefficients from the regression $(\tilde{T} - T)_{i,f} = \sum \sum_{b,q} \alpha_{b,q} * I(\text{income}_f \in \text{bin}_b) * I(\text{income}_i \in \text{quartile}_q) + \epsilon_{i,f}$, predicting average bias conditional on income quartile and the true tax owed, rounded into $5,000 bins.

Figure 4: Estimates of Residual Tax Misperception



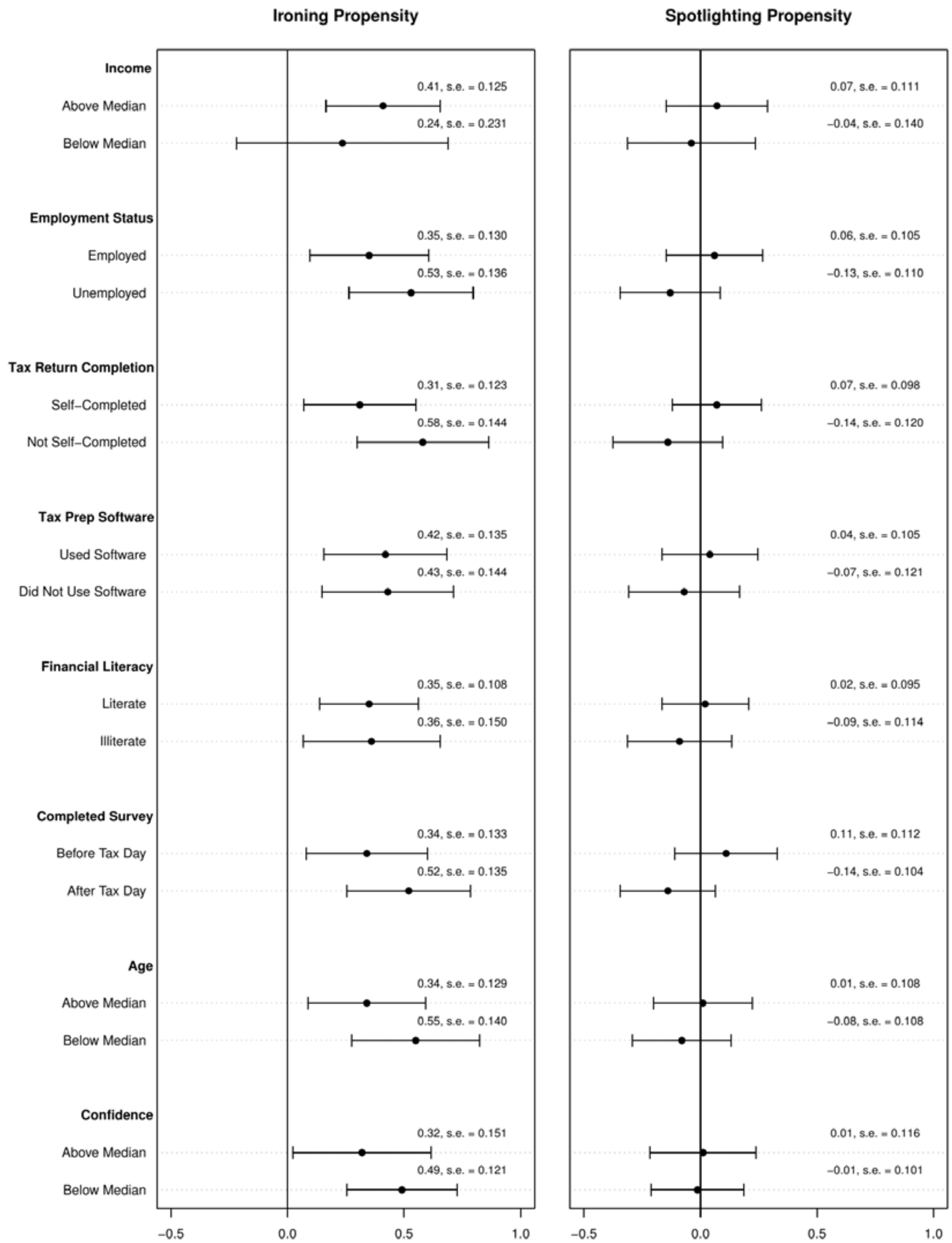
Notes: This figure plots the residual misperception functions estimated in columns 2 and 4 of table 3. These estimates indicate systematic overestimation of the taxes due when true taxes are comparatively small. For sufficiently large tax liabilities, this bias reverses into systematic underestimation of the taxes due.

Figure 5: Individual-Specific Estimates of Heuristic Propensity



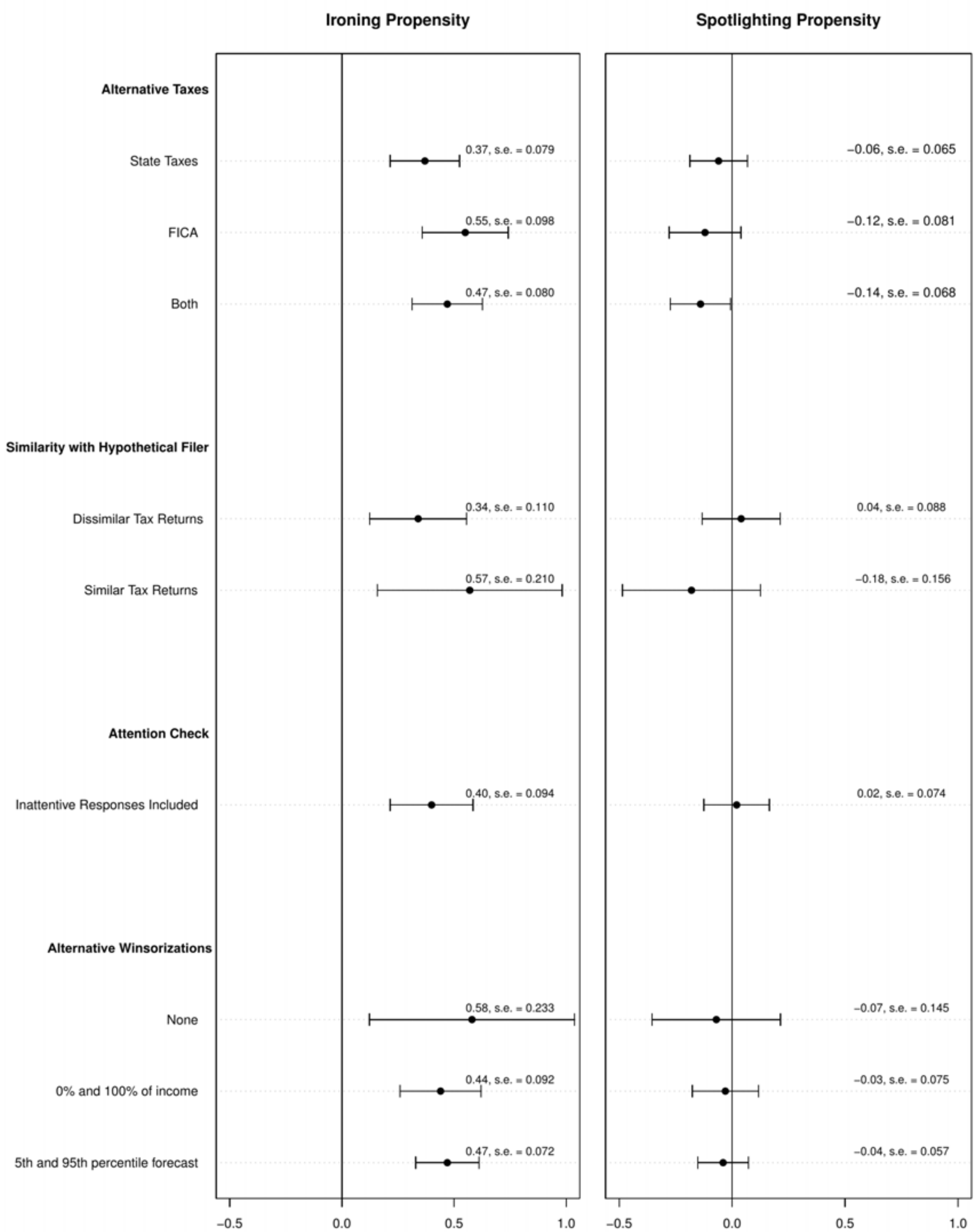
Notes: This table presents a kernel-density estimate of the joint distribution of individual-specific ironing and spotlighting parameters, as estimated in the exercise described in section 4.2. Marginal distributions are plotted in appendix figure A2. Note that individual-level NLLS regressions failed to converge for 7 respondents. Bandwidth: .2. Kernel: Gaussian.

Figure 6: Estimates of Heuristic Propensity: Robustness Analyses



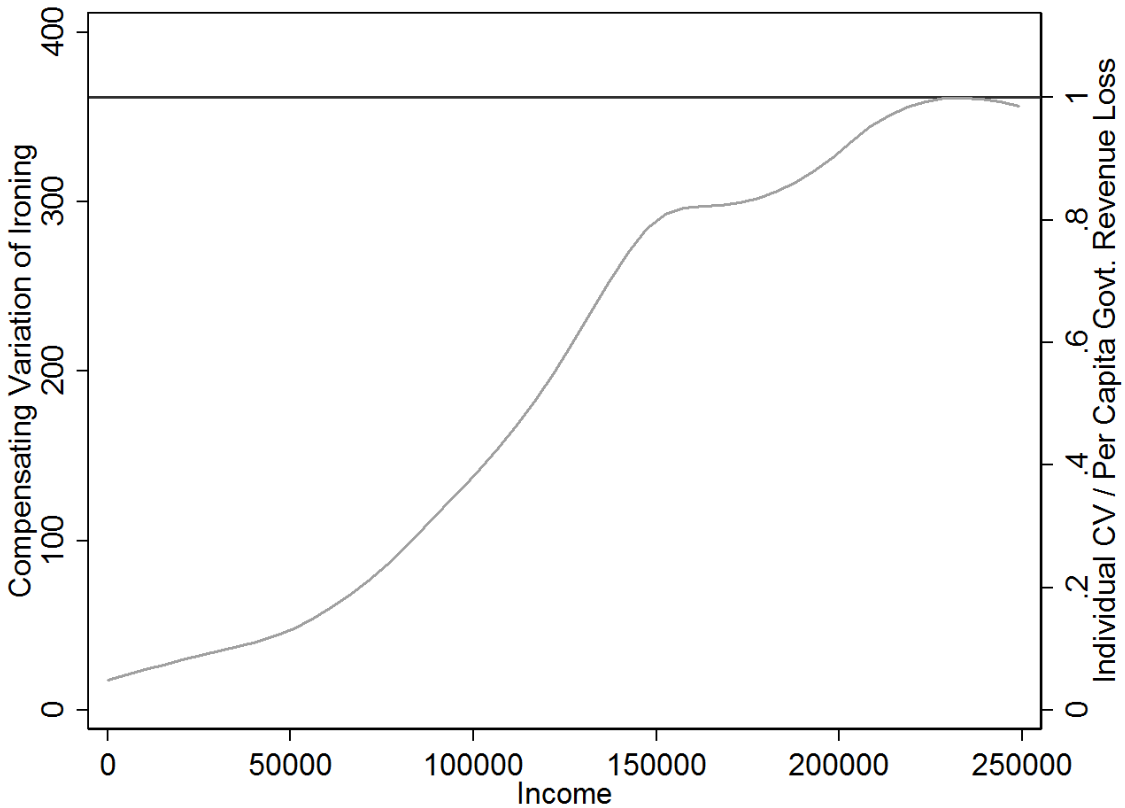
Notes: The figure summarizes the estimated propensity of ironing and spotlighting across a variety of sample restrictions. The estimates presented correspond to our preferred specification (column 4 of table 3), but are estimated according to the sample definitions described in the left of the figure. For complete discussion, see section 4.4.

