Does Indivisible Labor Explain the Difference between Micro and Macro Elasticities? A Meta-Analysis of Extensive Margin Elasticities*

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Abstract

Macroeconomic calibrations imply much larger labor supply elasticities than microeconometric studies. The most well known explanation for this divergence is that indivisible labor generates extensive margin responses that are not captured in micro studies of hours choices. We evaluate whether existing calibrations of macro models are consistent with micro evidence on extensive margin responses using two approaches. First, we use a standard calibrated macro model to simulate the impacts of tax policy changes on labor supply. Second, we present a meta-analysis of quasi-experimental estimates of extensive margin elasticities. We find that micro estimates are consistent with macro evidence on the steady-state (Hicksian) elasticities relevant for cross-country comparisons. However, micro estimates of extensive-margin elasticities are an order of magnitude smaller than the values needed to explain business cycle fluctuations in aggregate hours. Hence, indivisible labor supply does not explain the large gap between micro and macro estimates of intertemporal substitution (Frisch) elasticities.

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1 Introduction

Macroeconomic models that seek to explain fluctuations in hours of work over the business cycle or across countries imply much larger labor supply elasticities than microeconometric evidence. Understanding this divergence between micro and macro elasticities is critical for questions ranging from the sources of business cycles to the impacts of tax policy on growth and inequality. Starting with the seminal work of Rogerson (1988) and Hansen (1985), the most widely accepted explanation of the divergence is the extensive margin response created by indivisible labor supply. If labor supply is indivisible, changes in tax or wage rates can generate large changes in aggregate hours by inducing extensive margin (participation) responses even if they have little effect on hours conditional on employment. In view of this argument, modern macro models are calibrated to match low micro estimates of intensive margin elasticities. However, the extensive margin elasticity (equivalently, the density of the reservation wage distribution at the margin) is usually treated as a free parameter that can be calibrated purely to match macroeconomic moments.

We argue that the extensive margin elasticity should not be treated as a free parameter; rather, macro models should be calibrated to match micro estimates of extensive margin elasticities in the same way that they are calibrated to match micro estimates of intensive margin elasticities. The same marginal density that determines the impacts of macroeconomic variation on aggregate employment also determines the impacts of quasi-experiments such as tax policy changes on employment rates.[1] In this paper, we assess whether existing calibrations of macro models are consistent with the large body of micro evidence on extensive margin responses. In doing so, we find that it is crucial to distinguish between two types of "macro" elasticities: Hicksian elasticities, which govern steady state differences, and Frisch elasticities, which govern intertemporal substitution at business cycle frequencies. We take two approaches to comparing macro calibrations with micro elasticity estimates, both of which indicate that micro and macro evidence agree about Hicksian (steady state) elasticities but disagree about Frisch (intertemporal substitution) elasticities.

First, we simulate the impacts of policy changes that generate exogenous changes in incen-

[1] The distribution of reservation wages at the margin could vary across settings, potentially generating differences between micro and macro estimates of extensive-margin responses. We find that, if anything, such heterogeneity in elasticities reinforces the conclusions drawn below.

tives to work in a standard macro model and compare the predicted responses with the findings of microeconometric studies. We use Rogerson and Wallenius' (2009) [RW] calibrated model of life cycle labor supply, which generates an intertemporal substitution elasticity of aggregate hours above 2 even when calibrated to generate a Frisch intensive-margin elasticity below 0.5. We simulate labor supply responses to three policies: (1) a tax-free year in Iceland in 1987 studied by Bianchi et al. (2001), (2) a randomized experiment providing temporary subsidies for work to welfare recipients in Canada (Card and Hyslop 2005), and (3) the 1987 expansion of the Earned Income Tax Credit (EITC) for low-income individuals in the United States (Eissa and Liebman 1996). The first two examples are ideally suited for identifying Frisch elasticities because they induce temporary variation in wage rates. Bianchi et al. (2001) find that employment rates in Iceland do indeed rise in 1987, but the increase is only one fifth as large as that predicted by the RW model. Similarly, the calibrated RW model predicts intertemporal substitution responses to the work subsidies in Canada that are nearly four times larger than what Card and Hyslop observe in their data. The third example – the EITC expansion – generates permanent variation in tax rates and thus is well-suited for identifying steady-state elasticities. The RW model performs better in matching the impacts of the EITC expansion on employment rates because it generates a Hicksian aggregate hours elasticity of approximately 0.7, resulting in steady-state impacts of taxes on labor supply that are closer to micro estimates.

To explore whether the results of these three studies are representative of the broader literature, we conduct a meta-analysis of quasi-experimental estimates of extensive margin elasticities. We summarize results from fifteen studies that span a broad range of countries, demographic groups, time periods, and sources of variation. Despite the great variation in methodologies, there is consensus about extensive margin elasticities. The mean extensive margin elasticity among the studies we consider is 0.27 and every estimate is below 0.45. These small elasticities imply that most individuals are at a corner in their employment choices; that is, the density of individuals at the margin of employment is thin in practice. The intertemporal substitution elasticity estimates for temporary policy changes are similar to the steady-state elasticity estimates obtained from permanent policy changes. The elasticities are higher for subgroups that are less attached to the labor force, such as single mothers and individuals near retirement. The elasticities are much smaller for prime-age males and higher income individuals. This heterogeneity mirrors the heterogeneity observed in macro studies of steady-state responses. However, the heterogeneity across subgroups magnifies the discrepancy between micro and macro estimates of intertemporal substitution elasticities. Employment rates fluctuate substantially over the business cycle even for prime-age males, a sharp contrast with the near-zero micro extensive margin elasticity estimates for this subgroup.

We conclude our analysis by evaluating whether extensive margin elasticities around 0.25 are adequate to reconcile the gap between micro and macro estimates of aggregate hours elasticities. To do so, we summarize micro and macro estimates of Hicksian and Frisch elasticities on both the extensive and intensive margins. We find that micro and macro studies agree about the steady-state impacts of taxes on labor supply. Both micro and macro studies imply Hicksian extensive margin elasticities around 0.25. And both micro and macro evidence are consistent with intensive margin elasticities around 0.5 once one accounts for frictions that may attenuate observed micro estimates (Chetty 2009, Chetty et al. 2011). These findings indicate that labor supply responses to taxation could indeed explain much of the macroeconomic variation in hours of work across countries.[2]

On the intertemporal substitution margin, the limited existing evidence on intensive margin elasticities suggests that values around 0.5 are consistent with both micro and macro data. However, micro and macro estimates of extensive margin intertemporal substitution elasticities differ by an order of magnitude. Quasi-experimental estimates of extensive margin intertemporal substitution elasticities are around 0.25, whereas leading pure equilibrium macro models all imply intertemporal substitution extensive margin elasticities around 2.[3] Hence, the key puzzle to be resolved is why employment rates fluctuate so much over the business cycle relative to what one would predict based on the impacts of tax changes on employment rates – that is, why micro and macro estimates of the *Frisch* extensive margin elasticity are so different. Even accounting for indivisible labor, micro studies do not support widely used representative-agent macro models that generate Frisch elasticities above 1.

[2]Other factors, such as institutions or regulations, could also play a significant role in explaining cross-country hours differences (Alesina, Glaeser, and Sacerdote 2005). Our analysis does not aim to rule out such explanations; we simply explore what would one predict about cross-country differences based on micro estimates of labor supply elasticities.

[3]Recently developed search and matching macro models in which employment fluctuations are not driven purely by preferences (e.g. Hall 2009) can potentially match business cycle fluctuations with smaller extensive labor supply elasticities.

The paper is organized as follows. The next section briefly reviews the existing literature on indivisible labor. In Section 3, we establish a terminology for the various elasticity concepts, as these terms are often used in different ways in the existing literature. Section 4 reports simulations of the three quasi-experiments in the Rogerson and Wallenius (2009) model. Section 5 presents the meta-analysis of micro estimates. In Section 6, we compare micro and macro evidence on the intensive and extensive margins. Section 7 concludes. Details of the simulation methods and meta-analysis are given in the appendix.

2 Indivisible Labor: Background

Equilibrium macroeconomic models – in which differences in hours of work are driven by preferences – require large labor supply elasticities to explain the variation in hours of work over the business cycle and across countries with different tax regimes. Matching fluctuations in aggregate hours over the business cycle requires Frisch (intertemporal substitution) elasticities of 2 to 4 in leading equilibrium macro models (King and Rebelo 1999, Smets and Wouters 2007). Comparisons of aggregate hours of work across countries with different tax systems imply Hicksian (steady-state) labor supply elasticities around 0.7 (Prescott 2004, Davis and Henrekson 2005, Rogerson and Wallenius 2007, Ohanian et al. 2008). In contrast, quasi-experimental microeconometric studies of the impacts of tax reforms on hours of work and earnings typically obtain Frisch and Hicksian elasticities well below 0.25 for most groups except very high income earners.[4]

A large literature has posited that the discrepancy between micro and macro elasticities can be explained by indivisibilities in labor (e.g. Rogerson 1988, Hansen 1985, Cho and Rogerson 1988, Christiano and Eichenbaum 1992, Cho and Cooley 1994, King and Rebelo 1999, Chang and Kim 2006, Ljungqvist and Sargent 2006, Prescott, Rogerson, and Wallenius 2009, Rogerson and Wallenius 2009).[5] If individuals cannot freely choose hours of work or face fixed costs of entry, aggregate employment depends upon the distribution of reservation

[4] For instance, in a recent survey of microeconometric evidence, Saez et al. (2009) write that "the profession has settled on a value for this elasticity close to zero."

