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Intra-household Labour Income Responses to Changes in Tax Rates Among Older Workers

by Derek Messacar

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.. not available for a specific reference period
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0^s value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p} preliminary
^{r} revised
x suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E} use with caution
F too unreliable to be published
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Abstract

Despite a large literature estimating the effects of income taxation on the labour decisions of young and middle-aged workers, little is known about the extent to which older workers respond to changes in their income taxes. This paper explores this unresolved empirical issue, using longitudinal administrative data on more than one million individuals from Canada and exploiting a recent tax reform in the empirical identification strategy that explicitly targeted older couples. Specifically, this paper makes two contributions. First, older workers are shown to respond meaningfully to changes in their income taxes; however, in contrast with standard predictions, they are responsive to the average—not the marginal—tax rate. The compensated elasticities of labour income with respect to the average and marginal net-of-tax shares are estimated to be 0.421 and -0.112 conditional on being employed, respectively, of which only the former is statistically significant. In addition, each 1% increase in total after-tax income reduces the likelihood of being employed by 1.6 to 2.3 percentage points. Second, changes in individuals' taxes have spillover effects on the employment and labour income decisions of their spouses, although the income pooling prediction of the unitary model is rejected empirically. These findings offer new insight into the "black box" of intra-household labour supply and inform the optimal designs of income tax and retirement income systems.

Keywords: labour income, pension, effective tax rate, income splitting, unitary model, instrumental variables.

Executive summary

Using longitudinal administrative tax data on more than one million individuals and their spouses in Canada, this paper assesses the extent to which older workers respond to changes in their income taxes. In particular, the primary findings from this paper are as follows:

1. The compensated elasticity of taxable labour income with respect to the average net-of-tax share (one minus the tax rate) is 0.421, conditional on being employed. Therefore, a 10% increase in the average net-of-tax share leads to a 4.21% increase in the labour income of older workers.

2. Changes in tax liabilities also have large effects on individuals' labour market participation decisions. The analysis suggests that each 1% increase in total after-tax income reduces the likelihood that individuals are employed by 1.6 to 2.3 percentage points.

In addition, changes in individuals' tax rates and tax liabilities can have spillover effects on the employment and labour income decisions of their spouses. The findings from this intra-household analysis indicate the following:

3. Each 10% change in individuals' total after-tax income is estimated to induce spouses to reduce their labour earnings by 0.76% to 1.17% conditional on being employed, and to become 1.7 to 1.8 percentage points less likely to be employed.

4. Each 10% change in individuals' labour income following a tax reform is estimated to induce spouses to reduce their labour earnings by approximately 15%.

Taken together, the results of this paper suggest that the employment and labour income decisions of older workers respond meaningfully to changes in both their own income taxes and the income taxes of their spouses. These findings offer new insight into intra-household labour supply, and inform the optimal designs of income tax and retirement income systems.

1 Introduction

The aging of workforces and increasing life expectancies pose significant challenges for economic growth, national savings, and the solvency of public pension systems in many countries (Organisation for Economic Co-operation and Development [OECD] 2014). To address these concerns, governments have been increasing retirement ages and strengthening work incentives in order to raise employment rates among older workers and improve the sustainability of their pension systems (OECD 2012). These initiatives are motivated by a large literature that finds individuals' pension receipts or decisions to retire are responsive to the retirement incentives that public pension plans create (Baker and Benjamin 1999; Feldstein and Liebman 2002; Baker, Gruber and Milligan 2003; French and Jones 2012). In contrast to these pension reforms, the tax codes of many countries offer age-related deductions and reduced taxation of public pension income (OECD 2011), which lower the effective tax rates of older workers and create ambiguous labour supply incentives. Yet the extent to which older workers respond to income taxes, so that the tax code is a viable policy lever for influencing labour supply, has not received considerable attention in empirical research (Schmidt and Sevak 2009; Alpert and Powell 2014). A better understanding of the extent to which older workers respond to changes in their income taxes would inform the optimal designs of income tax and retirement income systems.

Using administrative data on more than one million taxfilers from Canada, this paper provides new insight into this unresolved issue by estimating employment and labour income responses to policy-induced changes in income tax rates among older workers. Specifically, this paper makes two key contributions. First, it credibly estimates whether older workers respond to exogenous changes in their effective net-of-tax shares.[1] The empirical identification strategy exploits a recent tax reform that targeted individuals near or of retirement age, making Canada an ideal setting to study this issue empirically. On January 1, 2007, the federal government implemented pension income splitting, which permits couples to notionally "split" private pension income for tax purposes. The unit of taxation in Canada is the individual, but the income tax system recognizes individuals' reduced ability to pay taxes when they have dependent spouses. Due to the reform, pension recipients can now transfer up to half of this income to their spouses to reduce household tax liabilities. When income is split, the effective tax rate of each individual may either decrease or increase depending on whether that individual sends or receives income, respectively. The reform also had different effects on tax liabilities depending on the pensioners' age and whether the pension income derives from an employer-sponsored pension plan (EPP), which creates several margins of variation in effective income tax rates to be exploited empirically. Instrumental variables (IV) are constructed for individuals' net-of-tax shares that vary over time due solely to this reform, following Auten and Carroll (1999) and Gruber and Saez (2002).

The results show that compensated changes in income tax rates induce large labour income responses conditional on being employed (the intensive margin). However, in contrast with standard predictions, older workers are responsive to the average—not the marginal—tax rate. The compensated elasticities of labour income with respect to the average and marginal net-of-tax shares are 0.421 and -0.112, respectively, of which only the former is statistically significant.[2] These findings support the "schmeduling" hypothesis of Liebman and Zeckhauser (2004), which posits that individuals use the average price as a proxy for the marginal price when nonlinear

1. The net-of-tax share (or "take-home rate") is calculated as one minus the tax rate.
2. Due to the type of tax reform analyzed in this study, it is possible to separately identify the effects of changes in the average tax rate and total after-tax income (i.e., to estimate a "compensated" labour income response to the average net-of-tax share). This issue is discussed in more detail below.

price schedules are so complex that knowing what marginal price is actually faced is difficult.[3] In addition, individuals exhibit large participation responses to changes in total tax liabilities (the extensive margin). For each 1% exogenous change in total after-tax income, individuals are estimated to become 1.6 to 2.3 percentage points less likely to be employed, on average.