Figure 7: Estimates of Heuristic Propensity: Robustness Analyses



Notes: The figure summarizes the estimated propensity of ironing and spotlighting across a variety of sample restrictions. The estimates presented correspond to our preferred specification (column 4 of table 3), but are estimated according to the sample definitions described in the left of the figure. For complete discussion, see section 4.4.

Figure 8: Consequences of Debiasing Across Income Distribution



Notes: This table presents local polynomial estimates that summarize the consequences of ironing for progressivity. For each taxpayer, we calculate the compensating variation in income that would lead an ironing taxpayer to have the same utility level as achieved by a correct forecaster. The left y-axis reports this value as in a money metric, and the right y-axis reports this value as a fraction of the per-capita loss of government revenue that arises from correcting ironing. Bandwidth: 25000. Kernel: Epanechnikov.

Table 1: Findings Consistent with "Schmeduling" Predictions in Survey Literature

		Lewis (1978)	*Auld (1979)*	*Fujii & Hawley (1988)*	*Blaufus et al (2015)*
	Predictions:				
1	Taxes on low- vs high-income		I		I
2	Taxes on low- vs high-income, by own income				
3	Perceptions of MTRs	I		I	
4	Slope of tax schedule				
5	Slope of tax schedule, by own income				
	Sample Size	200	1,294	3,197	1,009
	Country	UK	Canada	USA	Germany

Notes: This table summarizes the available results relevant to predictions 1-5 in the existing tax misperception literature. A result consistent with ironing or spotlighting is indicated with an I or S, respectively.

Table 2: Testing for "Flattening" of the Tax Schedule

	All Incomes	Income Quartiles			
	Pooled	1	2	3	4
Estimation Sample: Local Draws					
Scale of slope (β)	0.81***	1.01***	1.07***	0.83***	0.78***
	(0.043)	(0.205)	(0.113)	(0.058)	(0.054)
P-value of H_0: $\beta = 1$	0.000	0.975	0.552	0.003	0.000
Respondents	4197	1050	1062	1040	1045
Forecasts	17937	3143	4074	5293	5427
Estimation Sample: Mid-Range Sampling Distribution					
Scale of slope (β)	0.82***	0.70***	0.78***	0.80***	0.94***
	(0.013)	(0.029)	(0.030)	(0.026)	(0.023)
P-value of H_0: $\beta = 1$	0.000	0.000	0.000	0.000	0.005
Respondents	4197	1050	1062	1040	1045
Forecasts	41970	10500	10620	10400	10450
Estimation Sample: Full Sampling Distribution					
Scale of slope (β)	0.62***	0.53***	0.56***	0.61***	0.76***
	(0.010)	(0.020)	(0.021)	(0.019)	(0.017)
P-value of H_0: $\beta = 1$	0.000	0.000	0.000	0.000	0.000
Respondents	4197	1050	1062	1040	1045
Forecasts	58758	14700	14868	14560	14630

Notes: Standard errors, clustered by respondent, in parentheses. Presented are coefficients from OLS fixed-effect regressions of the form $\tilde{T}_{i,f} = \beta * T_{i,f} + \nu_i + \epsilon_{i,f}$. The coefficient β can be interpreted as a scaling of the slope induced by the true tax schedule, where estimated values less than 1 indicate a "flattening" of the tax schedule. Two-sided Wald-test p-values, testing the hypothesis that $\beta = 1$, are presented below each regression. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Parameter Estimates of Heuristic-Perception Model

	(1)	(2)	(3)	(4)
γ_I: weight on ironing forecast	0.21***	0.29***	0.47***	0.43***
	(0.037)	(0.052)	(0.048)	(0.095)
γ_S: weight on spotlighting forecast	-0.09*	-0.02	-0.03	-0.02
	(0.050)	(0.057)	(0.062)	(0.076)
Residual misperception function included	No	Yes	No	Yes
Income sampling distribution	Mid	Mid	Full	Full
Respondents	4197	4197	4197	4197
Forecasts	41970	41970	58758	58758

Notes: Standard errors, clustered by respondent, in parentheses. Presented are non-linear least squares estimates of ironing and spotlighting propensity. The estimated residual misperception function from columns 2 and 4 is plotted in figure 4. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Assessing Models' Fit Of MTR Perceptions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Model-Free	Preferred Specification			Out-of-Sample Ests.		
Ironing		X	X	X	X	X	X
Resid. misperceptions		X	X		X	X	
Spotlighting		X			X		
Scale of slope (β)	0.81	0.86	0.86	0.81	0.87	0.86	0.80
	(0.044)	(0.020)	(0.024)	(0.040)	(0.019)	(0.025)	(0.042)
Diff from model-free β		0.056	0.055	0.008	0.062	0.057	0.006
P-value of H_0: diff = 0		0.149	0.189	0.901	0.124	0.187	0.928

Notes: This table compares the the degree of MTR underestimation found empirically to that which would arise from our preferred specification of our empirical model. As a model-free baseline for comparison, column 1 reports the scaling parameter estimated in the top panel of table 2. Columns 2-4 present estimates of the scaling parameter predicted to arise under our estimated mixture model, progressively eliminating components of the model across columns. Columns 5-7 conduct an analogous exercise, but exclude local draws from the data used to estimate the forecasting model, and tests the ability of non-local forecasts to inform predictions of local tax understanding. Bootstrapped standard errors, resampled by subject with 1000 iterations, in parentheses.

Table 5: Revenue and Welfare Effects of Ironing

Structural Elasticity ($\frac{1}{k}$)	Increase in Tax Rev. (%)	*Net Welfare Increase (%)* Low λ $\lambda = U'_{50}$	— $\lambda = \bar{U}'$	High λ $\lambda = U'_{90}$
1/2	3.7	3.2	3.4	3.6
1/3	2.5	2.2	2.3	2.5
1/4	1.9	1.7	1.8	1.9
1/5	1.6	1.4	1.4	1.5

Notes: The numbers presented contrast the revenue collected or welfare attained when comparing a population with perfect tax perceptions against one in which 43% of filers apply the ironing heuristic. The first column presents the structural elasticity in our assumed utility model: $U(z) = log(z - T(z) - \frac{(z/w)^{1+k}}{1+k})$. The second column presents the additional government revenue collected when the ironers are present. The final three columns present estimates of the increase in social welfare attained due to the presence of ironers, under alternative assumptions on the cost of public funds. Welfare effects are expressed as the percentage of total tax revenues that a social planner would pay to avoid converting all ironers to correct forecasters.

Table 6: Revenue and Welfare Effects Changing to Flat Tax

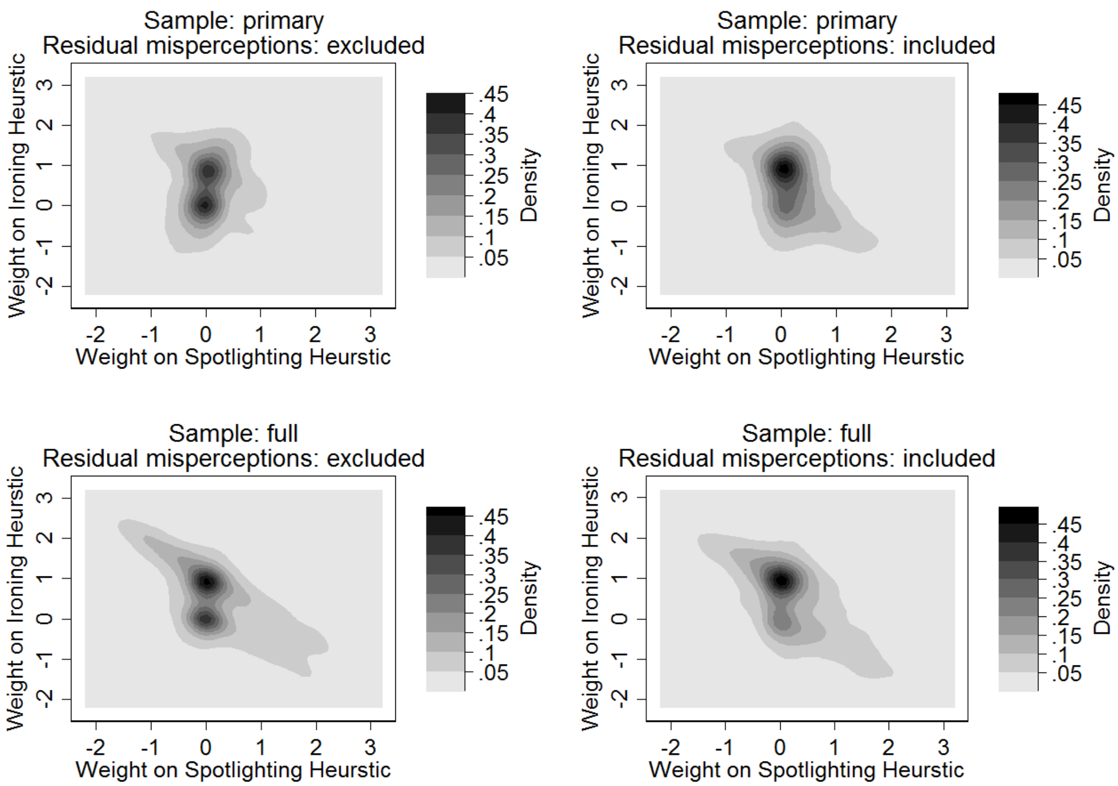
Structural Elasticity ($\frac{1}{k}$)	*All correct forecasters*		*43% ironers*	
	Δ Tax Rev. (%)	Δ Welfare (%)	Δ Tax Rev. (%)	Δ Welfare (%)
1/2	5.2	-9.9	2.9	-12.3
1/3	3.3	-11.6	1.9	-13.2
1/4	2.5	-12.4	1.4	-13.6
1/5	1.9	-12.9	1.1	-13.8

Notes: This table summarizes the revenue collected or welfare attained as a result replacing the progressive tax schedule with a linear schedule that would be revenue-neutral assuming no change in behavior. The first column presents the structural elasticity in our assumed utility model: $U(z) = log(z - T(z) - \frac{(z/w)^{1+k}}{1+k})$. The second and third columns present the additional government revenue and welfare, respectively, resulting from the tax-rate change under the assumption of perfect tax perceptions. The fourth and fifth columns provide analogous calculations under the assumption that 43% of the population irons. Welfare effects are expressed as the percentage of total tax revenues that a social planner would pay to avoid going to the flat tax.