[5] The literature has taken two approaches to aggregation with indivisible labor supply: aggregation over states via employment lotteries (e.g. Hansen 1985, Rogerson 1988) or aggregation over time periods in a lifecycle model (e.g. Mulligan 2001, Ljungqvist and Sargent 2006, Prescott, Rogerson, and Wallenius 2009). The micro evidence on extensive margin responses we review here is most easily interpreted through the modern life cycle models.

wages in the economy. If this distribution has substantial density at the margin – i.e., many individuals are indifferent between working and not working at prevailing wage rates – then a small reduction in wage rates could reduce aggregate hours of work significantly because many individuals will stop working. Yet the same change in wage rates may not affect hours of work conditional on employment very much, implying a small intensive margin labor supply elasticity. As a result, a model with large extensive margin elasticities and small intensive margin elasticities could match both the micro and macro evidence.

Motivated by these results, modern macro models are calibrated to match micro estimates of intensive margin elasticities but typically treat the extensive margin elasticity as a free parameter that can be calibrated purely to match macroeconomic moments. King and Rebelo (1999) observe that real business cycle models can match aggregate data even if calibrated with small intensive-margin elasticities provided that the extensive margin responses are sufficiently large. Rogerson and Wallenius (2009) argue that "micro and macro elasticities are effectively unrelated" because a small intensive margin response can always be offset by a larger extensive margin response. Ljungqvist and Sargent (2011) remark that "competing visions about the labor supply elasticity will be reconciled" by life cycle time-averaging models because retirement could be highly elastic even though hours of work are not.

In parallel with the development of macro models of indivisible labor supply, a large microeconometric literature has recognized the importance of the extensive margin in the analysis of labor supply. Heckman (1984) presents an early discussion emphasizing the importance of extensive margin labor supply choices in the analysis of aggregate fluctuations. Heckman and Killingsworth (1986), Heckman (1993), and Browning, Hansen and Heckman (1999) survey the literature on labor supply models that explicitly model participation decisions.

One reason that macro models may not have been calibrated to match micro evidence on the extensive margin is that extensive margin elasticities vary with the wage rate unless the density of the reservation wage distribution happens to be uniform. Hence, any micro estimate of an extensive margin elasticity is necessarily local to the wage variation used for identification. However, this argument does not justify treating the extensive margin elasticity as a free parameter for two reasons. First, if the micro estimates are identified using variation similar to that used in macroeconomic comparisons, one will obtain the appropriate local elasticity relevant for macro calibrations. Second, the same problem arises when calibrating macro models with micro estimates of intensive margin elasticities, insofar as elasticities will only be constant on the intensive margin if utility happens to produce a constant-elasticity labor supply function. We revisit this issue in Section 6 and show that, if anything, heterogeneity in elasticities reinforces the conclusions drawn below.

3 Terminology

It is helpful to establish some conventions about terminology given the various elasticity concepts discussed in this paper. We distinguish between elasticities based on the margin of response (extensive vs. intensive) and the timing of response (intertemporal substitution vs. steady state). There are four elasticities of interest: steady-state extensive, steady-state intensive, intertemporal extensive, and intertemporal intensive. Each of these four elasticities can be estimated using both micro (quasi-experimental) and macroeconomic variation. We use the terms "micro" and "macro" elasticities exclusively to refer to the source of variation used to estimate the elasticity. The elasticity of aggregate hours – the relevant parameter for calibrating a representative agent model – is the sum of the extensive and intensive margin elasticities, weighted by hours of work if individuals have heterogeneous preferences (Blundell, Bozio, and Laroque 2011).

The macro literature uses the term "macro elasticity" to refer to the Frisch elasticity of aggregate hours and "micro elasticity" to refer to the intensive-margin elasticity of hours conditional on employment (e.g. Prescott 2004, Rogerson and Wallenius 2009). This terminology has led to some confusion about the empirical evidence for two reasons. First, it suggests that extensive margin responses are purely a macroeconomic phenomenon and cannot be studied in micro data. However, as noted above, there is considerable microeconometric evidence on extensive-margin responses. Both extensive and intensive decisions are made at a microeconomic level, as individuals with heterogeneous tastes choose both whether to work and how much to work.

Second, and more importantly, the Frisch elasticity is critical for understanding business cycle fluctuations, but is not the relevant parameter for evaluating the steady-state impacts of differences in taxes across countries. The Frisch (marginal utility constant) elasticity controls intertemporal substitution responses to temporary wage fluctuations, while the Hicksian (wealth constant) elasticity controls steady-state responses (MaCurdy 1981).[6] Moreover, the welfare consequences of taxation depend purely on the Hicksian elasticity (Auerbach 1985).

The use of the Frisch elasticity in some macro studies and the Hicksian in others has fueled debates about the basic macro facts. Prescott (2004) reports that cross-country differences in aggregate hours imply an elasticity of 3 in a representative-agent model, whereas Davis and Henrekson (2005) estimate an elasticity of 0.6 using similar data. The reason for the difference in the quoted elasticities is that Prescott reports a Frisch elasticity whereas Davis and Henrekson report a Hicksian elasticity. Regressing log hours on log tax rates in Prescott's data yields a Hicksian elasticity of 0.7 (Alesina, Glaeser, and Sacerdote 2005). Prescott implicitly translates this estimate of the Hicksian elasticity into a value for a Frisch elasticity based on specific parametric assumptions about utility and the wealth-earnings ratio.[7] Under alternative assumptions – a utility that generates income effects consistent with microeconometric evidence (Holtz-Eakin, Joulfaian, and Rosen 1993, Imbens et al. 2001) and a wealth-earnings ratio that matches micro data (Dynan 2009) – the implied Frisch elasticity would be much closer to the Hicksian value of 0.7 (Chetty 2009).[8]

4 Simulations of Quasi-Experiments in the RW Model

We evaluate whether modern macro models with indivisible labor are consistent with micro evidence on extensive margin responses by focusing on the Rogerson and Wallenius (2009) model. The RW model is a leading example of recent models of indivisible labor that aggregate over individuals by time-averaging over the life cycle, as in Ljungqvist and Sargent (2006). The model is well-suited for our purposes because it features both an extensive and intensive margin of labor supply. RW calibrate their model to show that small intensive-margin micro elasticities are consistent with a large Frisch elasticity of aggregate hours. We adopt

[6]The Hicksian elasticity determines the impact of taxes in steady-state if government revenues are returned to the consumer as a lump sum, as commonly assumed in representative-agent macro models. If revenues are not returned to consumers, tax changes have income effects and the Marshallian elasticity becomes the relevant parameter.

[7]With time-separable utility, the relationship between Frisch (ε^F) and Hicksian (ε^H) elasticities is $\varepsilon^F = \varepsilon^H + \rho(\frac{d[wl]}{dA})^2 \frac{A}{wl}$, where ρ is the elasticity of intertemporal substitution (EIS), $\frac{d[wl]}{dA}$ is the marginal propensity to earn out of unearned income, and $\frac{A}{wl}$ is the ratio of assets to earned labor income (Ziliak and Kniesner 1999, Browning 2005).

[8]Subsequent studies calibrate models to match Prescott's Frisch elasticity of 3, but choose a different functional form for utility and wealth-earnings ratios (e.g. Trabandt and Uhlig 2009). The conclusions drawn by these studies – e.g. that reductions in tax rates would increase tax revenue – might differ had they directly matched the steady state elasticity of 0.7 implied by Prescott's data.

the parameters chosen by RW and simulate the impacts of policy changes analyzed in three prominent microeconometric studies.[9]

Setup. RW analyze an overlapping-generations model in which a unit mass of agents is born at each instant and lives for one unit of time. An individual who supplies $h(a) \in [0,1]$ hours at age a produces $e(a) \times \max\left\{h(a) - \bar{h}, 0\right\}$ efficiency units of labor, where $e(a) = 1 - 2(1-e_1)\left|\frac{1}{2} - a\right|$ is a tent-shaped life-cycle productivity profile and $\bar{h} > 0$. Complete asset markets lead to perfect consumption smoothing. With log utility over consumption, each generation solves

$$\max_{c,h(a)} \log(c) - \alpha \int_0^1 \frac{h(a)^{1+\gamma}}{1+\gamma} da \text{ s.t. } c = (1-\tau) \int_0^1 e(a) \max(h(a) - \bar{h}, 0) da + T$$

where τ is the tax rate and T is a lump-sum tax rebate that balances the government's budget. The model can be solved analytically as described in RW and in the online technical appendix to this paper.[10] Because wages are paid per efficiency unit, individuals have low hourly wage rates at the beginning and end of their lives and find it optimal not to work at those points. This generates an extensive margin of participation over the life cycle. The convex disutility over hours of work generates an intensive margin hours response to changes in wage rates as well. RW normalize the price of output to 1 and assume a constant-returns-to-scale production technology, so changes in tax rates have no impact on pre-tax wages and prices.