The second contribution of this paper is to test for spillover effects of changes in tax rates across spouses—an important issue among older couples whose retirement decisions could be codependent (Gustman and Steinmeier 2004, 2009; Banks, Blundell and Rivas 2010). In a model of taxable labour income augmented to include intra-household decisions, it is shown that the effect of a tax reform across spouses can be decomposed into 1) a cross-spouse income effect, owing to the change in household disposable income; and 2) a cross-spouse labour effect. Then, the extent to which each of these effects matters for determining employment and labour income decisions is examined separately. These results indicate that each 1% change in individuals' total after-tax income induces spouses to reduce their labour earnings by 0.076% to 0.117% conditional on being employed, and also reduces the likelihood of being employed by an average of 1.7 to 1.8 percentage points. Hence, there are large cross-spouse effects of changes in income taxes along both the intensive and extensive margins. However, in contrast with the income-pooling prediction of the unitary model of labour supply, individuals appear to be slightly more responsive along the extensive margin to changes in their own after-tax income than to the after-tax income of their spouses.

Overall, the results indicate that the tax code is a viable policy lever for influencing the employment and labour income decisions of older workers. These findings relate to several interconnected literatures. While many studies estimate the elasticity of taxable income with respect to the marginal net-of-tax share, that research has produced a range of empirical results owing to the diversity of tax reforms analyzed and model specifications used (Gruber and Saez 2002).[4] Of direct relevance to this paper are previous studies that estimate the elasticity of taxable labour or wage income to the marginal net-of-tax share (Moffitt and Wilhelm 1998; Saez 2003; Bloomquist and Selin 2010; Bosch and van der Klaauw 2012; Kleven and Schultz 2014). This work tends to find lower elasticities than the taxable income literature, perhaps owing to inflexible labour contracts or work preferences.[5]

Another explanation for the low tax responsiveness typically observed in this literature is that individuals use the average tax rate as a proxy for the marginal tax rate given the complexity of nonlinear income tax schedules. While this schmeduling hypothesis has been tested in other contexts—for example, Ito (2014) finds evidence of this behaviour in electricity consumption—this paper is the first to show that schmeduling occurs with respect to income taxes using a quasi-experimental design. The only other study that addresses this issue is that of de Bartolome (1995), who conducts a controlled experiment and shows that there are as many individuals who use the average tax rate as if it were the marginal tax rate as there are individuals who correctly use the

3. Milligan (2009) shows that the effective marginal income tax schedule in Canada is a complex function that varies over time and across province, age, marital status, and family composition. The implications of this paper's findings also extend to other jurisdictions. For example, Kotlikoff and Rapson (2007) show that marginal effective tax rates in the United States are complicated by incongruities between federal and state personal, corporate and excise taxes, payroll taxes, Social Security benefits, Medicare and Medicaid benefits, Food Stamps, welfare benefits and other transfer programs.
4. Much of this research centers on tax reforms enacted in the United States, including the *Economic Reform Tax Act of 1981*, the *Tax Reform Act of 1986*, and the *Omnibus Budget Reconciliation Act* of 1990 and 1993. Examples of studies on the effects of these reforms are Auerbach and Slemrod (1997), Sammartino and Weiner (1997), Carroll (1998), Moffitt and Wilhelm (1998), Gruber and Saez (2002), Saez (2003), Giertz (2007, 2010). Other studies investigating more recent reforms, including the *Economic Growth and Tax Relief Reconciliation Act of 2001* and the *Jobs and Growth Tax Relief Reconciliation Act of 2003*, include Heim (2009) and Singleton (2011). In addition, several studies conducted based on other countries include Sillamaa and Veall (2001) for Canada, Bloomquist and Selin (2010) and Gelber (2014) for Sweden, and Kleven and Schultz (2014) for Denmark.
5. Heim (2010) is a notable exception, who shows that the elasticity of taxable labour income is large among the self-employed in the context of the United States. However, that study also shows the elasticity of wage and salary income is low.

marginal tax rate. Hence, this paper's findings contribute to the wider issue of tax salience (Feldman and Katuščák 2006; Chetty, Looney and Kroft 2009; Finkelstein 2009; Chetty and Saez 2013; Taubinsky and Rees-Jones 2015; Feldman, Katuščák and Kawano 2016).

This paper is also among the first to estimate intra-household labour supply decisions using a reduced-form experimental design that exploits a tax reform in the identification. Previous studies tend to estimate cross-spouse effects structurally (Gustman and Steinmeier 2004, 2009; Banks, Blundell and Rivas 2010; Laitner and Silverman 2012; Michaud and Vermeulen 2011; Van Soest and Vonkova 2014). Two notable exceptions are the following: 1) Yamada (2011), who shows that the hours worked of married women responded significantly to a series of Japanese tax reforms during the 1990s, although that analysis assumed labour supply decisions within couples are determined sequentially for identification; and 2) Kabátek, Van Soest, and Stancanelli (2014), who estimate the effects of a tax reform on intra-household labour supply and domestic work decisions among couples in France, where the unit of taxation is the couple. Using a random coefficients model, the study concludes that spouses' labour market and housework hours are both responsive to changes in the tax code.[6] In contrast, the intra-household model of taxable labour income developed in Section 2 of this paper shows that, when the unit of taxation is the individual, a tax reform can be exploited to credibly estimate intra-household labour supply decisions using an IV approach, which offers a novel contribution to this literature.

The paper proceeds as follows. The next section presents a unitary model of taxable labour income to provide a framework for the empirical analysis. Section 3 describes the data, sample selection, and empirical methodology, including key features of the tax reform to be exploited in the identification and how the predicted tax measures are constructed. Sections 4 and 5 assess the effects of income tax changes on individuals' labour income and cross-spouse effects, respectively. Section 6 concludes.

2 Theoretical framework

This section presents a stylized model of taxable labour income (Gruber and Saez 2002; Kleven and Schultz 2014) and derives comparative statics to provide a framework for interpreting the empirical results. More precisely, the model is extended to a setting with intra-household labour supply (Chiappori 1988). This yields predictions of how individuals should respond to changes in their own tax rates relative to changes in the tax rates of their spouses, and validates an IV approach used in Section 5 to estimate cross-spouse labour effects.

2.1 Setup

In the intra-household model, a single economic agent maximizes a weighted average of utilities for individual i and spouse s, $U\left(c, z_i, z_s; \psi_i, \psi_s\right) \equiv \lambda u^i\left(c, z_i, z_s; \psi_i\right) + \left(1-\lambda\right) u^s\left(c, z_i, z_s; \psi_s\right)$, by choosing consumption c and taxable labour incomes z_i and z_s conditional on vectors of

6. Schirle (2008) is another notable exception, who shows that the rise in the labour force participation rates of older married men over the past few decades is well-explained by changes in their wives' labour force participation over this time period. That study exploits cohort effects driving the changes in older women's participation decisions and is not based on the impact of a tax reform.

personal traits ψ_i and ψ_s. The parameter $\lambda \in [0,1]$ is the weight factor.[7] This setup implicitly assumes that z_i and z_s depend on such factors as hours worked, effort, or tax sheltering, and that these activities are separable from consumption in the utility function (Kleven and Schultz 2014). The agent chooses the bundle $\{c, z_i, z_s\}$ subject to the budget constraint $c = z_i(1-\tau_i) + z_s(1-\tau_s) + R_i + R_s$, where τ_j is the marginal tax rate and R_j is virtual income for each $j \in \{i, s\}$.