Appendices (not for publication)

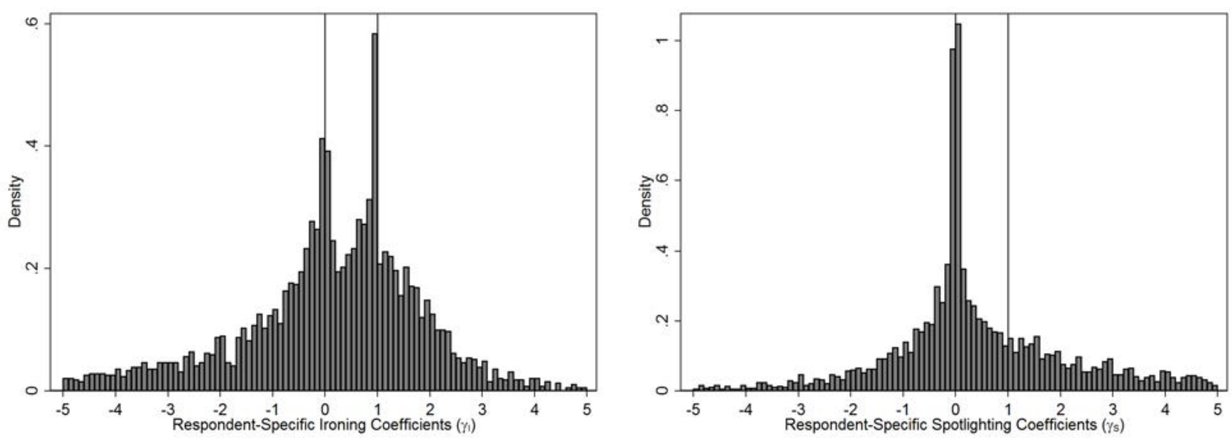
A Supplemental Figure and Tables

Figure A1: Alternative Versions of Figure 5



Notes: This figure plots alternative constructions of Figure 5, made to match the restrictions applied in each of the four columns of table 3. Note that individual-level NLLS regressions failed to converge for 13 respondents when using the mid-range sample, and for 7 respondents when using the full sample.

Figure A2: Marginal Distribution of Ironing and Spotlighting Parameters in Figure 5



Notes: This figure plots a histogram of the marginal distributions derived from the joint distribution plotted in figure 5.

Table A1: Demographics of Sample Compared to Census Data

	In-sample distribution	Census distribution
Gender		
Male	49%	49%
Female	51%	51%
Age		
18-44	39%	48%
45-64	44%	35%
65+	17%	17%
Income		
Under \$15,000	16%	12%
\$15,000 to \$24,999	12%	10%
\$25,000 to \$34,999	11%	10%
\$35,000 to \$49,999	15%	13%
\$50,000 to \$74,999	19%	17%
\$75,000 to \$99,999	13%	12%
\$100,000 to \$149,999	10%	14%
\$150,000 to \$199,999	3%	6%
\$200,000 +	1%	6%

Notes: This table presents tabulations of the gender, age, and income distributions reported in our sample for analysis, compared against the distributions reported in the census. Age distributions condition on being 18+.
Source: http://www.census.gov/prod/cen2010/briefs/c2010br-03.pdf and
https://www.census.gov/data/tables/2016/demo/income-poverty/p60-256.html.

Table A2: Parameter Estimates of Heuristic-Perception Model: Alt. Degrees of Polynomial

	(1)	(2)	(3)	(4)
γ_I: weight on ironing forecast	0.28***	0.41***	0.29***	0.43***
	(0.052)	(0.094)	(0.052)	(0.095)
γ_S: weight on spotlighting forecast	0.01	0.01	-0.00	-0.01
	(0.055)	(0.075)	(0.056)	(0.076)
Degree of $r(t)$ polynomial	1	1	2	2
γ_I: weight on ironing forecast	0.29***	0.43***	0.29***	0.43***
	(0.052)	(0.095)	(0.052)	(0.095)
γ_S: weight on spotlighting forecast	-0.01	-0.02	-0.02	-0.02
	(0.057)	(0.076)	(0.057)	(0.076)
Degree of $r(t)$ polynomial	3	3	4	4
γ_I: weight on ironing forecast	0.29***	0.43***	0.30***	0.43***
	(0.052)	(0.095)	(0.052)	(0.095)
γ_S: weight on spotlighting forecast	-0.02	-0.02	-0.02	-0.02
	(0.057)	(0.076)	(0.057)	(0.076)
Degree of $r(t)$ polynomial	5	5	6	6
γ_I: weight on ironing forecast	0.30***	0.43***	0.30***	0.43***
	(0.052)	(0.095)	(0.052)	(0.095)
γ_S: weight on spotlighting forecast	-0.02	-0.03	-0.02	-0.02
	(0.057)	(0.076)	(0.057)	(0.076)
Degree of $r(t)$ polynomial	7	7	8	8
γ_I: weight on ironing forecast	0.30***	0.43***	0.30***	0.43***
	(0.052)	(0.095)	(0.052)	(0.095)
γ_S: weight on spotlighting forecast	-0.02	-0.03	-0.02	-0.03
	(0.057)	(0.076)	(0.057)	(0.076)
Degree of $r(t)$ polynomial	9	9	10	10
Income Sampling Distribution	Mid	Mid	Full	Full
Respondents	4197	4197	4197	4197
Forecasts	41970	58758	41970	58758

Notes: Standard errors, clustered by respondent, in parentheses. This table reproduces the estimates from columns 2 and 4 of table 3, while varying the degree of the polynomial used to approximate residual misperception. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A3: Classification of Individuals to Ironing Parameters (Table 3 column 1 analog)

	Weight on Spotlighting Heuristic											
Weight on Ironing Heuristic	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Total
0%	1407	55	35	23	20	22	16	19	17	31	41	1686
10%	58	10	7	1	2	1	3	4	1	21	0	108
20%	36	11	2	4	3	3	0	3	12	0	0	74
30%	39	6	2	1	3	2	3	19	0	0	0	75
40%	38	12	4	1	1	4	21	0	0	0	0	81
50%	20	8	4	5	2	28	0	0	0	0	0	67
60%	27	16	5	7	24	0	0	0	0	0	0	79
70%	36	13	13	35	0	0	0	0	0	0	0	97
80%	29	18	59	0	0	0	0	0	0	0	0	106
90%	34	91	0	0	0	0	0	0	0	0	0	125
100%	1054	0	0	0	0	0	0	0	0	0	0	1054
Total	2778	240	131	77	55	60	43	45	30	52	41	3552

Notes: This table presents the distribution of individual-level classifications of heuristic-use parameters for all respondents with positive tax liability. For each respondent, we compared their 10 mid-range sample tax forecasts to the forecast of the model $\tilde{T_{f,i}} = (1 - \gamma_I - \gamma_S)T(z_{f,i}|\theta_i) + \gamma_I\tilde{T}_I(z_{f,i}|z_i^*, \theta_i) + \gamma_S\tilde{T}_S(z_{f,i}|z_i^*, \theta_i) + \epsilon_{f,i}$. We calculated this forecast for the grid of values of (γ_I, γ_S) indicated in the table above, and assigned each respondent to the parameter values which minimized the mean squared error of the difference.

Table A4: Classification of Individuals to Ironing Parameters (Table 3 column 2 analog)

		Weight on Spotlighting Heuristic											
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Total
Weight on Ironing Heuristic	0%	1101	84	72	70	77	56	42	26	14	24	28	1594
	10%	28	13	13	11	4	8	6	8	5	10	0	106
	20%	26	11	5	13	7	6	10	7	12	0	0	97
	30%	30	8	11	4	9	2	6	18	0	0	0	88
	40%	24	19	9	8	7	8	15	0	0	0	0	90
	50%	25	16	13	9	11	29	0	0	0	0	0	103
	60%	34	19	17	10	28	0	0	0	0	0	0	108
	70%	36	24	19	45	0	0	0	0	0	0	0	124
	80%	39	21	68	0	0	0	0	0	0	0	0	128
	90%	49	88	0	0	0	0	0	0	0	0	0	137
	100%	977	0	0	0	0	0	0	0	0	0	0	977
	Total	2369	303	227	170	143	109	79	59	31	34	28	3552

Notes: This table presents the distribution of individual-level classifications of heuristic-use parameters for all respondents with positive tax liability. For each respondent, we compared their 10 mid-range tax forecasts to the forecast of the model $\tilde{T_{f,i}} = (1-\gamma_I-\gamma_S)(T(z_{f,i}|\theta_i)+\hat{r}(T(z_{f,i}|\theta_i))) + \gamma_I\tilde{T}_I(z_{f,i}|z_i^*,\theta_i)+\gamma_S\tilde{T}_S(z_{f,i}|z_i^*,\theta_i)+\epsilon_{f,i}$, where $\hat{r}$ represents the fitted residual misperception function estimated in column 2 of table 3. We calculated this forecast for the grid of values of (γ_I, γ_S) indicated in the table above, and assigned each respondent to the parameter values which minimized the mean squared error of the difference.