RW calibrate the parameters α, e_1, and $\bar{h}$ to match empirically observed values for the fraction of life worked (f), the maximum hours worked per week over the life cycle ($h_{\max}$), and the wage rate at retirement relative to the maximum wage rate over the life cycle ($w_R/w_{\max}$). Following RW, we set $h_{\max} = 45\%$ (45 hours per week) and $w_R/w_{\max} = 1/2$. We set f to match the aggregate employment rate in the period prior to each policy experiment we consider. We set $\gamma = 2$ to obtain an intensive margin Frisch elasticity of $\varepsilon_{\text{INT}} = \frac{1}{\gamma} = 0.5$, consistent with the microeconometric evidence summarized below; we show in Appendix A that setting $\varepsilon_{\text{INT}} = 0.25$ yields similar results.[11] For each of the three tax policy changes

[9] On the intertemporal substitution margin, we sought to maximize the model's chance of fitting the data by analyzing the two studies that obtain the largest intertemporal elasticity estimates among those considered in our meta analysis (Table 1). On the steady-state response, we sought to pick a representative study of a well-known policy (the EITC) to show that the model is consistent with mid-range micro estimates.

[10] The technical appendix is available at http://obs.rc.fas.harvard.edu/chetty/ext_margin_tech_appx.pdf

[11] RW show that the intertemporal elasticity of aggregate hours in their model is not sensitive to the intensive-margin intertemporal elasticity. They therefore calibrate α, e_1, and $\bar{h}$ to match the three moments conditional on various values of γ.

simulated below, we choose the model's remaining parameters $\{\alpha, e_1, \bar{h}\}$ to match the moments $\{h_{\max}, w_R/w_{\max}, f\}$ under the tax system prior to the tax change.[12] In all three cases, the calibrated model generates an intertemporal substitution elasticity for aggregate hours above 2 despite having an intensive margin intertemporal substitution elasticity of only 0.5, consistent with RW's main result.[13]

To simulate the impacts of unanticipated tax changes, we must specify how the lump sum rebate T changes for each agent. To simplify aggregation, we assume that each generation receives a lump-sum rebate equal to the taxes they pay at each instant in time.[14] We ignore heterogeneity in the tax system across individuals and set τ equal to the average tax rate for the subgroup analyzed (which is relevant for extensive margin decisions).

Experiment 1: Tax Holiday in Iceland. In 1987, Iceland suspended its income tax for one year as it transitioned from a system under which taxes were paid on the previous year's income to a system where taxes were paid on current earnings. In 1987, individuals paid tax on income earned in 1986; in 1988, individuals were taxed on income earned in 1988, and thus income in 1987 was untaxed. The average tax rate was 14.5% in 1986, 0 in 1987, and 8.0% in 1988 (Bianchi et al. 2001). We simulate this reform in the RW model under the assumption that the tax system remains stable prior to 1986 and after 1988. The reform was announced in late 1986, so we model the tax change as an unanticipated change at the start of 1987. The average employment rate in the five year period prior to the reform is $f = 78.5\%$.

Figure 1a plots employment rates around the reform, demarcated by the vertical line. The Icelandic administrative records analyzed by Bianchi et al. (blue squares) show a modest but significant increase in employment rates in 1987 followed by a sharp dip in 1988, consistent with intertemporal substitution.[15] The impact predicted by the RW model (red circles) is an order of magnitude larger than the observed impact. In the data, employment is 3 percentage

[12] In one of the simulations, the welfare demonstration in Canada, a small enough fraction of the population is employed prior to the intervention that fitting $w_R/w_{\max} = 1/2$ would require negative productivity at certain points in the life cycle. Consequently, for that simulation, we set $e_1 = 0$, generating $\frac{w_R}{w_{\max}} = .615$.

[13] We calculate this and all other Frisch elasticities by simulating the impact of a small, temporary tax change in the RW model. This direct calculation of the Frisch elasticity differs from the values reported by RW. RW report aggregate hours Frisch elasticities for a stand-in household whose behavior matches the aggregate steady-state properties of their economy. However, this stand-in household's behavior does not necessarily match the aggregate intertemporal substitution properties of the RW model.

[14] Tax policy changes affect each generation differently because they are at different points in the lifecycle when the change occurs.

[15] The trends in observed employment rates prior to 1986 cannot be attributed to the tax reform. Bianchi et al. argue that they are due to other macroeconomic factors.

points higher in 1987 relative to 1988, but the RW model predicts that it would be 13.7 percentage points higher. The model generates a much larger spike in employment because the fraction of cohorts that are close to being indifferent between working and staying out of the labor force is large. The temporary increase in the wage rates therefore induces a large group of agents to work. Note that it is precisely this mechanism – having a large fraction of individual near the margin – that allows the RW model to generate a large Frisch elasticity for aggregate hours and thus explain fluctuations in aggregate hours over the business cycle.

Experiment 2: SSP Welfare Demonstration in Canada. The Iceland analysis focuses on employment changes in the aggregate economy, which are relevant for understanding business cycle fluctuations but may mask substantial heterogeneity across groups. Ljungqvist and Sargent (2006), Rogerson and Wallenius (2007), and others emphasize that certain groups of the population – such an individuals near retirement or those with low wage rates – are likely to exhibit particularly large extensive margin responses and drive the change in aggregate hours. To evaluate whether the model's predictions are more accurate for these more elastic subgroups, we consider a policy experiment targeted at welfare recipients who frequently transition in and out of the labor force.

In the early 1990s, the Canadian government conducted the Self Sufficiency Project (SSP) to test whether a temporary earnings subsidy could induce welfare recipients to start working. The project was a randomized experiment involving over 5,000 single parents who had been on welfare for at least one year. Half the individuals (the treatment group) were given a large subsidy if they worked more than 30 hours per week at at least the minimum wage. The subsidy lasted for 36 months.[16] Under the prevailing welfare system in Canada, welfare payments were reduced dollar-for-dollar with earnings above a low baseline level. As a result, a single parent with one child in the control group faced an effective average tax rate of 74.3% when moving from no work to full-time work (see Appendix A). In contrast, an individual in the treatment group faced an effective average tax rate of 16.7% for the same change. We model the SSP experiment as a tax reform that lowers the tax rate from $\tau = 74.3\%$ to $\tau = 16.7\%$ for a three year period, after which the tax rate reverts to $\tau = 74.3\%$. The

[16] Individuals were given up to one year to start working and the 36 month period began after they started to work. This feature of the program generated an incentive to establish eligibility for the subsidy by working within the first year, accentuating the intertemporal substitution incentive. We ignore this feature of the program in our simulation by assuming that the subsidy starts immediately after random assignment. This simplification biases the size of the employment increase predicted by our simulation downward.

employment rate during the month the experiment began was $f = 23.5\%$.

Card and Hyslop (2005) use survey data to calculate employment rates at a monthly frequency for 53 months starting from the month of random assignment. Figure 1b plots monthly employment rates after the experiment. The series in blue squares shows the difference in employment rates for the treatment group relative to the control group (Card and Hyslop, Figure 3a), with the pre-experiment employment rate of 23.5% added to the difference to facilitate interpretation of the scale. The data show that the subsidy had a substantial impact: employment rates rise by approximately 14 percentage points in the treatment group relative to the control group a year after the subsidy was introduced. These employment gains fade away after the subsidy expires, consistent with intertemporal substitution.

The series in red circles in Figure 1b shows the corresponding impacts predicted by the RW model. Because the sample analyzed by Card and Hyslop consists primarily of younger individuals (less than 2.5% of the sample is over age 50), we report simulated employment rates for individuals in the first half of the life cycle (ages 16-46). The impacts predicted by the calibrated model – an employment increase of 52.8 percentage points one year after the subsidy is introduced – are again substantially larger than what is observed in the data. Hence, even for subgroups that are closer to the margin of entering or exiting the labor force and are therefore more elastic, the RW model significantly over-predicts extensive margin responses.

Experiment 3: Earned Income Tax Credit in the U.S. The preceding policy experiments generate temporary variation in tax rates and thereby identify intertemporal substitution elasticities. The last policy change we consider – the expansion of the EITC in 1987 analyzed by Eissa and Liebman (1996) – is a permanent tax change whose impact is determined by the Hicksian rather than the Frisch elasticity.[17] The EITC expansion lowered average tax rates (including implicit taxes generated by the phase-out of transfers) from 58.9% in 1986 to 53.4% in 1989 for single mothers (Meyer and Rosenbaum 2000, Table 2). We model this tax change under the assumption that the tax system remains stable prior to 1985 and that the TRA86 change occurs immediately at the start of 1987, ignoring the phase-in of the reform. The average employment rate for the single mothers aged 16-44 studied by Eissa and Liebman

[17] If the tax change is not rebated to the consumer as a lump sum, its impact depends on the uncompensated (Marshallian) elasticity rather than the Hicksian elasticity. In practice, microeconometric estimates of income effects are quite small (Holtz-Eakin, Joulfaian, and Rosen 1993, Imbens, Rubin, and Sacerdote 2001), suggesting that the impact of the EITC change is well approximated by the Hicksian elasticity.