The following standard assumptions on the agent's utility function are imposed. For each $j \in \{i, s\}$: 1) $u_c^j > 0$ and $u_{z_j}^j < 0$, more consumption but less work is desired; 2) $u_{cc}^j < 0$ and $u_{z_j z_j}^j < 0$, there are diminishing returns to consumption and increasing marginal costs of labour supply; and 3) $u_{cz_j}^j = u_{z_j c}^j < 0$, the marginal utility of consumption is decreasing in the labour income requirements to achieve this consumption. On the assumption that leisure is (weakly) complementary across spouses, for each $j,k \in \{i, s\}$ subject to $j \neq k$, the following conditions are also assumed: 4) $u_{z_k}^j \leq 0$; 5) $u_{cz_k}^j = u_{z_k c}^j \leq 0$; and 6) $u_{z_j z_k}^j = u_{z_k z_j}^j \leq 0$.

2.2 The intensive margin

Conditional on participating in the labour market, the optimal taxable labour income z_i^* (for a given z_s) is implicitly solved for by the first-order condition:

$$\lambda\left(u_c^i(1-\tau_i) + u_{z_i}^i\right) + (1-\lambda)\left(u_c^s(1-\tau_i) + u_{z_i}^s\right) = 0 \tag{1}$$

To find the individual's labour income responses to changes in the own net-of-tax share and the net-of-tax share of the spouse, totally differentiate Equation (1) with respect to $(1-\tau_i)$ and $(1-\tau_s)$ and evaluate at $\{z_i^*, z_s^*\}$ to obtain:

$$dz_i^* = \Omega\left(\lambda u_c^i + (1-\lambda)u_c^s\right)d(1-\tau_i) - \Gamma\left(z_i^* d(1-\tau_i) + dR_i\right) - \Theta dz_s^* \tag{2}$$

$$dz_i^* = -\Gamma\left(z_s^* d(1-\tau_s) + dR_s\right) - \Theta dz_s^* \tag{3}$$

where $\Omega > 0$, $\Gamma > 0$, and $\Theta > 0$ are constants that depend entirely on the model's parameters and second-order partial derivatives of utility (see the Appendix for derivations). Equation (2) shows that the individual's response to a change in the own tax rate depends on: 1) a substitution (price) effect, evaluated relative to a weighted average of the marginal utilities of consumption for both spouses, $\lambda u_c^i + (1-\lambda)u_c^s$; 2) an income effect, expressed as the sum of the infra-marginal effect of the reform relative to z_i^* and the change in virtual income, dR_i; and 3) a cross-spouse

7. For simplicity, the weight parameter is modelled as a constant here, consistent with the unitary model. This could also be extended to a collective model with no effect on the comparative statics to the extent that the weight parameter is a function of such factors as consumption, the taxable labour incomes of both spouses, the personal traits of both spouses, and other distribution factors, but not the prices (tax rates). Browning, Chiappori and Lechene (2006) refer to the case where the weight parameter depends only on distribution factors—but not consumption or incomes—as a distribution-factor dependent unitary model. If the weight parameter were a function of prices, the comparative statics that follow assume local independence.

labour income response, dz_s^*. This expression forms the basis for the estimating equation of individuals' responsiveness to changes in taxes carried out in Section 4.

Further, Equation (3) shows that a change in the spouse's tax liability only has income and cross-spouse labour effects on the income adjustment of the individual. In this case, the income effect is expressed as the sum of an infra-marginal effect relative to z_s^* and the change in virtual income, dR_s. The lack of direct price effect arises because, despite the joint optimization, the spouse's tax rate is only levied on spousal labour income; a small deviation in $(1-\tau_s)$ does not affect the marginal value of an extra $1 earned by the individual.[8] Hence, combining Equations (2) and (3), exogenous variation in the net-of-tax share of the spouse, $d(1-\tau_s)$, is a valid excluded instrument for dz_s to estimate how a change in the taxable labour income of the spouse directly affects the taxable labour income of the individual, dz_i. The tests of cross-spouse income and labour effects are performed in Section 5, using these model implications to guide the analysis.

2.3 The extensive margin

The labour market participation decision depends on the utility gain from working relative to the cost. Suppose the utility cost of supplying labour is k_j for each $j \in \{i,s\}$. As in Alpert and Powell (2014), the agent solves the following maximization problem:

$$\begin{aligned} &\max_{z_i' \in \{0, z_i^*\}, z_s' \in \{0, z_s^*\}} U\left(z_i'(1-\tau_i) + z_s'(1-\tau_s) + R_i + R_s, z_i', z_s'; \psi_i, \psi_s\right) \\ &-1(z_i' > 0)k_i - 1(z_s' > 0)k_s \end{aligned} \tag{4}$$

where $1(\cdot)$ is an indicator function, and z_j^* for each $j \in \{i,s\}$ is the solution to the intensive-margin optimization problem outlined above. The participation decision only depends on the effect of total after-tax income on consumption—an income effect. To see this, notice that a tax reform that is revenue-neutral for the agent $(dc/d(1-\tau_i)=0)$ has no effect on participation. For a decrease in the total tax liability of either the individual or spouse, the benefit of working increases, in turn raising the likelihood that the individual is employed.

3 Data and empirical methodology

This section first describes the dataset and sample selection used. Then, a brief overview of Canada's income tax system is provided, including details of the tax reform exploited in the empirical analysis. This section concludes by presenting the estimating equations derived from the theoretical framework and outlining how the predicted tax measures were constructed.

3.1 Data and sample selection

The Longitudinal Administrative Databank (LAD) is used to carry out this study. The LAD is a panel dataset comprising a 20% nationally representative subset of the T1 Family File (T1FF). Importantly, the T1FF is a yearly cross-sectional dataset of taxfilers and their families based on records from Canada's central tax authorities. While individuals file tax returns independently in

8. The fact that cross-spouse price effects of taxes are zero is also discussed by Blundell, Pistaferri and Saporta-Eksten (2016) in the context of family labour supply responses to wage shocks.