Table A5: Classification of Individuals to Ironing Parameters

	Weight on Spotlighting Heuristic											
Weight on Ironing Heuristic	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Total
0%	1155	77	36	31	42	42	42	34	26	39	60	1584
10%	38	13	8	3	6	3	7	5	13	16	0	112
20%	24	8	4	4	3	4	2	2	22	0	0	73
30%	24	11	7	0	1	4	5	30	0	0	0	82
40%	20	12	5	4	3	1	34	0	0	0	0	79
50%	20	10	3	4	3	38	0	0	0	0	0	78
60%	20	11	9	4	40	0	0	0	0	0	0	84
70%	29	14	6	47	0	0	0	0	0	0	0	96
80%	20	12	64	0	0	0	0	0	0	0	0	96
90%	32	81	0	0	0	0	0	0	0	0	0	113
100%	1155	0	0	0	0	0	0	0	0	0	0	1155
Total	2537	249	142	97	98	92	90	71	61	55	60	3552

Notes: This table presents the distribution of individual-level classifications of heuristic-use parameters for all respondents with positive tax liability. For each respondent, we compared their 14 tax forecasts to the forecast of the model $\tilde{T_{f,i}} = (1 - \gamma_I - \gamma_S)T(z_{f,i}|\theta_i) + \gamma_I \tilde{T}_I(z_{f,i}|z_i^*, \theta_i) + \gamma_S \tilde{T}_S(z_{f,i}|z_i^*, \theta_i) + \epsilon_{f,i}$. We calculated this forecast for the grid of values of (γ_I, γ_S) indicated in the table above, and assigned each respondent to the parameter values which minimized the mean squared error of the difference.

Table A6: Classification of Individuals to Ironing Parameters (Table 3 column 4 analog)

Weight on Ironing Heuristic		**Weight on Spotlighting Heuristic**											
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Total
	0%	1118	97	47	33	49	27	35	20	23	15	25	1489
	10%	29	16	11	3	9	6	5	5	11	10	0	105
	20%	36	17	7	8	3	3	7	4	8	0	0	93
	30%	32	9	6	3	1	2	3	20	0	0	0	76
	40%	37	11	9	1	0	2	23	0	0	0	0	83
	50%	26	12	10	9	7	17	0	0	0	0	0	81
	60%	34	20	17	6	24	0	0	0	0	0	0	101
	70%	39	27	18	25	0	0	0	0	0	0	0	109
	80%	50	30	56	0	0	0	0	0	0	0	0	136
	90%	56	77	0	0	0	0	0	0	0	0	0	133
	100%	1146	0	0	0	0	0	0	0	0	0	0	1146
	Total	2603	316	181	88	93	57	73	49	42	25	25	3552

Notes: This table presents the distribution of individual-level classifications of heuristic-use parameters for all respondents with positive tax liability. For each respondent, we compared their 14 tax forecasts to the forecast of the model $\tilde{T_{f,i}} = (1-\gamma_I-\gamma_S)(T(z_{f,i}|\theta_i)+\hat{r}(T(z_{f,i}|\theta_i)))+\gamma_I\tilde{T}_I(z_{f,i}|z_i^*,\theta_i)+\gamma_S\tilde{T}_S(z_{f,i}|z_i^*,\theta_i)+\epsilon_{f,i}$, where $\hat{r}$ represents the fitted residual misperception function estimated in column 4 of table 3. We calculated this forecast for the grid of values of (γ_I,γ_S) indicated in the table above, and assigned each respondent to the parameter values which minimized the mean squared error of the difference.

B Theory Appendix

We assume that utility takes the form $G(u(c) - \psi(z/w))$, where u is smooth, increasing and concave, ψ is smooth, strictly increasing and convex, and $\psi(0) = 0$ and $\lim_{z\to\infty} \psi'(z) = \infty$. We also assume that $-xu''(x)/u'(x) < 1$ to ensure that substitution effects dominate income effects; that is, so that an increase in a flat tax rate decreases the marginal benefits of consumption.

B.1 Existence and Uniqueness of the Solution Concept

Definition 3. Choice $z^*(w)$ is a *Ironing Equilibrium (IE)*, if

$$z^*(w) \in \text{argmax}\{U(z - \tilde{T}(z|z^*(w), \gamma), z/w)\}$$

where $\tilde{T}(z|z^*) = (1-\gamma)T(z^*) + \gamma z A(z^*)$ and $A(z^*)$ is the average tax rate at z^*.

Proposition 1. *Suppose that $T(z)$ is continuous. Then*

1. *There exists a IE $z^*(w)$.*
2. *z^* is continuous and increasing in w.*
3. *z^* is continuous and increasing in γ.*

Proof of Proposition 1 Assume that $G(x) = x$; which is without loss of generality since monotonic transformations of utility functions preserve behaviors.

Part 1. Let $B_{w,\gamma}(z')$ denote an optimal choice of z by an individual facing tax schedule $\tilde{T}(z|z')$. We first establish the following

1. $\tilde{T}(z|z')$ is convex for each z' because $T(z)$ is convex. Because u is concave and ψ is strictly convex, this means that $u(z - \tilde{T}(z|z')) - \psi(z/w)$ is strictly concave in z. Thus $B_w(z')$ is uniquely defined.
2. $B_{w,\gamma}(z')$ is continuous in z' because $u(z - \tilde{T}(z|z')) - \psi(z/w)$ is continuous in z' and is strictly concave in z.
3. $B_{w,\gamma}(z')$ is decreasing in z'. To show this, first note that

$$\frac{d}{dz}u(z - \tilde{T}(z|z')) = [1 - (1-\gamma)T'(z) - \gamma A(z')]u'(\cdot)$$

and

$$\begin{aligned}
\frac{d}{dz'}\frac{d}{dz}u(z - \tilde{T}(z|z')) &= -\gamma A'(z')u'(\cdot) + [1 - (1-\gamma)T'(z) - \gamma A(z')](-\gamma z A'(z')u''(\cdot)] \\
&< -\gamma A'(z')u'(\cdot) + (-\gamma z A'(z')u''(\cdot)] \\
&= -\gamma A'(z')u'(\cdot)[1 + zu''(\cdot)/u'(\cdot)] \\
&< 0
\end{aligned}$$

This implies that the perceived marginal benefits of increasing z are decreasing in z', and thus $B_{w,\gamma}(z')$ must be decreasing in z'.

4. $B_{w,\gamma}(0) > 0$, since the assumption that $\psi(0) = 0$ guarantees that the optimal choice of z is interior for any perceived tax schedule. Also, $B_{w,\gamma}(z') < z'$ for large enough z' by the assumption that $\lim_{z\to\infty} \psi'(z) = \infty$.

The above four facts show that $B_{w,\gamma}(z')$ is a continuous and decreasing function, that $B_{w,\gamma}(0) > 0$ and that there exists a $\bar{z}$ large enough such that $B_{w,\gamma}(z) \in [0, \bar{z}]$ for every $z \in [0, \bar{z}]$. Brower's theorem guarantees that a fixed point exists. It must also be unique: If $B_{w,\gamma}(x) = x$ and $B_{w,\gamma}(x') = x'$ for $x < x'$ then because $B_{w,\gamma}(x)$ is a decreasing function of x, it must follow that $0 < B_{w,\gamma}(x) - B_{w,\gamma}(x') = x - x'$, which is a contradiction.

Part 2. Because $u(z - \tilde{T}(z|z')) - \psi(z/w)$ is continuous in w and is strictly concave in z, it follows that $B_{w,\gamma}(z')$ is continuous in w. Because $B_{w,\gamma}$ is continuous in w and has a unique fixed point, its fixed point must be continuous as well. If this were not the case, there would be a $\delta > 0$ such that for any $\epsilon > 0$, the fixed points z_ϵ of $B_{w+\epsilon,\gamma}$ and z of $B_{w,\gamma}$ would always satisfy $|z_\epsilon - z| > \delta$. But $\lim_{\epsilon\to 0} B_{w+\epsilon,\gamma}(z) = B_{w,\gamma}(z) = z$ because B is continuous in w. Now that implies that there exists a series $\epsilon_i \to 0$ such that, without loss of generality, $z_{\epsilon_i} > z$ for all i. But then $B_{w+\epsilon_i,\gamma}(z_{\epsilon_i}) < B_{w+\epsilon_i,\gamma}(z)$ for all i, while $z_{\epsilon_i} - z > \delta$ for all i. This leads to the contradiction that $0 \geq \lim_{\epsilon_i\to 0}(B_{w+\epsilon_i,\gamma}(z_{\epsilon_i}) - B_{w+\epsilon_i,\gamma}(z)) = (z_{\epsilon_i} - z) > \delta$,

Next, we show that for any $z_1 > z_2$ and z', $\Big(u(z_1 - \tilde{T}(z_1|z')) - \psi(z_1/w)\Big) - \Big(u(z_2 - \tilde{T}(z_2|z')) - \psi(z_2/w)\Big)$ is strictly increasing in w. To see this, take the derivative with respect to w:

$$\frac{1}{w^2}\psi'(z_1/w) - \frac{1}{w^2}\psi'(z_2/w)$$

The above equation is positive because ψ' is increasing. Thus for $w_1 < w_2$, $B_{w_1,\gamma}(z) < B_{w_2,\gamma}(z)$ for all z. Moreover, the assumption that $\lim_{z\to\infty}\psi'(z) = \infty$ guarantees that there exists a $\bar{z}$ such that $B_{w_i,\gamma}(z) \in [0, \bar{z}]$ for all $z \in [0, \bar{z}]$ and all $i \in \{1, 2\}$. The statement in the proposition is thus a standard comparative static on fixed points (e.g., Theorem 1 of Villas-Boas, 1997).