(1996) is $f = 72.0\%$ in the five years preceding the reform.

Eissa and Liebman calculate annual employment rates using CPS data. Figure 1c shows that employment rates of single mothers increased from 73.0% in 1986 to 76.1% in 1989 after the tax reform was fully phased in. The RW model predicts a 4.8 percentage point increase in employment rates on impact and an additional .4 percentage point rise over the subsequent seven years. The RW model performs much better in predicting the impacts of the EITC expansion than the preceding experiments because it predicts much smaller steady-state responses than intertemporal substitution responses. Intuitively, a permanent change generates a much lower elasticity because all generations increase their labor supply at the point in their life cycle when they are most productive, smoothing the aggregate response across time. With a temporary change, every generation has an incentive to work when net-of-tax wage rates are high, resulting in a large Frisch elasticity. In the RW model, a large mass of cohorts is at the margin with respect to a temporary tax change or wage fluctuation because individuals do not have strong preferences over when they work during their lives. However, in any given period, a much smaller fraction of individuals within each cohort are at the margin with respect to a permanent change in incentives.

Together, the simulations highlight two results that we develop further below. First, the extensive margin elasticities required to explain the sharp fluctuations in aggregate hours over the business cycle are far larger than micro estimates. Second, micro and macro evidence are in much closer alignment about the steady-state impacts of taxes on labor supply. The calibrated RW model over-predicts the impacts of the EITC expansion by 50% because the parameters chosen generate an intensive Hicksian elasticity below 0.15 and an extensive Hicksian elasticity above 0.5. An alternative calibration that generates a larger Hicksian intensive elasticity and a smaller Hicksian extensive elasticity would match micro estimates of both elasticities, as we discuss below. However, no parametrization of the model would match micro estimates of both intensive and extensive intertemporal substitution elasticities.

Although the quantitative results of our simulations depend to some extent upon the parametric choices made by RW, we expect these lessons to apply more broadly. Generating a large macro Frisch elasticity by having a large fraction of individuals who are nearly indifferent between working and not working is precisely what delivers predictions about how temporary tax changes affect employment rates that contradict the data. A macro model calibrated to match micro estimates of extensive margin intertemporal substitution elasticities would no longer generate large Frisch elasticities for aggregate hours.

5 Meta-Analysis

In this section, we evaluate whether the three quasi-experiments considered above are representative of the broader literature by conducting a meta-analysis of extensive margin elasticity estimates. Although several papers have reviewed intensive margin elasticities (e.g. Pencavel 1986, Blundell and MaCurdy 1999, Chetty 2009), we are not aware of a meta-analysis of quasi-experimental estimates of extensive margin elasticities.

We focus on reduced-form studies that use changes in tax policies or long-term wage trends for identification rather than structural studies that exploit variation in wage rates at the individual level to fully identify a structural model. Keane and Rogerson (2010) argue that obtaining consistent structural estimates from wage variation over the life cycle requires accounting for a broad range of factors such as human capital accumulation (Imai and Keane 2004), credit constraints (Domeij and Floden 2006), and uninsurable risks (Low 2005). Moreover, structural models typically rely on strong exclusion restrictions for identification.[18] The quasi-experimental studies we consider here exploit variation that is orthogonal to wage rates and thus are more robust to the biases emphasized by Keane and Rogerson. The exclusion restriction underlying these studies is that the differential changes in tax rates across groups is not correlated with unobserved determinants of employment rates, typically a weaker assumption than those required for full identification of a structural model.[19]

Table 1 summarizes extensive margin elasticity estimates from fifteen quasi-experimental studies. The calculations underlying the estimates are described in Appendix B. We calculate the extensive margin labor supply elasticity as the change in log employment rates divided by the change in log net-of-tax wage rates. Employment rates are typically defined as working

[18] Common instruments for wage rates include nonlinear age and time trends (Kimmel and Kniesner 1998) or interactions of education and experience (Gourio and Noual 2009) conditional on individual fixed effects. Keane (2010) uses years of schooling as an instrument for the wage to identify an elasticity in Eckstein and Wolpin's (1989) classic structural model. The exclusion restrictions for these instruments are that employment rates do not vary with age conditional on wage rates or that individuals with different levels of education do not have different employment trajectories over their lifecycle. If factors that predict high wage rates also predict high latent tastes for work, the elasticity estimates would be biased upward.

[19] Keane (2010) and Keane and Rogerson (2010) review structural estimates and find larger values than the quasi-experimental estimates summarized below. It would be useful to simulate the impacts of tax policy changes in these structural models to understand why their predictions differ from the reduced-form evidence.

at any point during the year, though there are some differences across studies as described in the appendix. We use the authors' preferred estimate whenever possible. For studies that do not report such an estimate, we construct elasticities from reported estimates of changes in participation and calculations of the change in net-of-average-tax wage rates.

The studies summarized in Table 1 report labor supply elasticities for various countries and subgroups using many different sources of variation. Yet the elasticity estimates exhibit substantial consensus. The elasticity estimates range from 0.13 to 0.43, with an overall unweighted mean across the fifteen studies of 0.27. To obtain further insight into the key patterns, we divide the studies into two groups – steady-state and intertemporal substitution – based on the type of variation they use for identification.

The first panel in Table 1 shows steady-state (Hicksian) elasticities identified from permanent wage changes resulting from tax reforms or long term trends in wage rates across regions or skill-groups.[20] The simplest empirical designs (e.g. Eissa and Liebman 1996) use difference-in-differences approaches, while more recent studies (e.g. Meghir and Philips 2010) combine multiple reforms over time that affect individuals differently. The mean elasticity across the ten studies that estimate steady-state elasticities is 0.26.

The second panel in Table 1 summarizes results from studies that exploit temporary wage changes to identify intertemporal substitution (Frisch) elasticities. Some of these studies exploit temporary tax changes such as the Iceland tax holiday discussed above. Other studies analyze the impact of anticipated variation in wages generated by pension schemes on retirement behavior. For instance, Gruber and Wise (1999) correlate employment rates of adults near retirement with the implicit tax generated by social security systems across OECD countries. Their analysis implies an elasticity of 0.23. Brown (2009) and Manoli and Weber (2010) estimate elasticities using the bunching of retirements around the kinks in the budget set created by discontinuities in pension systems. The small elasticities found by these studies suggests that the fraction of individuals who are "at a corner with respect to the decision to retire" is quite large in practice (Ljungqvist and Sargent 2011).

The mean estimate of the intertemporal substitution elasticity across the five studies in Panel B is 0.28, only slightly larger than the estimates of steady-state elasticities in Panel

[20] Some studies explicitly identify a Hicksian elasticity by accounting for income effects, but many do not. As noted above, microeconometric estimates of income effects are typically quite small, suggesting that the difference between Hicksian and Marshallian elasticities is small.

A. The similarity between Hicksian and Frisch elasticities is consistent with evidence that income effects are not large enough to produce a substantial difference between intertemporal substitution and steady-state responses (Ziliak and Kniesner 1998, Chetty 2009).

The elasticity estimates vary across subgroups in correspondence with their mean employment rates, as is well known from prior work (Heckman 1993, Keane and Rogerson 2010). Groups that have the weakest attachment to the labor force, such as single mothers or older workers near retirement, are the most elastic on the extensive margin (e.g. Meyer and Rosenbaum 2001, Gruber and Wise 1999). Among prime-age males, high rates of labor force participation and low aggregate hours elasticities (which combine the intensive and extensive margins) have led researchers to conclude that the extensive margin response is likely to be quite small (see e.g., Hausman 1985 and Juhn, Murphy, and Topel 1991). This is why most of the studies in Table 1 focus on groups with relatively low participation rates. Hence, the mean extensive margin elasticity in the population as a whole is likely to be below the unweighted mean across the studies in Table 1 of 0.27.

The heterogeneity in elasticities across subgroups implies that there is no single value of the extensive margin elasticity that can be used across applications. For instance, a recession or tax policy change that affects prime-age males may generate smaller employment responses in the macroeconomy than a change in incentives that affects other groups. The estimates in Table 1 should therefore be interpreted as a rough guide to plausible targets for calibration: they suggest that extensive margin elasticities around 0.25 are reasonable, while values above 1 are not.