Canada, census families (both legal and common-law) were created in the T1FF based on the spousal social insurance number listed on each individual's tax form or by matching based on name, address, age, sex, and marital status. Therefore, the LAD provides data on both individuals and their spouses, which is needed to carry out this intra-household analysis.[9] Since the LAD does not contain information on individuals' tax rates, these measures were constructed using Milligan's (2012) Canadian Tax and Credit Simulator (CTaCS) along with the wide scope of information available in the data to accurately predict tax liabilities.

The following sample restrictions are imposed. First, individuals were included in the sample only if they were observed filing taxes in every year from 2005 to 2008, a time period that encompasses the relevant tax reform. This restriction is needed for the analysis to control for fixed effects in the empirical analysis; approximately 90% of taxfilers meet this requirement. Second, both individuals and their spouses must have been 55 years of age or older in 2008 (the last year of data used), so that the analysis centers on older workers. Third, individuals and their spouses must have been 54 years of age or younger in at least one year from 1991 to 2006, for methodological reasons discussed below.

Table 1 presents descriptive statistics for this sample. Individuals are 60 years old on average, of whom approximately half are male and 6.1% are immigrants. Importantly, more than half of individuals and their spouses were employed in 2006 (62.9% and 62.6%, respectively), and many couples consisted of at least one pensioner (44.2%), which means there is a large share of households whose labour decisions were potentially affected by the tax reform. Total after-tax labour income in 2006 averaged $38,650 and $38,100 for individuals and their spouses, respectively, and the corresponding marginal tax rates with respect to labour income were 24.1% and 20.5%.

9. In the LAD, spousal variables are matched to the individual taxfiler. Hence, among individuals who are married or in common-law relationships, each observation contains tax data covering two people.

Table 1
Descriptive statistics

Statistic	Median	Average
	years	
Demographics		
Individual's age	60.0	60.3
Spouse's age	60.0	60.3
	percent	
Female	…	49.8
Male	…	50.2
Married	…	100.0
Immigrant	…	6.1
Non-pension income		
Individual has labour income	…	62.9
Spouse has labour income	…	62.6
Family has capital gains	…	26.8
Family has investment income	…	62.5
Family has Employment Insurance income	…	12.5
Family has social assistance income	…	1.8
Pension income		
Individual has private pension income	…	28.4
Spouse has private pension income	…	28.2
Family has private pension income	…	44.2
	nominal dollars	
Earnings		
Individual's labour income	10,000	27,500
Spouse's labour income	9,750	26,950
Individual's total after-tax income	28,950	38,650
Spouse's total after-tax income	28,700	38,100
	percent	
Allowances		
Family has disability allowances	…	3.9
Family has medical expense allowances	…	42.5
Marginal tax rates		
Individual's marginal tax rate	26.7	24.1
Spouse's marginal tax rate	19.2	20.5
Average tax rates		
Individual's average tax rate	18.2	14.8
Spouse's average tax rate	14.7	14.3

… not applicable

Notes: These descriptive statistics pertain to the relevant sample of individuals and their spouses in 2006, the year prior to the introduction of pension income splitting. The earnings values are rounded to the nearest $50. The number of observations in the sample is 527,286.

Source: Statistics Canada, Longitudinal Administrative Databank.

3.2 Pension income splitting reform

Personal income tax in Canada is calculated based on a measure of taxable income (net of permitted deductions), then tax credits are applied to determine the net amount of income tax payable. While the unit of taxation is the individual, the personal income tax system recognizes taxpayers' reduced ability to pay taxes when individuals have dependent spouses and in certain cases when taxpayers support other dependent relatives (e.g., parents or grandparents). This recognition is generally provided in the form of additional tax credits and through permitting the transfer of certain dependents' unused portion of personal tax credits to the taxpayers.

Taxes are determined at the federal and provincial levels, with the federal and provincial governments each applying separate tax rates to a uniform measure of taxable income and each

applying separate tax credits to determine the net amount of federal and provincial tax owing.[10] At the federal level, taxable income in 2006 was divided into four brackets: 1) the first $36,378 of income; 2) from $36,379 to $72,756; 3) from $72,757 to $118,285; and 4) over $118,285. The income tax rates for these brackets were 15.25%, 22%, 26%, and 29%, respectively, and the federal basic exemption was $9,039. At the provincial level, there is significant heterogeneity in income tax structures and rates. For example, Alberta levied provincial taxes using the same bracket structure as the federal level, whereas Nova Scotia, Ontario, and British Columbia had eight brackets; basic exemptions ranged from $7,231 in Nova Scotia to $14,799 in Alberta. Given the plethora of factors that affect taxable income, some researchers regard the *Income Tax Act* as one of Canada's most complex pieces of legislation (Wolfson et al. 2016).

On January 1, 2007, the federal government implemented pension income splitting, which permits individuals to notionally "split" private pension income with their spouses. In particular, pension recipients with high income (the "pensioners") may allocate up to 50% of their eligible pension income to their spouses (the "transferees") to reduce household tax liabilities. To qualify, the pension income must satisfy certain criteria. If a pensioner is 65 years of age or older, eligible pension income includes lifetime annuity payments under employer-sponsored pension plans (EPPs), registered retirement savings plans, and payments out of Registered Retirement Income Funds. However, if a pensioner is less than 65 years old, eligible pension income only includes lifetime annuity payments from EPPs and certain payments received as a result of the death of a spouse.

3.3 Empirical model

The objective of this study is to estimate both individual and cross-spouse responses to changes in tax rates. The empirical model extends the work of Gruber and Saez (2002), Gelber (2014), and the related literature by expressing the change in the individual's log of labour income to the changes in the individual's log of the net-of-tax share and log of total after-tax income, as well as the direct adjustment to the spouse's log of labour income. The baseline estimating equation for the intensive-margin analysis, derived from Equation (2), is as follows:

$$\Delta \ln\left(z_{it}\right) = \alpha_0 + \beta_0 \Delta \ln\left(1-\tau_{it}\right) + \gamma_0 \Delta \ln\left(Y_{it} - T_{it}\right) + \zeta_0 \Delta \ln\left(z_{st}\right) + X_{it}^{'}\theta_0 + f\left[\ln\left(z_{i,t-1}\right)\right] + \epsilon_{it} \qquad (5)$$

where Y_{jt} is total pre-tax income and T_{jt} is tax liability for each $j \in \{i,s\}$ at time t; $\tau_{jt} = \partial T_{jt} / z_{jt}$ is the marginal tax rate with respect to labour income; X_{jt} is a set of observed covariates; ϵ_{it} is the statistical residual; and Δ is the difference operator, $\Delta A_t = A_{t+1} - A_t$. Thus, $\Delta \ln\left(1-\tau_{jt}\right)$ measures the change in the log of the net-of-tax share, and $\Delta \ln\left(Y_{jt} - T_{jt}\right)$ measures the change in the log of total after-tax income. The regression parameters of interest are: 1) β_0, the substitution response to a marginal deviation in the price of labour; and 2) γ_0, the income effect of the change in total after-tax income. The model predicts that $\hat{\beta}_0 > 0$ and $\hat{\gamma}_0 < 0$.