Part 3. Continuity in γ follows as in part 2. Next, it follows that for $z_1 > z_2$, $\tilde{T}(z_1|z') - \tilde{T}(z_2|z')$ is decreasing in γ. Thus, for any $z_1 > z_2$ and z', $\Big(c - \psi(z_1/w) - \tilde{T}(z_1|z')\Big) - \Big(c - \psi(z_2/w) - \tilde{T}(z_2|z')\Big)$ is increasing in γ. The result then follows as in Part 2 by Villas-Boas (1997). ■

An observation: It is useful to note that convexity of T plays two important roles in the proof of Proposition 1. First, it ensures that the individual's optimization problem is convex, and thus that B_w is single-valued. In particular, this then ensures that B_w has a closed graph, a property that would not hold for all possible T. Second, convexity of T ensures that B_w is a decreasing function. If T were concave, however, B_w would be an increasing function; and more generally, B_w could be increasing in some regions and decreasing in others for some tax schedules T. Existence and uniqueness are thus not guaranteed for all possible T. To ensure existence, the ME concept would need to be extended to allow for "mixed strategies."

B.2 An Instructive Two-Bracket Model

For purposes of crisp and simple exposition, we will illustrate the main qualitative implications of ironing using a model in which individuals are either low-income earners ($w = w_L$) or high-income earners ($w = w_H$). We assume utility takes the form $G(c - \psi(l))$, where ψ is isoelastic with structural elasticity $\varepsilon < 1$. Motivated by our empirical results, we also assume that workers either correctly perceive taxes or are pure ironers ($\gamma = 0$ or $\gamma = 1$), with $Pr(\gamma = 1) \equiv \gamma_I$ for both wage types.

The policymaker sets a two-bracket income tax given by $T(z) = \tau_1 z$ for $z \le z^\dagger$ and $T(z) = \tau_1 z^\dagger + \tau_2(z - z^\dagger)$ for $z > z^\dagger$. We assume that the parameters are such that low-income earners fall in the bottom bracket while high-income earners fall in the top bracket. For the low-income earners, we assume that $g(w_L, \gamma) > 1$; that is, the policymaker would transfer additional resources to them if he could do it in a non-distortionary way. For the high-income earner, we assume that w_H is high enough that $(\lambda - G'(z - T(z) - \psi(z/w_H)))\, z$ is increasing in z for all $z \in [z^*(w_H, 0), z^*(w_H, 1)]$. This is a slightly stronger version of the assumption that $g(w_H, \gamma) < 1$ for the high income earners, and must be true for high enough w_H. Throughout, we also assume that τ_2 is lower than the revenue-maximizing tax rate.

Preliminaries

We begin with some preliminary observations we use repeatedly in other proofs.

- For high types, the ATR is $A(z) = \frac{\tau_1 z^\dagger + \tau_2(z - z^\dagger)}{z} = \tau_2 - (\tau_2 - \tau_1)z^\dagger/z$.
- Thus $T'(z) - A(z) = (\tau_2 - \tau_1)z^\dagger/z$ and the perceived MTR by ironing H types is $\tilde{\tau}_2^H(z) = (1-\gamma)\tau_2 + \gamma A(z) = \tau_2 - \gamma(\tau_2 - \tau_1)z^\dagger/z$.
- $\frac{\partial A}{\partial \tau_2} = (1 - z^\dagger/z)$ and $\frac{\partial \tilde{\tau}_2}{\partial \tau_2} = 1 - \gamma z^\dagger/z$.
- $\frac{\partial A}{\partial z} = (\tau_2 - \tau_1)z^\dagger/z^2$, and $\frac{\partial \tilde{\tau}_2}{\partial z} = \gamma(\tau_2 - \tau_1)z^\dagger/z^2$.
- The structural elasticity ε is given by $\varepsilon = \frac{1}{(1/w^2)\psi''(z/w)} \cdot \frac{(1/w)\psi'(z/w)}{z} = \frac{\psi'(z/w)}{(z/w)\psi''(z/w)}$.

Lemma 1. *For the high types,* $\frac{dz}{d\gamma} = \frac{\varepsilon z^\dagger(\tau_2 - \tau_1)}{1 - \tau_2 + \gamma(1+\varepsilon)(\tau_2 - \tau_1)(z^\dagger/z)}$.

Proof. The high types' first-order condition for choice of z is

$$(1/w)\psi'(z/w) = 1 - \tilde{\tau}_2^H(z) = 1 - \tau_2 + \gamma(\tau_2 - \tau_1)z^\dagger/z.$$

Differentiating implicitly with respect to γ yields

$$(1/w^2)\psi''(z/w)\frac{dz}{d\gamma} = -\frac{\gamma(\tau_2 - \tau_1)z^\dagger}{z^2}\frac{dz}{d\gamma} + (\tau_2 - \tau_1)(z^\dagger/z)$$

and thus

$$\frac{dz}{d\gamma} = \frac{(\tau_2 - \tau_1)(z^\dagger/z)}{(1/w^2)\psi''(z/w) + \frac{\gamma(\tau_2 - \tau_1)z^\dagger}{z^2}} > 0.$$

This establishes that high-income ironers (those with $\gamma = 1$) choose higher labor supply than high-income non-ironers (those with $\gamma = 0$).

We now have

$$\begin{aligned}
\frac{dz}{d\gamma} &= \frac{(\tau_2-\tau_1)(z^\dagger/z)}{(1/w^2)\psi''(z/w)+\frac{\gamma(\tau_2-\tau_1)z^\dagger}{z^2}} \\
&= \frac{(\tau_2-\tau_1)(z^\dagger/z)}{(1/\varepsilon)(1/w)(1/z)\psi'(z/w)+\frac{\gamma(\tau_2-\tau_1)z^\dagger}{z^2}} \\
&= \frac{\varepsilon z^\dagger(\tau_2-\tau_1)}{(1/w)\psi'(z/w)+\varepsilon\gamma(\tau_2-\tau_1)(z^\dagger/z)} \\
&= \frac{\varepsilon z^\dagger(\tau_2-\tau_1)}{1-\tilde{\tau}_2+\varepsilon\gamma(\tau_2-\tau_1)(z^\dagger/z)} \\
&= \frac{\varepsilon z^\dagger(\tau_2-\tau_1)}{1-\tau_2+\gamma(\tau_2-\tau_1)z^\dagger/z+\varepsilon\gamma(\tau_2-\tau_1)(z^\dagger/z)} \\
&= \frac{\varepsilon z^\dagger(\tau_2-\tau_1)}{1-\tau_2+\gamma(1+\varepsilon)(\tau_2-\tau_1)(z^\dagger/z)}
\end{aligned}$$

□

Lemma 2. *For the high types,* $\frac{dz}{d\tau_2} = -\frac{z\varepsilon-\gamma z^\dagger\varepsilon}{1-\tau_2+\gamma(1+\varepsilon)(\tau_2-\tau_1)z^\dagger/z} < 0$

Proof. We have

$$\begin{aligned}
\frac{dz}{d\tau_2} &= -\frac{1-\gamma z^\dagger/z}{\frac{1}{w^2}\psi''(z/w)+\gamma(\tau_2-\tau_1)z^\dagger/z^2} \\
&= -\frac{1-\gamma z^\dagger/z}{\frac{1-\tilde{\tau}_2}{z\varepsilon}+\gamma(\tau_2-\tau_1)z^\dagger/z^2} \\
&= -\frac{z\varepsilon-\gamma z^\dagger\varepsilon}{1-\tilde{\tau}_2+\gamma\varepsilon(\tau_2-\tau_1)z^\dagger/z} \\
&= -\frac{z\varepsilon-\gamma z^\dagger\varepsilon}{1-\tau_2+\gamma(\tau_2-\tau_1)z^\dagger/z+\gamma\varepsilon(\tau_2-\tau_1)z^\dagger/z} \\
&= -\frac{z\varepsilon-\gamma z^\dagger\varepsilon}{1-\tau_2+\gamma(1+\varepsilon)(\tau_2-\tau_1)z^\dagger/z}
\end{aligned}$$

This is negative because $\gamma z^\dagger < z$. □

Lemma 3. *For the high types,* $\frac{d\tilde{\tau}_2}{d\tau_2} > 0$

Proof. Start with the FOC $1-\tilde{\tau}_2 = \psi'(z/w)/w$. Now by Lemma 2, z is decreasing in τ_2, and thus the right-hand-side of the FOC is decreasing in τ_2 (by convexity of ψ). Since the right-hand-side is decreasing in τ_2 , $\tilde{\tau}_2$ must be increasing in τ_2. □

Main results:

Claim 1. Labor supply and thus government revenue increase in the propensity to iron.

Proof. Follows by Lemma 1. □

Claim 2. The extra revenue raised due to ironing is raised progressively.

Proof. Notice that in the two-bracket model, the term $T'(z) - A(z)$ is zero for the low-earning types and is positive for high-earning types, indicating that the entire burden of misoptimization falls on the comparatively rich. Combined with the earlier implication that ironing increases government revenue, this additional result establishes that the additional revenue is raised in a manner that is desirable for redistributive purposes. □

Claim 3. Ironing increases social welfare.

Proof. The first two observations—that ironing counteracts the distortionary affects of taxation by raising earnings, and that it increases government revenue in a progressive fashion—lead to the implication that ironing leads to progressive revenue collection. To see this simply in our two-bracket model, notice that ironing has no effect on the behavior of the low-income earners, for whom the marginal and the average tax rate both equal τ_1. The social welfare effect of increasing the γ of a high-income earner (normalized by the marginal value of public funds), for whom the difference between marginal and average tax rates is $(\tau_2 - \tau_1)\frac{z^\dagger}{z}$, is

$$\underbrace{T'(z)\frac{dz}{d\gamma}}_{\text{Gov revenue}} + \underbrace{\frac{d}{dz}G(z - T(z) - \psi(z/w))\frac{dz}{d\gamma}/\lambda}_{\text{Individual utility cost}} = (T'(z) - g(w_H,\gamma)\gamma(T'(z) - A(z)))\frac{dz}{d\gamma} \tag{5}$$

$$= \left(\tau_2 - g(w_H,\gamma)\gamma(\tau_2 - \tau_1)\frac{z^\dagger}{z}\right)\frac{dz}{d\gamma}$$

Now since $g < 1$ for the high income earners, and since $\gamma(\tau_2 - \tau_1)\frac{z^\dagger}{z} < \tau_2$ for all $z \geq z^\dagger$, it follows that the social welfare impact of increasing the $\gamma$of a high income earner is positive. This directly implies that social welfare is increasing in the propensity to iron. □

Claim 4. The revenue and welfare effects of raising tax rates on high incomes are increasing in the propensity to iron.

We prove the result via a series of instructive lemmas that establish intermediate results that further help flesh out the intuition behind how ironers respond to tax rate perturbations. In the first two lemmas we first show that the impact of ironing on earnings is strongest the more convex the the tax schedule is-–that is, the higher is τ_2.