6 Comparing Micro and Macro Estimates

The micro evidence points to Frisch and Hicksian extensive margin elasticities around 0.25. Does this estimate generate aggregate hours elasticities consistent with macro estimates? The answer to this question depends on the size of intensive margin elasticities because aggregate hours elasticities combine extensive and intensive elasticities. We therefore begin by summarizing the micro and macro evidence on both extensive and intensive margins in Table 2. The sources and calculations underlying these estimates are described in Appendix C. The rows of Table 2 consider steady-state (Hicksian) vs. intertemporal substitution (Frisch) elasticities, while the columns compare intensive margin (hours conditional on employment) and extensive margin (participation) elasticities. Within each of the four cells, we report micro and macro estimates of the elasticity based on (unweighted) means of existing studies. We also calculate aggregate hours elasticities – the parameter relevant for calibrating representative agent models – by summing the extensive and intensive elasticities.[21]

It is important to note that there are wide confidence intervals associated with each of the point estimates in Table 2, as well as ongoing methodological disputes about the validity of some of the underlying studies (see e.g., Saez, Slemrod, and Giertz 2009). Therefore, the estimates should be treated as rough values used to gauge orders of magnitude: differences of 0.1 between elasticity estimates could well be due to noise or choice of specification, while differences of 1 likely reflect fundamental discrepancies. We consider the evidence on steady-state and intertemporal elasticities in turn.

Steady-State. On the extensive margin, our rough estimate of the steady state elasticity from the micro literature is the mean of the estimates in Panel A of Table 1, which is 0.26. On the intensive margin, Chetty (2009) presents a meta-analysis of micro estimates of Hicksian elasticities and reports a mean value of 0.12 (Chetty 2009, Table 1, unweighted mean of Panels A and B). However, Chetty argues that these elasticities are significantly attenuated by optimization frictions: the small tax changes used to identify micro elasticities do not generate substantial changes in hours because the adjustment costs agents have to pay to change hours outweigh the second-order benefits of reoptimization. Chetty develops a bounding method of recovering the underlying structural elasticity relevant for evaluating the steady-state impacts of taxes. Pooling the twenty studies he analyzes, he obtains a structural intensive margin Hicksian elasticity of 0.5.[22]

Macro steady-state estimates are obtained from comparisons across countries with different tax regimes. Nickell (2003) and Davis and Henrekson (2005) find extensive steady-state

[21] For micro studies, this calculation requires that preferences are homogenous across the population. If some groups work few hours and also have higher extensive elasticities, as suggested by existing evidence, this calculation will yield an upper bound on the aggregate hours elasticity (Blundell, Bozio, and Laroque 2011).

[22] Our proposed elasticities of 0.5 on the intensive margin and 0.26 on the extensive margin may appear to contradict the common view that tax changes have smaller short-run effects on the intensive margin than extensive margin. Chetty (2009) argues that the structural intensive margin elasticity relevant for long-run comparisons is larger than the structural extensive margin elasticity once one accounts for frictions. In particular, he shows that frictions attenuate observed extensive margin elasticities much less than intensive margin elasticities because the utility gains from reoptimizing are first-order on the extensive margin and second-order on the intensive margin.

elasticities of 0.21 on average by regressing log employment-population ratios on log mean net-of-tax rates across countries. Davis and Henrekson (2005) also report a steady-state intensive elasticity of 0.35 by regressing log hours conditional on employment on log net-of-tax rates. As noted above, Prescott's (2004) data produces a steady-state aggregate hours elasticity of 0.7; subtracting the extensive margin macro elasticity of 0.21 estimated by Nickell and Davis and Henrekson, Prescott's data therefore implies an intensive steady-state elasticity of 0.49. The macro data thus imply steady-state elasticities of around 0.21 on the extensive margin and 0.42 on the intensive margin. We conclude that micro and macro estimates of steady state aggregate hours elasticities match once one accounts for extensive margin responses and the attenuation of intensive margin micro elasticities due to optimization frictions.

Intertemporal Substitution. On the extensive margin, our preferred micro estimate of the intertemporal elasticity is the mean of the estimates in Panel B of Table 1, which is 0.28. On the intensive margin, there is less quasi-experimental evidence on intertemporal substitution elasticities. Bianchi et al. (2001) find an intensive-margin elasticity from the Iceland reform of 0.29 (see Chetty (2009) for the elasticity calculation using Bianchi et al.'s estimates). Pistaferri (2003) reports a Frisch intensive elasticity of 0.7 using microdata on expectations about wages. The similarity between these estimates and our preferred estimate of the intensive Hicksian elasticity of 0.5 is not surprising. In particular, Chetty (2009) shows that the Frisch elasticity must be less than 0.82 given a Hicksian elasticity of 0.5 in a model with balanced growth and an elasticity of intertemporal substitution below 1. Hence, micro evidence suggests that Frisch and Hicksian elasticities are similar in magnitude.

Equilibrium macro models identify intertemporal substitution labor supply elasticities from fluctuations in hours over the business cycle. Most macro studies calibrate representative agent models and therefore report only intertemporal elasticities of aggregate hours. The intertemporal aggregate hours elasticity required to match business cycle data is between 2.61 and 4 in real business cycle models (Cho and Cooley 1994, Table 1; King and Rebelo 1999, p975) and 1.92 in menu cost models (Smets and Wouters 2007, Table 1A). The mean intertemporal aggregate hours elasticities implied by these three models is 2.84 as shown in Table 2. Micro estimates imply a Frisch elasticity of aggregate hours of 0.78, well below this value.

The few available decompositions of macro aggregate hours elasticities into extensive and intensive margins suggest that macro estimates are roughly in alignment with micro estimates on the intensive margin. Business cycle fluctuations in hours conditional on employment account for only 1/6 of the fluctuations in aggregate hours at an annual level (Heckman 1984). Given that elasticities of 4 fit the fluctuations in aggregate hours in real business cycle models, we infer that intensive Frisch elasticities around 0.66 would match macro evidence in RBC models. Cho and Cooley (1994, Table 2) calibrate an RBC model with both intensive and extensive margins and find that an intensive Frisch elasticity of 1 fits quarterly fluctuations in hours conditional on employment. Hall's (2009) search and matching model fits observed fluctuations in hours conditional on employment with an intensive Frisch elasticity of 0.7. These values are modestly larger than the intensive intertemporal elasticity of 0.5 implied by micro evidence.

In contrast, macro evidence sharply contradicts micro estimates of the extensive intertemporal elasticity. The fact that employment fluctuations account for 5/6 of the fluctuation in aggregate hours suggests that extensive elasticities above 3 would be needed to match the data in standard RBC models. Cho and Cooley's (1994) RBC model implies an extensive Frisch elasticity of 1.61. If the models considered in Table 2 were calibrated to match an intensive intertemporal elasticity of 0.5, they would require extensive intertemporal elasticities of 2.84-0.5 = 2.34 on average to match aggregate hours fluctuations. This value is an order of magnitude larger than all of the micro estimates shown in Table 1. Hence, extensive labor supply responses are not large enough to explain the large fluctuations in employment rates at business cycle frequencies.

The macro models we considered above are pure equilibrium models in the sense that employment fluctuations are driven by labor supply decisions of workers. Hall (2009) develops a search and matching model in which search frictions drive fluctuations in employment. Hall shows that this model can match observed fluctuations in employment rates over the business cycle without requiring large extensive labor supply responses.[23] The micro evidence points in favor of such models that do not rely exclusively on labor supply choices to explain aggregate fluctuations in hours.

[23] In Hall's model, workers decide whether to participate in the labor market based on both standard labor supply factors and the time and effort needed to find a job. Employment conditional on participation is then determined according to a standard Diamond-Mortensen-Pissarides model with non-Nash bargaining. These forces generate an employment elasticity of 1.9, matching the data.

Heterogeneity. As noted above, macro models may not perfectly match micro evidence on the extensive margin because extensive margin elasticities vary with the distribution of reservation wages at the margin. While one may be reluctant to calibrate a macro model to match an extensive margin elasticity estimate from any single study, the fact that every quasi-experimental study we reviewed finds elasticities less than 0.45 casts doubt upon macro models calibrated with extensive margin elasticities above 1. Moreover, observable heterogeneity in elasticities reinforces the main conclusions drawn above. The heterogeneity in extensive margin responses across groups documented in Table 1 mirrors the heterogeneity observed in extensive margin responses when comparing steady-state behavior across countries with different tax regimes. In particular, individuals near retirement and secondary earners exhibit the largest differences in employment rates across countries with different tax systems (Rogerson and Wallenius 2007, Blundell, Bozio, and Laroque 2011).

In contrast, heterogeneity amplifies the discrepancy between micro and macro estimates of intertemporal substitution elasticities. While microeconomic evidence suggests that extensive margin elasticities are near zero for prime-age men, employment rates fluctuate substantially over the business cycle even for this subgroup (Clark and Summers 1981, Jaimovich and Siu 2009). The sharp divergence between micro and macro estimates of extensive margin elasticities within subgroups further suggests that indivisible labor supply cannot fully account for the fluctuations in aggregate hours over the business cycle.