Implicit in Equation (5) is the fact that tax liability is a function of the income and personal characteristics of both the individual and spouse (which affect taxable income through various allowances), as well as a vector of tax parameters. Formally, $T_{jt} = T\left(\Psi_{jt}; \Pi_t\right)$ subject to $\Psi_{jt} = \{Y_{it}, Y_{st}, X_{it}, X_{st}\}$ and Π_t is the set of relevant tax parameters at time t. As is common in the

10. In the province of Quebec, taxes are administered and enforced by Revenu Québec. In all other provinces and territories, this process is handled by the Canada Revenue Agency.

elasticity of taxable income literature, lagged labour income, $z_{i,t-1}$, is controlled for flexibly in order to account for mean-reversion bias and potential changes in income inequality around the time of the tax reform (Auten and Carroll 1999; Gruber and Saez 2002; Saez, Slemrod and Giertz 2012; Gelber 2014; Kleven and Schultz 2014). Specifically, $f\left[\cdot\right]$ is set to be a 10-piece spline based on percentiles. Most of the literature cited above estimates tax elasticities using policy-induced variation in marginal income tax schedules over time. That approach assumes individuals at one point in the income distribution are a reasonable control group for individuals at the other points in the distribution, which makes controlling for mean-reversion and a changing income distribution especially important. Yet including controls that are too flexible invariably absorbs much of the tax rate variation created by the reform that is useful in the identification. This issue is less of a concern in this analysis because variation in effective tax rates brought on by the introduction of a new tax allowance is exploited. The pension income splitting reform affected individuals differently across multiple dimensions including, but not limited to, the income distribution. This analysis will show how the results change as lagged income becomes controlled for.

Based on Equation (4), the extensive-margin analysis relates the change in labour market participation to the change in the log of total after-tax income, as well as the change in spousal labour market participation. Specifically, the estimating equation is:

$$\Delta 1\left(z_{it}>0\right)=\iota_0+\kappa_0\Delta\ln\left(Y_{it}-T_{it}\right)+\mu_0\Delta 1\left(z_{st}>0\right)+X_{it}^{'}\phi_0+f\left[\ln\left(z_{i,t-1}\right)\right]+\nu_{it} \tag{6}$$

where these variables are defined above. The expectation is that an increase in the after-tax income of the individual makes leisure more affordable and reduces the incidence of being employed, $\hat{\kappa}_0<0$. While mean-reversion and distributional changes in income are less of an issue in the extensive-margin analysis, a 10-piece spline for lagged labour income is still included, as described in the Table 2 notes.

An implicit assumption of the empirical model is that hourly wages are uncorrelated with the change in taxes, so that the full burden of an income tax reform operates through its effect on time spent working. As in Gelber (2014), this analysis partly addresses concerns regarding this assumption by controlling for an array of job-specific characteristics in the intensive-margin analysis, including indicators for union status, EPP coverage, and sector of employment, although excluding these variables would have no qualitative effect on the results.

3.4 Instruments

The instruments for the changes in the net-of-tax shares and total after-tax income are predicted tax measures, calculated by estimating how tax liabilities would have changed due to the reform holding everything else constant. Denote π_t as the parameter governing pension income splitting and $\tilde{\Pi}_t$ as the vector of all other tax parameters. In addition, for each $j\in\{i,s\}$, denote $\hat{Y}_{jt}=Y_{jt}+\hat{s}_{jt}$ as the pre-reform total income (Y_{jt}) net of a predicted amount that would have been split ($\hat{s}_{jt}$) in this period had this practice been permissible, where $\hat{s}_{jt}>0$ if individual j is the transferee and $\hat{s}_{jt}<0$ if j is the pensioner. In other words, ($\hat{Y}_{jt}-Y_{jt}$) is the predicted change in total income around the introduction of pension income splitting resulting exclusively from this tax reform; the process for calculating $\hat{s}_{jt}$ is described below. Taken together, the instruments for the changes in the marginal net-of-tax share and total after-tax income are:

$$\Delta \ln\left(1-\tau_{jt}\right)^{IV} = \ln\left(1-\frac{\partial T\left(\hat{\Psi}_{jt};\pi_{t+1},\tilde{\Pi}_{t}\right)}{\partial z_{jt}}\right) - \ln\left(1-\frac{\partial T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)}{\partial z_{jt}}\right) \quad (7)$$

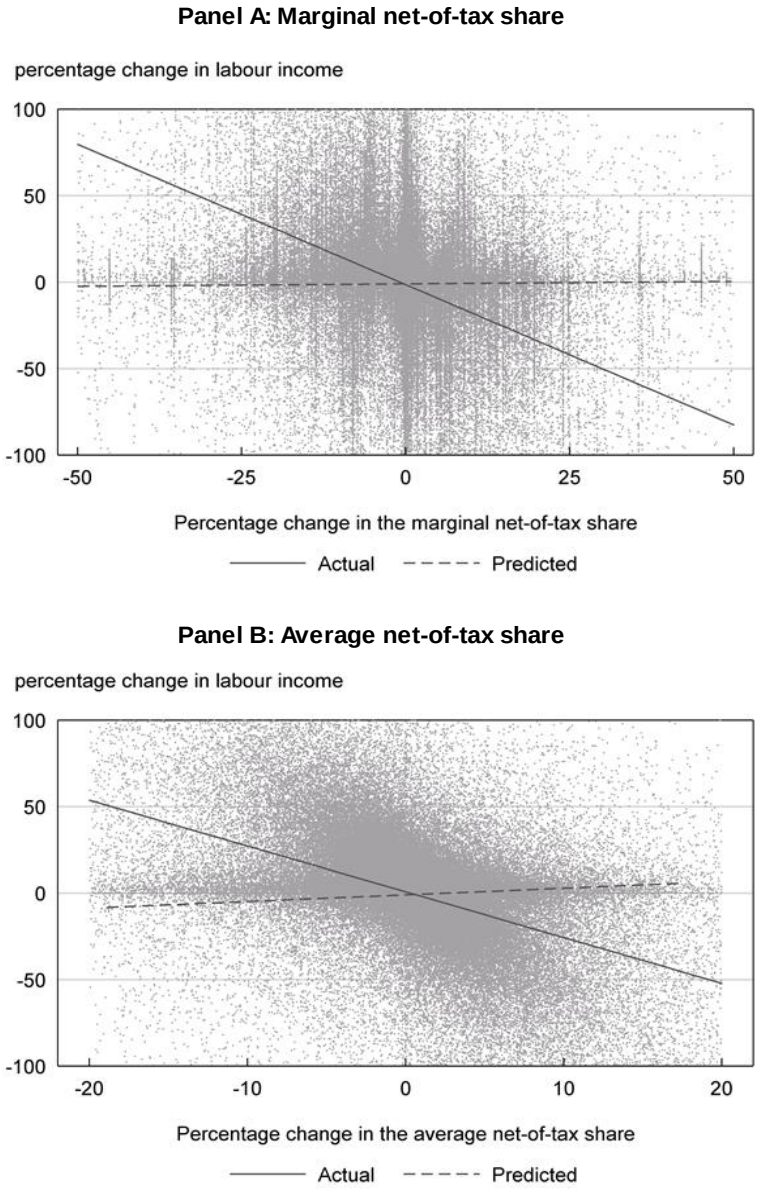
$$\Delta \ln\left(Y_{jt}-T_{jt}\right)^{IV} = \ln\left(\hat{Y}_{jt}-T\left(\hat{\Psi}_{jt};\pi_{t+1},\tilde{\Pi}_{t}\right)\right) - \ln\left(Y_{jt}-T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)\right) \quad (8)$$