Lemma 4. *For the high type, earnings, $\frac{d}{d\tau_2}\frac{d}{d\gamma}z > 0$ as long as τ_2 is not so high that raising it further would decrease revenue collected from ironers.*

Proof. That τ_2 is lower than the revenue-maximizing tax-rate for ironers implies that $z + \tau_2\frac{dz}{d\tau_2} \geq 0$, and thus that $\frac{1}{z}\frac{dz}{d\tau_2} \geq -\frac{1}{\tau_2}$. Thus

$$
\begin{aligned}
\frac{d}{d\tau_2}\frac{d}{d\gamma}z = & \frac{d}{d\tau_2}\frac{(\tau_2-\tau_1)}{1-\tilde{\tau}_2+\gamma\varepsilon(\tau_2-\tau_1)(z^\dagger/z)} \\
& \propto (1-\tilde{\tau}_2)+\gamma\varepsilon(\tau_2-\tau_1)(z^\dagger/z) \\
& -(\tau_2-\tau_1)\left[-\frac{d\tilde{\tau}_2}{d\tau_2}-\gamma\varepsilon(\tau_2-\tau_1)(z^\dagger/z^2)\frac{dz}{d\tau_2}\right] \\
& \geq (1-\tilde{\tau}_2)+\gamma\varepsilon(\tau_2-\tau_1)(z^\dagger/z)+(\tau_2-\tau_1)\frac{d\tilde{\tau}_2}{d\tau_2} \\
& -\gamma\varepsilon(\tau_2-\tau_1)^2(z^\dagger/z)(1/\tau_2) \\
& = (\tau_2-\tau_1)\frac{d\tilde{\tau}_2}{d\tau_2}+(1-\tilde{\tau}_2)+\gamma\varepsilon(\tau_2-\tau_1)(z^\dagger/z)(1-(\tau_2-\tau_1)/\tau_2) \\
& = (\tau_2-\tau_1)\frac{d\tilde{\tau}_2}{d\tau_2}+(1-\tilde{\tau}_2)+\gamma\varepsilon\,(\tau_2-\tau_1)\,(z^\dagger/z)(\tau_1/\tau_2) \\
& > 0
\end{aligned}
$$

□

To complete our result claim that the impact of ironing on earnings is increasing with τ_2 we now show that as long as τ_2 is below the revenue-maximizing tax-rate, the revenue from ironers will increase in τ_2, a condition of Lemma 4.

Lemma 5. *The tax rate $\bar{\tau}_2^I$ that maximizes revenue from the ironing individuals is higher than the tax rate $\bar{\tau}_2^{NI}$ that maximizes revenue from the non-ironing individuals.*

Proof. Suppose, for the sake of contradiction, that $\bar{\tau}_2^I < \bar{\tau}_2^{NI}$. Then by the previous lemma, $z+\tau_2\frac{dz}{d\tau_2}=0$ for the ironers at $\tau=\bar{\tau}_2^I$, while $z+\tau_2\frac{dz}{d\tau_2}<0$ for the non-ironers at $\tau=\bar{\tau}_2^I$. We will now reach a contradiction if we can show that the revenue extracted from non-ironers is a concave function of τ_2. To that end, note that for the non-ironers, $\frac{dz}{d\tau_2}=-\frac{z\varepsilon}{1-\tau_2}$, and thus

$$
\begin{aligned}
\frac{d}{d\tau_2}\left(z+\tau_2\frac{dz}{d\tau_2}\right) &= 2\frac{dz}{d\tau_2}-\tau_2\frac{d}{d\tau_2}\frac{z\varepsilon}{1-\tau_2} \\
&= 2\frac{dz}{d\tau_2}-\tau_2\frac{\varepsilon(1-\tau_2)\frac{dz}{d\tau_2}+z\varepsilon}{(1-\tau_2)^2} \\
&= 2\frac{dz}{d\tau_2}-\tau_2\frac{-z\varepsilon^2+z\varepsilon}{(1-\tau_2)^2} \\
&= 2\frac{dz}{d\tau_2}-z\varepsilon\tau_2\frac{1-\varepsilon}{(1-\tau_2)^2}<0
\end{aligned}
$$

□

Lemma 6. *Under the assumption that τ_2 is lower than the tax-rate that maximizes revenue, $\frac{d}{d\tau_2}\frac{d}{d\gamma}z>0$ for the high types.*

Proof. Follows directly from the previous two lemmas. □

Having characterized the revenue effects of ironing on increasing τ_2, we now proceed to analyze the welfare effects. We begin by characterizing just the effect of increasing τ_2 on an ironer's welfare:

Lemma 7. *An increase in the tax rate impacts a high type ironer's utility by* $-\frac{dz}{d\tau_2}\gamma(\tau_2 - \tau_1)z^\dagger/z$

Proof. We have

$$\begin{aligned}
\frac{d}{d\tau_2}(z - T(z) - \psi(z/w)) &= -z + (1 - T'(z) - \psi'(z/w)/w)\frac{dz}{d\tau_2} \\
&= -z + \left(1 - T'(z) - (1 - \tilde{T}'(z))\right)\frac{dz}{d\tau_2} \\
&= -z - \gamma(T'(z) - A(z))\frac{dz}{d\tau_2} \\
&= -z - \gamma(\tau_2 - \tau_1)z^\dagger/z\frac{dz}{d\tau_2}
\end{aligned}$$

□

We now compute the social marginal welfare effect of increasing τ_2, taking into account the revenue effects.

Lemma 8. *The welfare impact of increasing the tax rate on high types with ironing weight* γ *and social marginal welfare weight* g *is given by* $\frac{dW}{d\tau_2} = \frac{dz}{d\tau_2}\left(\tau_2 - g\gamma(\tau_2 - \tau_1)z^\dagger/z\right) + (1-g)z$

Proof. Increasing τ_2 mechanically increases revenue by z. This is offset by the substitution to leisure, which leads to a revenue loss of $-\frac{dz}{d\tau_2}\tau_2$. Putting the revenue effects, which are weighted by λ, together with the impact on individual welfare as computed in Lemma 8, which is weighted by $g(z)$ leads to the statement in the proposition. □

We are now ready complete the proof of Claim 4. Lemma 6 implies that a tax rate change impacts ironers less than it does non-ironers. For the welfare effect, note that because $\frac{dz}{d\tau_2}$ is increasing in γ, and because $g\gamma(\tau_2 - \tau_1)z^\dagger/z$ is plainly higher for $\gamma = 1$ than for $\gamma = 0$, the term $\frac{dz}{d\tau_2}\left(\tau_2 - g\gamma(\tau_2 - \tau_1)z^\dagger/z\right)$ is higher for ironers than for non-ironers. Moreover, because z is higher for ironers than non-ironers by Implication 1, our assumptions imply that $(1-g)z$ is higher for ironers than for non-ironers. This completes the proof of Implication 4.

Claim 5. The revenue and welfare effects of raising tax rates on low incomes are decreasing in the propensity to iron.

Proof: Reasoning analogous to Lemma 7 shows that the impact of increasing τ_1 on the utility of high-income full ironers is given by $-\frac{dz}{d\tau_1}\gamma(\tau_2 - \tau_1)z^\dagger/z$. The direct impact on public funds is $z^\dagger$. The indirect substitution effect generates revenue losses given by $-\frac{dz}{d\tau_1}\tau_2$. Putting this together, the social marginal welfare effect stemming from high-income full ironers is given by

$$\begin{aligned}
&\frac{dz}{d\tau_1}\left(\tau_2 - g(w_H, 1)(\tau_2 - \tau_1)z^\dagger/z\right) + (1 - g(w_H, 1))z^\dagger \\
&= \frac{dz}{d\tau_1}\left((1 - g(w_H, 1))\tau_2 + g(w_H, 1)A(z)\right) + (1 - g(w_H, 0))z^\dagger
\end{aligned}$$

By comparison, the social marginal welfare effect stemming from non-ironers is simply $(1 - g(w_H, 0))z^\dagger$. Because , ironing leads to lower individual utility $g(w_H, 0) > g(w_H, 1)$ and thus $(1 - g(w_H, 1))z^\dagger < (1 - g(w_H, 0))z^\dagger$. Moreover, $\frac{dz}{d\tau_1} < 0$ for ironers. Thus the social marginal welfare effect from increasing τ_1 is decreasing in the number of (full) ironers.

Claim 6. Ironing increases the welfare consequences of making taxes more progressive.

Proof. This is a direct corollary of Implications 5 and 6. □

B.3 Results for a General Income Tax

We now consider perturbations of any smooth income tax $T(z)$ in a model with a continuum of types. We first solve for the effects of increasing the marginal tax rate by some amount $d\tau$ on all incomes above $z(w^\dagger, 0)$—the earnings of non-ironers with wage $w^\dagger$. We then use this to characterize the optimal nonlinear income tax. We assume that the fraction of ironers is γ_I, which is independent of w. We consider a social welfare function $W = \int \alpha(z, w, 1_\gamma)U(c, z/w)dF(w)$, with α denoting the social welfare weights and $U(c, l) = G(c - \psi(l))$. We let λ denote the social marginal value of public funds. We assume that welfare weights α are such that the social marginal welfare weights $g = \alpha U_c/\lambda$ depend only on z. This assumption follows the Saez (2002a) treatment of multidimensional heterogeneity.

B.3.1 Preliminary Results

As is standard, we define the structural elasticity to be $\varepsilon(z, w) := \frac{\psi'(z/w)/w}{z\psi''(z/w)/w^2}$. This is the elasticity with respect to a linear tax rate of an individual with wage w earning income z. Note that for a utility function $U(c, l) = c - \frac{l^{1+k}}{1+k}$, the elasticity is $\varepsilon \equiv 1/k$.