7 Conclusion

Indivisible labor is a central feature of many modern macroeconomic models that seek to explain aggregate labor supply. From a qualitative perspective, microeconometric evidence clearly supports the importance of indivisible labor: every microeconometric study we reviewed found extensive margin responses to changes in wage rates. From a quantitative perspective, observed extensive margin responses are adequate to explain the gap between micro and macro estimates of steady-state elasticities when combined with factors such as frictions. However, extensive margin labor supply responses are not large enough to explain the gap between micro and macro estimates of intertemporal substitution elasticities. In the terminology of Ljungqvist and Sargent (2011), the micro data reveal that most individuals are at a corner with respect to employment decisions.

Based on our reading of the micro evidence, we recommend calibrating macro models to match a Frisch extensive margin elasticity of 0.25 and a Frisch intensive margin elasticity of 0.5.[24] Hence, it would be reasonable to calibrate representative agent macro models to match a Frisch elasticity of aggregate hours of 0.75.[25] These elasticities are consistent with the observed differences in aggregate hours across countries with different tax systems. They also match the relatively small fluctuations in hours conditional on employment over the business cycle. The challenge is to formulate models that fit the large fluctuations in employment rates over the business cycle when calibrated to match an extensive margin labor supply elasticity of 0.25. Even with indivisible labor, models that require a Frisch elasticity of aggregate hours above 1 are inconsistent with micro evidence.

[24] That is, one should choose a reservation wage distribution such that a *temporary* 10% increase in the net-of-tax wage leads to a 2.5% increase in employment rates. More generally, simulating quasi-experiments such as the tax policy changes analyzed here would be a simple way to evaluate which macro models are consistent with micro data.

[25] We suspect that this estimate is, if anything, biased upward for two reasons: (1) the mean extensive margin elasticity for the population as a whole is less than 0.25 as noted above and (2) publication bias drives micro studies toward reporting higher elasticity estimates (Card and Krueger 1995).

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Appendix A. Simulations of Quasi-Experiments (Figure 1)

This appendix describes the simulations of three quasi-experiments in the Rogerson and Wallenius (2009) model and the robustness of the simulations to alternative assumptions about the intensive margin labor supply elasticity. The online technical appendix describes the analytic solution method in detail.

Calibration. The target values used to calibrate the model's parameters $\{\alpha, e_1, \bar{h}, \gamma\}$ are described in the main text. In choosing the fraction of life worked (f) for the calibration, we use the frequency at which employment is measured in the data. For instance, in the EITC simulation we calculate labor force participation in a given year as whether an individual worked at all in the past year to match the annual employment observation CPS. Because of this, the fraction of life worked at any given instant (f) differs slightly from the stated target value. To calibrate $\{\alpha, e_1, \bar{h}, \gamma\}$, we set $\gamma = \frac{1}{\varepsilon_{\text{INT}}}$ to match the target for the intensive Frisch elasticity. We then calibrate the remaining parameters using the model's equilibrium conditions. Finally, we manually adjust e_1 to match $w_R/w_{\max}$, following RW.

Experiment 1: Tax Holiday in Iceland. Bianchi et al.'s data is the ratio of the total number of weeks worked to the potential supply of weeks that could have been worked by all working-age individuals in a given calendar year. We define labor force participation by whether a generation works in a given week. We then average across weeks for each calendar year to get an annual measure comparable to Bianchi et al.'s data. With $\varepsilon_{INT} = .5$, $f = 78.5\%$, $h_{\max} = .45$, and $w_R/w_{\max} = 1/2$, the calibrated values are $\gamma = 2$, $\bar{h} = .384$, $\alpha = 10.197$, and $e_1 = .589$. These parameter values generate a Frisch aggregate hours elasticity of 2.117 and a Frisch labor force participation elasticity of 1.807. These and all subsequent reported Frisch elasticities are calculated by simulating a temporary, small tax change using the same methodology as the Iceland and Canada SSP simulations; see the technical appendix for details. The parameter values generate a compensated aggregate hours elasticity of .700, a compensated labor force participation elasticity of .619, and a compensated intensive margin hours elasticity of .144. These and all subsequent reported compensated elasticities are calculated by comparing the steady state change in response to a small tax change; see the technical appendix for details. After the tax change, the maximum hours worked over the life cyle are .737 and the minimum hours worked are .576.

Experiment 2: SSP Welfare Demonstration in Canada. We generate the effective tax rates for the treatment and control groups of the SSP welfare demonstration in Canada using information on the hypothetical income of the average individual in the treatment group from Lin et al. (1998). Lin et al. use a wage regression to estimate that the predicted wage of the average individual in the treatment group is \$6.24 per hour for individuals in British Columbia and \$5.53 per hour for individuals in New Brunswick. Lin et al. then present in Table G.2 an itemized calculation of the average treatment group individual's income accounting for taxes and other transfers under the SSP subsidy and for an individual on the standard Income Assistance (IA) welfare program. This is called hypothetical income because they use the hourly wage rate and assume the individual works 30 hours per week for 52 weeks per year in both cases.

Using this calculation, in New Brunswick an individual receiving the SSP subsidy would make \$20,184 per year net of taxes and transfers, while an individual working and receiving IA would make \$14,847 per year. If the individual did not work at all and took IA, they would not realize their earnings of \$8,627 but would have an IA payment that is \$6,117 higher. This reflects the almost dollar-for-dollar reduction of welfare payments of earnings above \$2,400. The individual's income would have been \$12,337 if they had not worked. The additional income from working 1,560 hours per year is thus \$2,510 for an individual on IA and \$7,847 for an individual receiving the SSP subsidy. This implies an hourly wage rate of \$1.61 on IA and an effective tax rate of 70.9% under IA. Under SSP, however, the hourly wage rate is \$5.03 and the effective tax rate is 9.04%.

Similarly, for an individual in British Columbia, an individual receiving the SSP subsidy would make \$28,267 per year net of taxes and transfers, while an individual working and receiving IA would make \$23,078 per year. If the individual did not work at all and took IA, they would not realize their earnings of \$9,734 but would have an IA payment that is \$7,557 higher. The individual's income would have been \$20,901 if they had not worked. The additional income from working 1,560 hours per year is thus \$2,177 for an individual on IA and \$7,366 for an individual receiving the SSP subsidy. This implies an hourly wage rate of \$1.40 on IA and an effective tax rate of 77.6% under IA. Under SSP, however, the hourly wage rate is \$4.72 and the effective tax rate is 24.3%.

Averaging the British Columbia and New Brunswick results together (as roughly half the sample resides in each area), an average single parent with one child in the control group faced effective average tax rates of 74.3% when moving from no work to full-time work at the minimum wage. An average individual in the treatment group faced effective average tax rates of 16.7% for the same change.

Card and Hyslop observe employment rates at a monthly frequency for 53 months starting from the month of random assignment. To replicate this data as closely as possible, we define labor force participation by whether a generation works in a given month. Generating $w_R/w_{\max} = 1/2$ would require $e_1 < 0$. We therefore set $e_1 = 0$, generating $w_R/w_{\max} = .615$. With $\varepsilon_{INT} = .5$, $f = 23.25\%$, and $h_{\max} = .45$, the calibrated values are $\gamma = 2$, $\bar{h} = .263$, and $\alpha = 38.378$. These parameter values generate a Frisch aggregate hours elasticity of 3.294 and a participation Frisch elasticity of 3.016. The compensated aggregate hours elasticity is .765, the compensated participation elasticity is .705, and the compensated intensive margin hours elasticity is .109. After the tax change, the maximum hours worked are .746 and the minimum hours worked are .394.

Finally, the vast majority of individuals in the SSP sample were between the ages of 16 and 46, corresponding to the first half of life in our model. Consequently, in our simulation we only consider individuals in the first half of their life, corresponding to ages 16 to 46 out of a 60-year working life from 16 to 76.

Experiment 3: Earned Income Tax Credit in the U.S. The effective tax rates for the 1987 EITC expansion come from Meyer and Rosenbaum (2000), Table 2: the gain from working for a single mother, which includes changes in wages, welfare, Medicaid, and taxes as a result of the labor supply decision, was $7,722 in 1984 and $8,458 in 1990. This is relative to wages of $18,165, generating effective tax rates of 58.9% in 1986 to 53.4% in 1989.

Eissa and Liebman observe employment rates at an annual level using CPS data. To replicate this data as closely as possible, we define labor force participation by whether a generation works in a given month. Because of this, we use a target value of $f = .687$ rather than $f = .720$ as in the data, as if $f = .687$ at each instant, the fraction of individuals working in each year before the quasi-experiment is approximately 72.0%. Eissa and Liebman have data on individuals aged 16 to 44. Consequently, in our simulation we only consider individuals in the first half of their life, corresponding to simulated ages of 16 to 46 out of a 60-year simulated working life from 16 to 76.

With $\varepsilon_{INT} = .5$, $f = 68.7\%$, $h_{\max} = .45$, and $w_R/w_{\max} = 1/2$, the calibrated values are $\gamma = 2$, $\bar{h} = .247$, $\alpha = 21.091$, and $e_1 = .530$. These parameter values generate a Frisch aggregate hours elasticity of 2.248 and a Frisch participation elasticity of 1.952. The compensated aggregate hours elasticity is .667, the compensated participation elasticity is .581, and the compensated intensive margin hours elasticity is .144. Maximum hours worked after the tax change are .459 and minimum hours worked are .370.