where $\hat{\Psi}_{jt} = \left\{\hat{Y}_{it}, \hat{Y}_{st}, X_{it}, X_{st}\right\}$. Equations (7) and (8) show that the only factor for each instrument that changes within individuals over time is due to pension income splitting, namely as a result of the reform's introduction ($\pi_t \rightarrow \pi_{t+1}$) and the amount of pension income predicted to be sent or received resulting from the reform ($Y_{jt} \rightarrow \hat{Y}_{jt}$). The variation across individuals comes from the differential effects of the reform on transferees versus pensioners, age groups, and whether the pension income is derived from EPPs. Exploiting policy-induced variation in net-of-tax shares is necessary to estimate the elasticity of taxable labour income consistently because of tax progressivity. Since the marginal tax rate increases with income, the ordinary least squares (OLS) estimator is biased downwards. Figure 1 shows this downward bias, as well as a reduced-form look at how the instrument overcomes this problem.

The process for predicting the amount of pension income split ($\hat{s}_{jt}$) is based on two assumptions. First, although eligibility to split pension income depends on whether this income is derived from EPPs, the tax data do not reveal such information. To address this issue, sources of pension income are inferred using the longitudinal component of the data: workers who were observed with a positive EPP contribution from 1991 to 2006 at least once during normal working years (defined here as 54 years of age or younger) are assumed to draw all their pension income from an EPP.[11] All other pension recipients are assumed to be drawing from other private savings accounts and are, therefore, subject to the age restriction for splitting.[12] Second, it is assumed that the person in each family with the highest pension income always transfers 50% of this income in order to predict changes in taxes resulting from the reform. Splitting a lesser amount may be optimal in practice, especially when spouses' incomes are similar. However, predicting splitting using an optimization approach is difficult to implement in practice, and would require a strong assumption that all taxfilers are sufficiently knowledgeable about the tax system to optimize correctly. Imposing that 50% is always transferred avoids any behavioural assumptions and is correlated with the reform's true effect since this method is strictly based on a maximum eligibility rule.[13]

11. An individual or spouse is determined to have a positive EPP contribution if the pension adjustment is positive in the reference year; see Morissette and Ostrovsky (2006) for a discussion of this variable. The pension adjustment was introduced in 1991.
12. Requiring individuals and their spouses to be less than 55 years old in at least one year from 1991 to 2006, and at least 55 years old in 2008, means they are 53 to 69 years old in 2006.
13. Imposing that 50% is always transferred is sensible for most taxfilers in this study. For example, among couples with at least one pensioner in 2006, more than 71% of them had a difference in employment and private pension income of more than $10,000; the median and average values of their differences in income are $20,400 and $29,150, respectively (rounded to the nearest $50). Yet the unconditional median and average predicted values of the amount split, assuming 50% is always transferred, are only $0 and $2,300, respectively. Conditional on predicting positive splitting, the median and average predicted values of the amount split are $10,400 and $11,750, respectively. Hence, the magnitude of the overestimate of splitting based on the assumption that exactly 50% is transferred is modest, and the strong F-statistics from the first-stage IV regressions indicate that measurement error is not a significant issue.