We next quantify how non-ironers change their earnings in response to a small decrease η in their marginal tax rate. Their FOC is $\psi'(z/w)/w = (1 - T'(z)) + \eta$. The derivative with respect to η is $\psi''(z/w)/w^2 \frac{dz}{d\eta} = (-T''(z))\frac{dz}{d\eta} + 1$. Thus

$$\begin{aligned}
\frac{dz}{d\eta} &= \frac{1}{\psi''(z/w)/w^2 + T''(z)} \\
&= \frac{1}{(1 - T')/(z\varepsilon) + T''} \\
&= \frac{z\varepsilon}{1 - T' + z\varepsilon T''}
\end{aligned}$$

We now analogously compute how ironers respond to a small decrease η in their average tax rate. Consider the ironer's FOC $\psi'(z/w) = w(1 - A(z)) + \eta$. Differentiating that with respect to η yields $\psi''(z/w)/w^2 \frac{dz}{d\eta} = (-A'(z))\frac{dz}{d\eta} + 1$. Now $A = T(z)/z$ and thus $A'(z) = \frac{T'z - T}{z^2} = \frac{T' - A}{z}$. Thus

$$\begin{aligned}
\frac{dz}{d\eta} &= \frac{1}{\psi''/w^2 + \frac{T' - A}{z}} \\
&= \frac{1}{(1 - A)/(z\varepsilon) + (T' - A)/z} \\
&= \frac{z\varepsilon}{1 - A + \varepsilon(T' - A)}
\end{aligned}$$

B.3.2 Welfare Gains of Raising Tax Rates

Let $\bar{\gamma}_I(z)$ be the fraction of ironers with incomes above z. Consider increasing the marginal tax rate by some amount $d\tau$ on all incomes above $z^\dagger$. This has the following effects:

1. A mechanical revenue effect, net of welfare loss, given by $d\tau Pr(z \geq z^\dagger)E\left[(z - z^\dagger)(1 - g(z))|z \geq z^\dagger\right]$
2. Substitution toward leisure by the non-ironers. For a given individual, this is $\frac{dz}{d(1-\tau)} = \frac{-z\varepsilon}{1-T'+z\varepsilon T''}$. This leads to an overall loss to public funds given by $d\tau Pr(z \geq z^\dagger|1_\gamma(z) = 0)E\left[\frac{z\varepsilon T'(z)}{1-T'(z)+z\varepsilon T''(z)}|z \geq z^\dagger, 1_\gamma(z) = 0\right]$.
3. Substitution toward leisures by the ironers. Note that the ironers set $(1-A)-\psi'(z/w)/w = 0$, and thus the impact on a given ironer's welfare from a change dz in earnings is $((1 - T'(z)) - (1 - A(z)))dz = (A(z) - T'(z))dz = (A(z) - T'(z))dz$. The impact on public funds is again $T'(z)dz$. The change dz is $\frac{dz}{d(1-A)} \cdot \left(\frac{z-z^\dagger}{z}\right) d\tau = -\frac{z\varepsilon}{1-A+\varepsilon(T'-A)}\left(\frac{z-z^\dagger}{z}\right) d\tau$. This leads to an overall welfare impact of $d\tau Pr(z \geq z^\dagger|1_\gamma(z) = 1)E\left[\frac{z\varepsilon\tilde{\tau}(z)}{1-A(z)+\varepsilon(T'-A)}\frac{z-z^\dagger}{z}|z \geq z^\dagger, 1_\gamma(z) = 1\right]$, where $\tilde{\tau}(z) = T'(z) + g(z)(A(z) - T'(z)) = (1 - g(z))T'(z) + g(z)A(z)$.

Putting this together, the overall effect of an increase $d\tau$ in the marginal tax rate on all incomes above $z^\dagger$ is:

$$\begin{aligned} &Pr(z \geq z^\dagger)E\left[(z - z^\dagger)(1 - g(z))|z \geq z^\dagger\right] \\ &-Pr(z \geq z^\dagger)(1 - \bar{\gamma}_I(z^\dagger))E\left[\frac{z\varepsilon T'(z)}{1 - T'(z) + z\varepsilon T''(z)}|z \geq z^\dagger, 1_\gamma(z) = 0\right] \\ &-Pr(z \geq z^\dagger)\bar{\gamma}_I(z^\dagger)E\left[\frac{z\varepsilon\tilde{\tau}(z)}{1 - A(z) + \varepsilon(T' - A)}\frac{z - z^\dagger}{z}|z \geq z^\dagger, 1_\gamma(z) = 1\right] \end{aligned}$$

Note that $\tilde{\tau}(z) \leq T'(z)$ when $g(z) > 0$ and $T'(z) \geq A(z)$. Thus,

$$\frac{z\varepsilon T'(z)}{1 - T'(z) + z\varepsilon T''(z)} = -\frac{dz}{d(1 - T')}|_{1_\gamma=1} > \frac{dz}{d(1 - A)}|_{1_\gamma=0} = \frac{z\varepsilon\tilde{\tau}(z)}{1 - A(z) + \varepsilon(T'(z) - A(z))}$$

whenever $1 - T'(z) + z\varepsilon T''(z) < 1 - A + \varepsilon(T'(z) - A(z))$. This occurs at each point z at which T is not too convex. In particular, this inequality holds for any point z on a linear part of the schedule. This establishes that increasing marginal tax rates, particularly in the top bracket, generates higher welfare gains in the presence of more ironers when the tax schedule is progressive ($T'(z) > A(z)$ over the income range under consideration).

B.3.3 Top Marginal Tax Rate

We now follow Saez (2001) to derive the top marginal tax rate. We assume that $\lim_{z\to\infty} T'(z)$ exists and is finite. This implies that $\lim_{z\to\infty} T'(z) - A(z) = 0$ and that $\lim_{z\to\infty} T''(z) = 0$. We also assume that the elasticity $\varepsilon(z)$ converges to $\bar{\varepsilon}$. Finally, we assume that the social marginal welfare weights for the top converge to $\bar{g}$ and that the propensity to iron is uncorrelated with earnings ability at the top.

We use the Saez (2001) result that $\lim_{z^\dagger\to\infty} E[z|z \geq z^\dagger]/z^\dagger = a/(a-1)$, where a is the pareto parameter of the income distribution. In the limit, the effect of an increase $d\tau$ in the marginal tax rate on all incomes above $z^\dagger$ is then

$$Pr(z \geq z^{\dagger})E\left[(z - z^{\dagger})(1-\bar{g})|z \geq z^{\dagger}\right]$$
$$-Pr(z \geq z^{\dagger})(1-\bar{\gamma}_I(z^{\dagger}))E\left[\frac{z\bar{\varepsilon}T'}{1-T'}|z \geq z^{\dagger}\right]$$
$$-Pr(z \geq z^{\dagger})\bar{\gamma}_I(z^{\dagger})E\left[\frac{z\bar{\varepsilon}T'}{1-T'}\frac{z-z^{\dagger}}{z}|z \geq z^{\dagger}\right]$$

Note that we do not condition on 1_γ in the second and third lines because the schedule is approximately linear at the top, and thus ironers and non-ironers have the same distribution of earnings as long as the propensity to iron is not correlated with earnings ability at the top. Thus, for $z_m := E[z|z \geq z^{\dagger}]$

$$(1-\bar{g})(z_m - z^{\dagger}) - \frac{T'}{1-T'}\varepsilon\left(z_m - \bar{\gamma}_I z^{\dagger}\right) = 0$$

from which it follows that

$$\begin{aligned}
\frac{T'}{1-T'} &= \frac{(1-\bar{g})(z_m - z^{\dagger})}{\bar{\varepsilon}(z_m - \bar{\gamma}_I z^{\dagger})} \\
&= \frac{(1-\bar{g})(z_m/z^{\dagger} - 1)}{\bar{\varepsilon}(z_m/z^{\dagger} - \bar{\gamma}_I)} \\
&= \frac{(1-\bar{g})\left(\frac{a}{a-1} - 1\right)}{\bar{\varepsilon}\left(\frac{a}{a-1} - \bar{\gamma}_I\right)} \\
&= \frac{(1-\bar{g})}{\bar{\varepsilon}(a - \bar{\gamma}_I a + \bar{\gamma}_I)} \\
&= \frac{1-\bar{g}}{[(1-\bar{\gamma}_I)a + \bar{\gamma}_I]\bar{\varepsilon}}
\end{aligned}$$

Note that since the pareto parameter $a > 1$, the optimal top tax rate is increasing in the propensity to iron. Liebman and Zeckhauser (2004) prove a special case of this result for $\bar{\gamma}_I = 1$: in this case, $\frac{T'}{1-T'} = \frac{1-\bar{g}}{\bar{\varepsilon}}$ at the top.

B.3.4 Optimal Income Tax Derivation

Let $w_N^{\dagger}$ be the wage of the non-ironers earning $z^{\dagger}$ and let $w_I^{\dagger}$ be the wage of the ironers earning $z^{\dagger}$. Let $z(w, 1_\gamma)$ denote the income chosen by a type $(w, 1_\gamma)$.

For simplicity, we assume here that the propensity to iron is independent of earnings ability w. Let f be the conditional density function of w and let F be the cumulative density function. Let H be the distribution over types $(w, 1_\gamma)$. In terms of wages, the welfare impact of increasing the tax rates by $d\tau$ on all incomes $z \geq z$ is

$$
\begin{aligned}
dW = &-(1-\gamma_I)\int_{w\geq w_N^\dagger} T'(z(w))\frac{dz(w)}{d(1-\tau)}f(w)dw \\
&-(1-\gamma_I)\int_{w\geq w_I^\dagger} T'(z(w))\frac{dz(w)}{d(1-\tau)}f(w)dw \\
&-\int_{z(w,1_\gamma)\geq z(w_N^\dagger,0)}(1-g(z)))(z-z(w_N^\dagger,0))dH(w)
\end{aligned}
$$

The above has to be equal to zero at the optimum for all $w^\dagger$. Thus the derivative of the above with respect to $w^\dagger$ must also equal zero. Differentiating it with respect to $w^\dagger$ leads to

$$
\begin{aligned}
0 = &(1-\gamma_I)T'(z(w_N^\dagger))\frac{dz(w,0)}{d(1-\tau)}|_{w=w_N^\dagger}f(w) + \gamma_I\int_{w\geq w_I^\dagger}\tilde{\tau}(w)\left(\frac{dz(w,0)}{dw}\right)\frac{dz}{d(1-A)}\frac{1}{z(w,1)}f(w) \\
&-\int_{z(w,\gamma)\geq z(w_N^\dagger,0)}(1-g(w,\gamma)))\left(\frac{dz(w_N^\dagger,0)}{dw_N^\dagger}\right)dF \\
&=(1-\gamma_I)T'(z(w))\frac{dz(w,0)}{d(1-\tau)}|_{w=w_N^\dagger}f(w_I^\dagger)+\gamma_I(1-T')\frac{\varepsilon+1}{\varepsilon w_I^\dagger}\frac{dz(w,0)}{d(1-\tau)}|_{w=w_N^\dagger}\int_{w\geq w_I^\dagger}\tilde{\tau}(w)\frac{dz}{d(1-A)}\frac{1}{z(w,1)}f(w)dw \\
&+-(1-T')\frac{\varepsilon+1}{\varepsilon w_N^\dagger}\frac{dz(w,0)}{d(1-\tau)}|_{w=w_N^\dagger}\int_{z(w,1_\gamma)\geq z(w^\dagger,0)}(1-g(w,\gamma)))dH(w) \qquad (6)
\end{aligned}
$$