Robustness. We now evaluate the robustness of the results to calibrating to an intensive margin Frisch elasticity of $\varepsilon_{\mathrm{INT}} = .25$.

For the Iceland simulation, the calibrated values are $\gamma = 4$, $\bar{h} = .509$, and $\alpha = 33.159$. These parameter values generate a Frisch aggregate hours elasticity of 1.929 and a Frisch participation elasticity of 1.771. With these parameters, labor force participation jumps from 78.5% to 91.95%, rather than 92.2% as presented in the main text. Maximum hours worked after the tax change are .719 and minimum hours worked are .635.

For the Canada SSP simulation, the calibrated values are $\gamma = 4$, $\bar{h} = .337$, and $\alpha = 306.149$. As above we set $e_1 = 0$, which generates $w_R/w_{\max} = .611$. These parameter values generate a Frisch aggregate hours elasticity of 3.089 and a participation Frisch elasticity of 2.949. With these parameters, labor force participation jumps from 23.5% to 76.3% one year after the subsidy is introduced. After the tax change, maximum hours worked are .585 and minimum hours worked are .421.

For the U.S. EITC simulation, the calibrated values are $\gamma = 4$, $\bar{h} = .327$, $\alpha = 165.947$, and $e_1 = .538$. These parameter values generate a Frisch aggregate hours elasticity of 1.629 and a participation Frisch elasticity of 1.546. With these parameters, labor force participation jumps from 72.0% to 77.1% on impact and then rises to 77.5% over the next seven years. The Frisch aggregate hours elasticity is 2.155, the compensated aggregate hours elasticity is .664, and the compensated labor force participation elasticity is .621. Maximum hours after the tax change are .455 and minimum hours are .409.

Calibrating to a smaller intensive Frisch elasticity of $\varepsilon_{\mathrm{INT}} = .25$ thus does not change our conclusions: the RW model over-predicts the impacts of the temporary changes in Iceland and Canada by an order of magnitude, but is closer to matching the steady-state impact of the EITC permanent tax change.

Appendix B. Meta-Analysis of Quasi-Experimental Estimates (Table 1)

This appendix describes how the participation elasticities in column 2 of Table 1 are calculated.

1. Juhn, Murphy, and Topel (1991): The partial elasticity is computed by taking a weighted average of the estimates in column (3) of Table 9; the weights are computed as the fraction of the population represented by each estimate using the wage percentiles listed in column (1) of Table 9. We normalize this partial elasticity by the mean of the employment rate from 1970-89 using 1-non-employment values reported in column (3) of Table 1. Participation is defined at the weekly level (by the fraction of weeks worked in the year).

2. Eissa and Liebman (1996): The percentage change in participation is reported in Table III, column (4) as 2.8%. The participation rate of single mothers is reported in Table II, column (1) as 73%. The percentage change in net earnings for the same data source is reported by Meyer and Rosenbaum (2000), Table 2, as the financial gain from working for single mothers in 1990 ($8,458) relative to the gain from working in 1984 ($7,469). The elasticity is thus calculated as (log(0.73+0.028)-log(0.73))/(log(8458)-log(7469)). Participation is defined as positive work hours in the past calendar year.

3. Graversen (1998): Table 5, elasticity of participation rate with respect to after tax wage, average of the four reported estimates for married women and single women, bottom panel, columns (1) and (4).

4. Meyer and Rosenbaum (2001): On page 1092, an elasticity of 1.07 for any employment (positive work hours) during the year is reported using gross earnings of single mothers as the base level of earnings. However, the correct denominator to calculate the percentage wage increase is net earnings prior to the reform after accounting for taxes and transfers. Making the correction requires multiplying the reported elasticity by the ratio of net earnings to gross earnings prior to the reform. Meyer and Rosenbaum (2000, page 1043) report that this ratio is 7270/18165, and thus the percentage increase in the wage is actually 45% rather than the 18% assumed to calculate the elasticity reported in Meyer and Rosenbaum (2000). The corrected elasticity estimate is given by $1.07 \times 7270/18165 = 0.43$.

5. Devereux (2004): Table 4, column (1), own-wage elasticity. Participation is defined as positive work hours in the past calendar year.

6. Eissa and Hoynes (2004): Table 6, elasticity of participation with respect wages, average estimate of married women and married men, 2nd row from bottom. Participation is defined as positive work hours in the last year.

7. Liebman and Saez (2006): The numerator for the elasticity is computed as log(.483-.012)-log(.483) using the Change in Wife Labor Force Participation reported in row (1) and column (1) of Table 6 and the Percent of Wives with Positive Earnings (1990-1992) reported in column (3) of Table 5. The denominator for the elasticity is computed as log(1-.419)-log(1-.31) based on the change in tax rates reported on pages 10-11 for OBRA93. Participation is defined as an indicator for positive annual earnings in the past year.

8. Blau and Kahn (2007): The elasticity is the mean of the three values across the three decades reported for Model 4 in row 1 of Table 6. Participation is defined as positive work hours in the past year.

9. Meghir and Phillips (2010): Page 247, last paragraph, average of single and married men in-work-income elasticities, 0.27 and 0.53 respectively.

10. Blundell, Bozio and Laroque (2011). Page 25, median overall extensive elasticity. Participation is defined as positive work hours in the past calendar year.

11. Gruber and Wise (1999): Using data reported in Table 1, the elasticity estimate is based on a regression of log(labor force participation at age 59) on log(effective net-of-tax rate) across countries. Labor force participation is defined as 1 minus fraction of Men Out of Labor Force at age 59; effective net-of-tax rate is defined as 1-implicit tax on earnings. The Netherlands is omitted from the regression because it has an implicit tax above 1.

12. Bianchi, Gudmundsson, and Zoega (2001): average of the elasticities for men and women reported in the text, paragraph 4, page 1570. Participation is defined at the weekly level (fraction of weeks worked in the past year).

13. Card and Hyslop (2005): Change in labor force participation during the SSP eligibility period from 0.236 to 0.371 from Figure 3. Estimated average tax rates are computed from figures in Lin et al. (1998) as described in Appendix A. Participation is defined as any employment in the past month.

14. Brown (2009): We obtain an estimate of 0.08 for the elasticity of retirement age with respect to the wage using the average of the three estimates reported in column 4 of Table 2. Footnote 33 and Section 6.1 suggest that this is the author's preferred estimate. To convert

this retirement age elasticity into an elasticity of years of work with respect to the wage rate, we follow footnote 30 and multiply the elasticity by the ratio of the mean age at retirement to the mean years of service reported in Table 1. The resulting elasticity is $0.08 \times (60.73/26.75)$. Participation is defined as years of work, with variation on the retirement margin.

15. Manoli and Weber (2010): preferred estimate of elasticity of quarterly employment rate with respect to net wage (adjusting for taxes and pensions).

Appendix C. Micro vs. Macro Elasticities (Table 2)

This appendix describes how each of the values in Table 2 are calculated. With the exception of the Frisch aggregate hours macro elasticity, the aggregate hours elasticities are defined as the sums of the intensive and extensive margin elasticities.

Hicksian, extensive margin: The micro estimate is the mean of the in Panel A of Table 1. The macro estimate is computed by taking the mean of 0.27 from Davis and Henrekson (2005) and 0.14 from Nickell (2003). The elasticity from Davis and Henrekson is computed using the log difference in employment based on the slope coefficient in Table 3 (bottom panel, Schneider tax data) and the sample means of labor force participation and tax rates in Table 1 for the corresponding sample. The elasticity from Nickell is computed using log differences in employment based on the average point estimate of 2 percent (reported on page 10) and the sample means of employment rates and tax rates from Tables 1 and 2, respectively.