Figure 1
Graphical inspection of the net-of-tax shares, actual and instruments

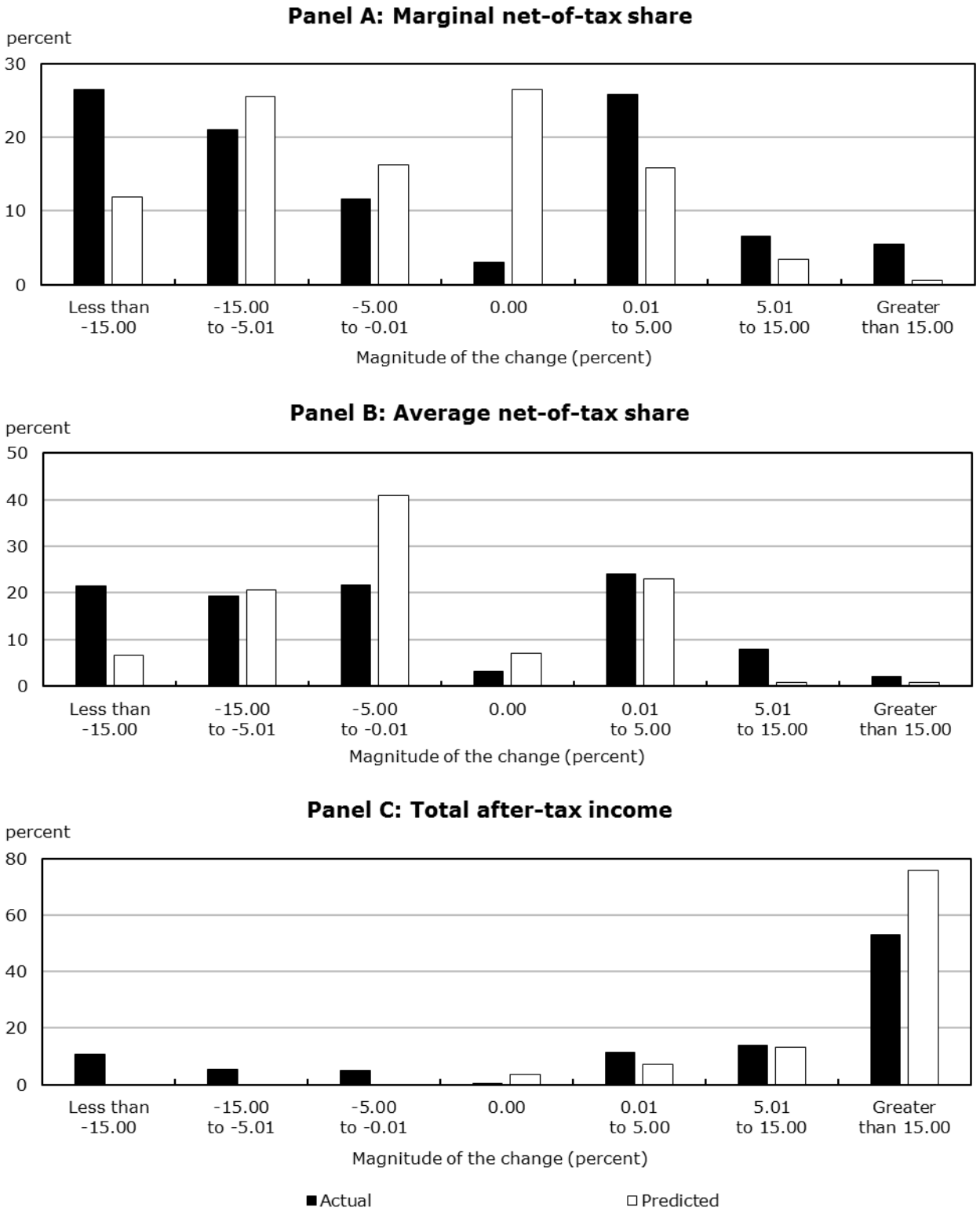


Notes: The relationship between labour income and the marginal (Panel A) and average (Panel B) net-of-tax shares are shown. Each dot corresponds to a unique observation, reflecting the individual's percentage changes in labour income and actual net-of-tax share. The kernel-weighted local polynomial smoothing of these relationships are also shown, for both the actual and predicted net-of-tax shares.
Source: Statistics Canada, Longitudinal Administrative Databank.

To illustrate the actual and predicted variations in the net-of-tax shares and total after-tax income due to splitting, Charts 1 and 2 show the distributions of individuals who experienced different changes in each variable among couples with at least one pensioner, based on whether the individual was predicted to be the transferee or pensioner. These charts illustrate that there are large shares of individuals who experienced both decreases and increases in the tax measures owing to the tax reform. On balance, the instruments reasonably approximate the actual changes in taxes around the time that pension income splitting was introduced. However, the mass of individuals who experienced no change in each instrument is disproportionately large relative to

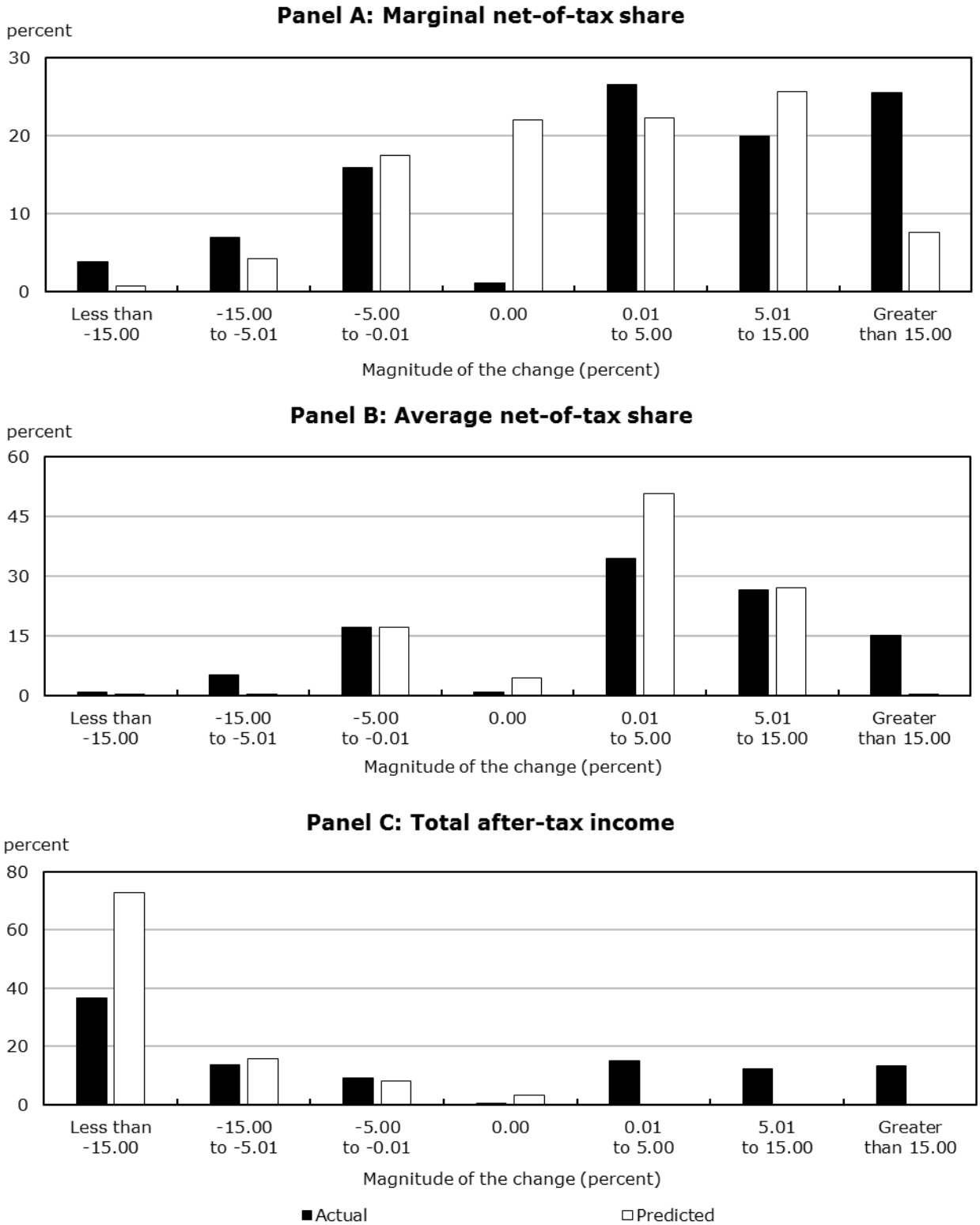
the corresponding actual variable given that no splitting is predicted to occur if: 1) individuals and spouses have equal pension incomes; or 2) the age and EPP requirements for splitting eligibility are not met. The predicted after-tax income is shown to be non-decreasing for transferees and non-increasing for pensioners, which occurs by design. As a result, the marginal and average net-of-tax shares tend to decrease by a lesser amount than the actual declines in these variables for transferees, while the opposite is true for pensioners.