For $\gamma_I < 1$, rearranging yields

$$
\begin{aligned}
\frac{T'(z^{\dagger)}}{1-T'(z^\dagger)} = &-\frac{\gamma_I}{1-\gamma_I}\frac{\varepsilon+1}{\varepsilon}\frac{1-F(w_I^\dagger)}{w_N^\dagger f(w_N^\dagger)}E\left[\tilde{\tau}(w)\frac{dz(w,1)}{d(1-A)}\frac{1}{z(w,1)}|z(w,1)\geq z^\dagger\right] \\
&+\frac{1}{1-\gamma_I}\frac{\varepsilon+1}{\varepsilon}\frac{1-\gamma_I F(w_N^\dagger)-(1-\gamma_I)F(w_I^\dagger)}{w_N^\dagger f(w_N^\dagger)}E\left[(1-g(z)|z\geq z^\dagger\right].
\end{aligned}
$$

Instead, when $\gamma_I = 1$, equation (6) reduces to

$$
\int_{w\geq w_I^\dagger}\tilde{\tau}(w)\frac{dz}{d(1-A)}\frac{1}{z(w,1)}f(w)dw - \int_{w\geq w_I^\dagger}(1-g(z(w)))f(w)dw = 0
$$

Differentiating with respect to $w_I^\dagger$ yields

$$
\frac{\varepsilon\tilde{\tau}(w_I)}{1-A+\varepsilon(T'-A)} = (1-g(z^\dagger))
$$

Rearranging generates $\frac{A}{1-A} = \frac{1-g(z)}{\varepsilon}$.

C Welfare Simulations: Robustness Analyses

Alternative Strengths of Redistributive Preferences: Our simulations assume individual utility takes the form $U(z) = log(z - T(z) - \frac{(z/w)^{1+k}}{1+k})$, referred to as "Type 1" utility functions in Saez (2001). While this functional form is common in the public finance literature, one might argue that the assumption of log curvature imposes greater redistributive preferences than may exist in practice. To explore the sensitivity of our conclusions to weaker demand for redistribution, we reconduct our simulation with utility of the form $U(z) = (z - T(z) - \frac{(z/w)^{1+k}}{1+k})^{(1-\rho)}/(1-\rho)$. Log utility corresponds to the case where $\rho = 1$, we reestimate our primary tables under the assumptions that $\rho = 0.5$ or $\rho = 0.25$. As illustrated by these tables, the qualitative importance of both the presence of ironing and its interaction with simplification policies remains.

Table A7: Revenue and Welfare Effects of Ironing: Alt. Redistributive Preferences

Structural Elasticity ($\frac{1}{k}$)	Increase in Tax Rev. (%)	*Net Welfare Increase (%)* Low λ $\lambda = U'_{50}$	— $\lambda = \bar{U}'$	High λ $\lambda = U'_{90}$
Lower Redistributive Preferences: $\rho = 0.5$				
1/2	3.7	3.1	3.2	3.4
1/3	2.5	2.1	2.2	2.3
1/4	1.9	1.6	1.7	1.8
1/5	1.6	1.3	1.4	1.5
Lowest Redistributive Preferences: $\rho = 0.25$				
1/2	3.7	3.0	3.0	3.2
1/3	2.5	2.1	2.1	2.2
1/4	1.9	1.6	1.6	1.7
1/5	1.6	1.3	1.3	1.4

Notes: The numbers presented contrast the revenue collected or welfare attained when comparing a population with perfect tax perceptions against one in which 43% of filers apply the ironing heuristic. Assumed utility model: $U(z) = (z - T(z) - \frac{(z/w)^{1+k}}{1+k})^{(1-\rho)}/(1-\rho)$. The top panel sets $\rho = 0.5$ and the bottom panel sets $\rho = 0.25$. The first column presents the structural elasticity (1/k). The second column presents the additional government revenue collected when the ironers are present. The final three columns present estimates of the increase in social welfare attained due to the presence of ironers, under alternative assumptions on the cost of public funds. Welfare effects are expressed as the percentage of total tax revenues that a social planner would pay to avoid converting all ironers to correct forecasters.

Table A8: Revenue and Welfare Effects Changing to Flat Tax: Alt. Redistributive Preferences

Structural Elasticity ($\frac{1}{k}$)	*All correct forecasters* Δ Tax Rev. (%)	Δ Welfare (%)	*43% ironers* Δ Tax Rev. (%)	Δ Welfare (%)
Lower Redistributive Preferences: $\rho = 0.5$				
1/2	5.2	-2.6	2.9	-5.4
1/3	3.3	-4.9	1.9	-6.7
1/4	2.5	-6.0	1.4	-7.3
1/5	1.9	-6.6	1.1	-7.7
Lowest Redistributive Preferences: $\rho = 0.25$				
1/2	5.2	2.3	2.9	-0.7
1/3	3.3	-0.3	1.9	-2.3
1/4	2.5	-1.5	1.4	-3.0
1/5	1.9	-2.3	1.1	-3.5

Notes: This table summarizes the revenue collected or welfare attained as a result replacing the progressive tax schedule with a linear schedule that would be revenue-neutral assuming no change in behavior. Assumed utility model: $U(z) = (z - T(z) - \frac{(z/w)^{1+k}}{1+k})^{(1-\rho)}/(1-\rho)$. The top panel sets $\rho = 0.5$ and the bottom panel sets $\rho = 0.25$. The first column presents the structural elasticity (1/k). The second and third columns present the additional government revenue and welfare, respectively, resulting from the tax-rate change under the assumption of perfect tax perceptions. The fourth and fifth columns provide analogous calculations under the assumption that 43% of the population irons. Welfare effects are expressed as the percentage of total tax revenues that a social planner would pay to avoid going to the flat tax.

Alternative Flat-Tax Rates: Table 6 analyzes the welfare consequences of moving to a flat tax. The imposed tax rate of 11.06% would be revenue neutral *assuming no behavioral response.* In practice, a policymaker aiming to implement a revenue-neutral flat tax may tailor the rate to account for elastic labor supply. We analyze the sensitivity of our conclusions to rates tailored for these purposes in Table A9. The top panel analyzes the welfare consequences of moving to a flat tax with a rate of 10.49%—the rate that would be revenue neutral assuming optimal response governed by a structural elasticity of $\frac{1}{2}$, our most elastic specification. The bottom panel analyzes the welfare consequences of moving to a flat tax with a rate of 10.85%—the rate that would be revenue neutral assuming optimal response governed by a structural elasticity of $\frac{1}{5}$, our least elastic specification. Across both exercises, we continue to substantially larger welfare costs of moving to the flat tax in the presence of ironing. Under our preferred elasticity of $\frac{1}{3}$, the presence of ironing increases the welfare costs of the flat tax by 11% and 13%, respectively. For comparison, the analysis in Table 6 suggests that the presence of ironing increases welfare costs by 14%.

Table A9: Revenue and Welfare Effects Changing to Flat Tax: Alternative Rates

Structural Elasticity ($\frac{1}{k}$)	*All correct forecasters* Δ Tax Rev. (%)	*All correct forecasters* Δ Welfare (%)	*43% ironers* Δ Tax Rev. (%)	*43% ironers* Δ Welfare (%)
Tax rate: 10.49% (revenue neutral when elasticity = $\frac{1}{2}$)				
1/2	0.0	-12.3	-2.1	-14.6
1/3	-1.8	-14.1	-3.2	-15.6
1/4	-2.7	-14.9	-3.7	-16.1
1/5	-3.2	-15.4	-4.0	-16.3
Tax rate: 10.85% (revenue neutral when elasticity = $\frac{1}{5}$)				
1/2	3.2	-10.8	1.1	-13.2
1/3	1.4	-12.5	0.0	-14.1
1/4	0.5	-13.4	-0.5	-14.5
1/5	0.0	-13.8	-0.8	-14.8

Notes: This table reproduces the analysis of table 6 under alternative assumptions on the rate of the flat tax imposed. Whereas table 6 analyzes a flat tax that would be revenue neutral assuming no behavioral response, this table considers reforms that would be revenue neutral assuming optimal behavior governed by the maximum and minimum elasticities of our considered range.

Omission of Very-High-Income Filers: Due to our sampling structure, our within-sample income distribution closely approximates the U.S. income distribution, with the caveat of being truncated at $250,000. While filers above this income threshold account for only 2% of tax returns, they pay 46% of all federal income tax revenue.[31] Their exclusion influences our estimates in two important ways.

First, if top tax filers exhibit the propensity to iron documented in this paper, the welfare gains associated with ironing become more dramatic. Since the social planner down-weights individual taxpayers' misoptimization costs by their social marginal welfare weights, which are typically assumed to tend to zero for sufficiently rich filers. The welfare-relevant consequence of debiasing a top-2-percent filer would therefore be nearly entirely driven by the fiscal externality component of the equation, guaranteeing that this taxpayers' individual contribution to the welfare effect of debiasing would be negative. We believe that our focus

[31] See https://www.irs.gov/uac/soi-tax-stats-individual-income-tax-returns#prelim.

on within-sample analysis provides the most principled and conservative approach to approximating welfare costs, as it does not rely on untested assumptions that the absolute richest filers exhibit the same misperceptions measured in our population. However, if they do, their effect would only increase the quantitative importance of accounting for ironing.

Second, however, notice that in several of our calculations in Table 5, we benchmark revenue losses or welfare effects against total government revenue. The lack of top-2-percent tax filers in our sample would naturally lead our within-sample revenue forecasts to underestimate true total revenue. Since the omitted range of returns pays 46% of total taxes, rescaling columns 2-4 of Table 5 by 0.54 corrects for their omitted revenue. After this correction, our preferred estimate of the welfare benefit of ironing implies an equivalence with a 1.2% government revenue windfall, and thus still represents a large welfare consideration relative to commonly-studied interventions.