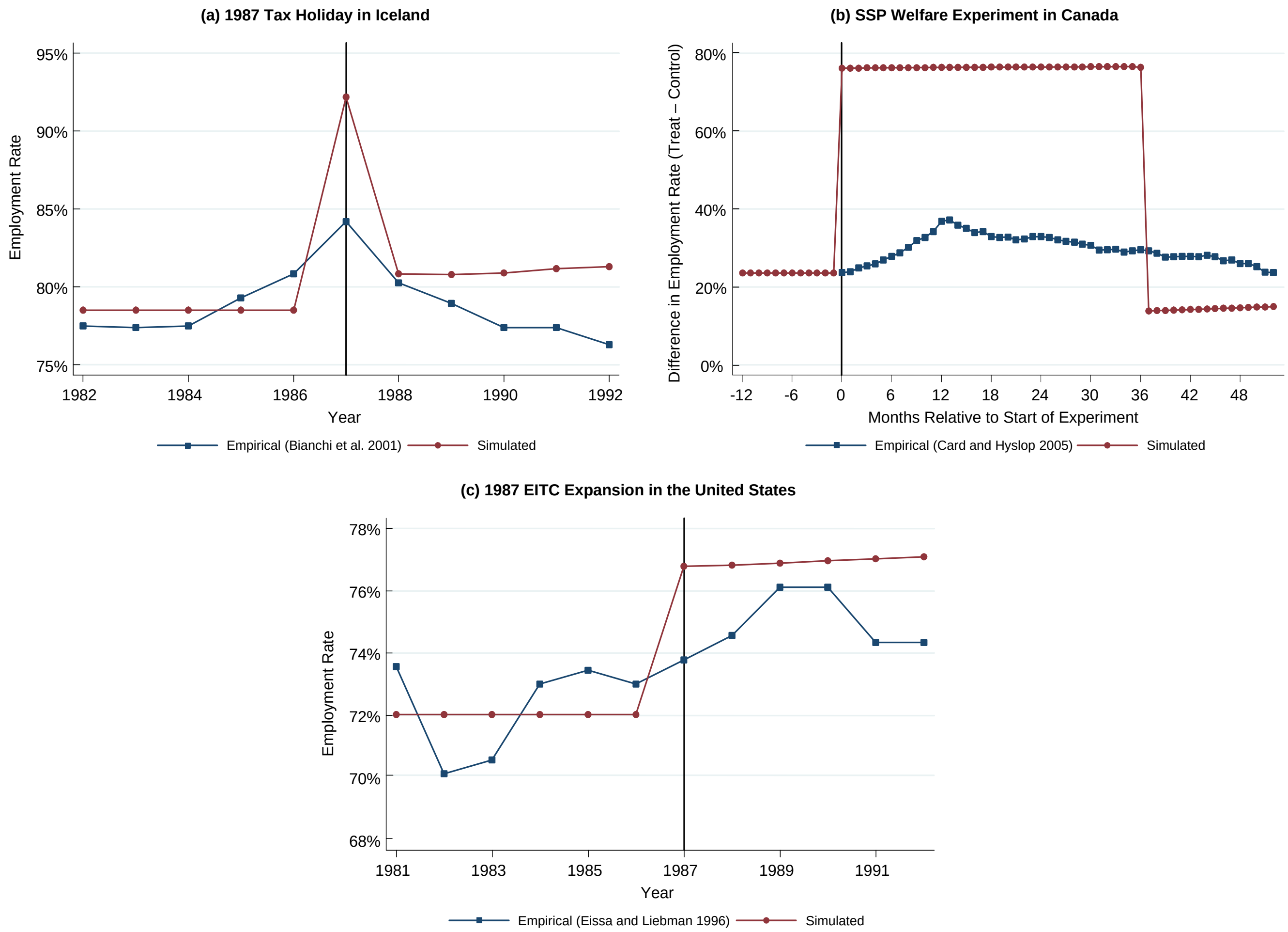
Hicksian, intensive margin: The micro estimate is the unweighted average of the unified bounds in Table 1 of Chetty (2010). The macro estimate is the mean of the values reported by Davis and Henrekson (2005) and Prescott (2004). The value from Davis and Henrekson (2005) is computed using log differences in annual hours per employed adult based on the slope coefficient in Table 3 (middle panel, Schneider tax data) and the sample means of annual hours per employed person and tax rates in Table 1 for the corresponding sample. The value from Prescott (2004) comes from subtracting the Hicksian macro extensive margin elasticity (0.21) from the aggregate hours elasticity (0.70), which is estimated by regressing log actual hours on log net-of-tax rates $(1 - \tau)$ reported by Prescott in Table 2.

Frisch, intensive margin elasticities: the micro estimate is the unweighted mean of 0.70 in Table 2 from Pistaferri (2003) and 0.29 (as reported in Chetty 2009). The macro value in brackets is set equal to the micro estimate.

Frisch, extensive margin: The micro estimate is the mean of the estimates in Panel B of Table 1. The macro value in brackets is computed by subtracting the Frisch micro intensive margin elasticity from the Frisch aggregate hours macro elasticity.

Frisch, aggregate hours macro: the estimate is computed by taking the mean of the aggregate (total hours) elasticities implied by three models of business cycles: (1) Cho and Cooley (1994): 2.61 from the sum of the intensive and extensive margin elasticities implied by the parameters in Table 2; (2) King and Rebelo (1999): 4 for representative agent RBC models, from page 975, and (3) Smets and Wouters (2007): 1.92 from Table 1A, Posterior Distribution, Mode.

FIGURE 1
Impacts of Tax Changes on Employment Rates: Simulations vs. Data



Notes: Each panel shows the impact of an unanticipated change in incentives to work on employment rates. The series in red circles show the impact predicted by the calibrated Rogerson and Wallenius (2009) model, while the series in blue squares shows the impact observed in the data. Panel (a): Iceland suspended its income tax for one year in 1987. Average tax rates in Iceland changed from 14.5% in 1986 to 0% in 1987 and then 8.0% in 1988. Following Bianchi et al. (2001), we define the employment rate as the fraction of weeks worked in a given year in the adult population. Panel (b): The Canadian SSP demonstration randomly assigned a group of welfare recipients a wage subsidy for 36 months in the early 1990s. Individuals in the control group faced an effective average tax rate of 74.3% for working full time at the minimum wage, while individuals in the treatment group faced an effective average tax rate of 16.7%. Following Card and Hyslop (2005), we report the difference in monthly employment rates between the treatment and control groups. We add the observed control group mean at the start of the experiment (23.5%) to the difference for scaling purposes. Simulated employment rates are the fraction of individuals age 16 to 46 working in a given month, reflecting the age distribution of the SSP treatment group (see Appendix A). Panel (c): The EITC expansion in the US in 1987 lowered average tax rates net of taxes and transfers for single mothers from 58.9% in 1986 to 53.4% in 1989. Eissa and Liebman (1996) report annual employment rates for single mothers aged 16 to 44; simulated employment rates are reported for the same age group.

TABLE 1
Extensive Margin Elasticity Estimates from Quasi-Experimental Studies

Study	Elasticity	Population and Variation
A. Steady State Elasticities		
1. Juhn, Murphy, and Topel (1991)	0.13	Men, skill-specific trends, 1971-1990
2. Eissa and Liebman (1996)	0.30	Single Mothers, U.S. 1984-1990
3. Graversen (1998)	0.24	Women, Denmark 1986 tax reform
4. Meyer and Rosenbaum (2001)	0.43	Single Women, U.S. Welfare Reforms 1985-1997
5. Devereux (2004)	0.17	Married Women, U.S. wage trends 1980-1990
6. Eissa and Hoynes (2004)	0.15	Low-Income Married Men and Women, U.S. EITC expansions 1984-1996
7. Liebman and Saez (2006)	0.15	Women Married to High Income Men, U.S. tax reforms 1991-97
8. Blau and Kahn (2007)	0.41	Married Women, U.S. wage trends 1989-2001
9. Meghir and Phillips (2010)	0.40	Low-Education Men, U.K. wage trends, 1994-2004
10. Blundell, Bozio, and Laroque (2011)	0.30	Prime-age Men and Women, U.K., tax reforms 1978-2007
Unweighted Mean	**0.26**	
B. Intertemporal Substitution Elasticities		
11. Gruber and Wise (1999)	0.23	Men, Age 59, variation in social security replacement rates
12. Bianchi, Gudmunndsson, and Zoega (2001)	0.42	Iceland 1987 zero tax year
13. Card and Hyslop (2005)	0.38	Single Mothers, Canadian Self Sufficiency Project
14. Brown (2009)	0.18	Teachers Near Retirement, California Pension System Cutoffs
15. Manoli and Weber (2010)	0.20	Workers Aged 55-70, Austria severance pay discontinuities
Unweighted Mean	**0.28**	

Notes: This table reports elasticities of employment rates with respect to wages, defined as the log change in employment rates divided by the log change in net-of-tax wages. Where possible, we report elasticities from the authors' preferred specification. When estimates are available for multiple populations or for multiple specifications without a stated preference among them, we report an unweighted mean of the relevant elasticities. See Appendix B for details on sources of estimates.

TABLE 2
Micro vs. Macro Labor Supply Elasticities

		Intensive Margin	Extensive Margin	Aggregate Hours
Steady State (Hicksian)	micro	0.50	0.26	0.76
	macro	0.42	0.21	0.63
Intertemporal Substitution	micro	0.50	0.28	0.78
(Frisch)	macro	[0.50]	[2.34]	2.84

Notes: Each cell shows a point estimate of the relevant elasticity based on meta analyses of existing micro and macro evidence. Micro estimates are identified from quasi-experimental studies; macro estimates are identified from cross-country variation in tax rates (steady state elasticities) and business cycle fluctuations (intertemporal substitution elasticities). The aggregate hours elasticity is defined as the sum of the extensive and intensive elasticities. Macro studies report intertemporal aggregate hours elasticities but do not always decompose these values into extensive and intensive elasticities. Therefore, the estimates in brackets show the values implied by the macro aggregate hours elasticity if the intensive Frisch elasticity is chosen to match the micro estimate of 0.5. See Appendix C for sources of these estimates.