Chart 1
Mechanical variation in the tax variables, among predicted transferees



Notes: This chart shows the percentage of individuals who experienced different signs and magnitudes of change in the actual and predicted tax variables from 2006 to 2007. The results are conditional on individuals who are predicted to be transferees.
Source: Statistics Canada, Longitudinal Administrative Databank.

Chart 2
Mechanical variation in the tax variables, among predicted pensioners



Notes: This chart shows the percentage of individuals who experienced different signs and magnitudes of change in the actual and predicted tax variables from 2006 to 2007. The results are conditional on individuals who are predicted to be pensioners.
Source: Statistics Canada, Longitudinal Administrative Databank.

4 Labour income responses to tax rates

The regression estimates of individuals' labour income responses to changes in their net-of-tax shares and total after-tax income are presented in this section, based on empirical model specifications derived from Equations (2) and (4) of the theoretical framework. To estimate these responses consistently, the predicted tax measures defined in Equations (7) and (8) are used as instruments in a two-stage least squares (2SLS) approach.

4.1 Primary results

In Table 2, the first-stage effects of the instruments for the marginal net-of-tax share and total after-tax income on the endogenous regressors in Equations (5) and (6) are shown, for both the intensive-margin analysis in Panel A and the extensive-margin analysis in Panel B. As expected, these results indicate that the instruments are strong predictors of the true variation in taxes around the time of the pension income splitting reform, with large F-statistics for the tests of excluded instruments. Each regression controls for many observed characteristics across both individuals and their spouses, including age and spousal age fixed effects, sex, marital status, immigrant status, and province of residence; log values of family income from capital gains, investments, Employment Insurance, and social assistance; and log values of family tax allowances for disability and medical expenses. In addition, several job characteristics of the individual are controlled for in the intensive-margin analysis: indicators of union status, EPP coverage status, and sector of employment based on the 2-digit North American Industrial Classification System (NAICS) code. Throughout the analysis, standard errors are always clustered by individual.

Table 2
First-stage inspection of the instruments

	Uncompensated effect	Compensated effect		Income effect
	Marginal net-of-tax share	Marginal net-of-tax share	Total after-tax income	Total after-tax income
		estimates		
Panel A: Intensive margin				
Coefficient estimates				
Predicted marginal net-of-tax share	0.669 ***	0.531 ***	-0.136 ***	…
Predicted total after-tax income	…	-0.127 ***	0.570 ***	…
F-statistic	3,782.96 ***	3,730.15 ***	1,801.85 ***	…
Panel B: Extensive margin				
Coefficient estimates				
Predicted marginal net-of-tax share	0.734 ***	0.649 ***	-0.389 ***	…
Predicted total after-tax income	…	-0.070 ***	0.706 ***	0.731 ***
F-statistic	27,607.80 ***	27,362.69 ***	11,077.97 ***	16,810.34 ***

… not applicable

*** significantly different from reference category ($p < 0.001$)

Notes: The following control variables are included in the extensive-margin analysis: cohort fixed effects for both the individual and spouse; sex, marital status, immigrant status, and the province of residence of the individual; log values of family income from capital gains, investments, Employment Insurance, and social assistance; and log values of family tax allowances for disability and medical expenses. In addition to these variables, the intensive-margin analysis also controls for the following job-related factors of the individual: union status, employer-sponsored pension plan coverage status, and sector of employment using the two-digit North American Industrial Classification System (NAICS) code. A 10-piece spline in the one-period lagged value of the log of labour income is also always included in the regressions. Standard errors are clustered by individual. The bottom column headers show the dependent variable used in each regression. The number of observations is 178,064 for the intensive-margin analysis and 527,286 for the extensive-margin analysis.

Source: Statistics Canada, Longitudinal Administrative Databank.

The second-stage regression results for the intensive-margin analysis are shown in Table 3 using both OLS and IV (reduced-form and 2SLS) estimators. The downward bias of the OLS estimator for the marginal net-of-tax share caused by tax progressivity is apparent. In addition, there is significant upward bias in the OLS estimates of the effects of total after-tax income on labour earnings, which arises because individuals with higher labour earnings are more likely to also have higher total income. The predicted measure of total after-tax income effectively and consistently corrects for this bias. Along the intensive margin, in Panels A and B of Table 3, the uncompensated regression estimates—not instrumenting for $\Delta \ln\left(Y_{it} - T_{it}\right)$ using the corresponding predicted variable—suggest that individuals respond meaningfully to changes in their marginal net-of-tax shares. Specifically, each 1% increase in the net-of-tax share appears to induce a 1.004% to 1.036% increase in labour income, on average, depending on whether the lagged labour income controls are included. However, controlling for income effects of the tax reform by instrumenting for the change in total after-tax income using $\Delta \ln\left(Y_{it} - T_{it}\right)^{IV}$ absorbs this effect—a finding that is consistent with previous studies. Hence, these results ultimately indicate that individuals' labour income decisions are unresponsive to exogenous changes in their marginal tax rates.

Table 3
Intensive margin—Labour income responses to changes in the marginal net-of-tax share and total after-tax income

		Instrumental variables	
	Ordinary least squares	Reduced form	Two-stage least squares
		coefficient estimates	
Panel A: No lagged income controls			
Uncompensated effect			
Marginal net-of-tax share	-0.884 ***	0.693 ***	1.036 ***
Compensated effect			
Marginal net-of-tax share	-0.884 ***	0.010	0.015
Total after-tax income	0.515 ***	-0.014	-0.021
Panel B: 10-piece spline for the one-period lagged labour income			
Uncompensated effect			
Marginal net-of-tax share	-0.890 ***	0.671 ***	1.004 ***
Compensated effect			
Marginal net-of-tax share	-0.890 ***	-0.023	-0.054
Total after-tax income	0.509 ***	-0.016	-0.041

*** significantly different from reference category (p < 0.001)

Notes: The dependent variable is the log value of labour income. The reduced-form model directly estimates how the predicted tax variables affect labour income. The covariates listed in the notes of Table 2 and a spousal variable for the log of labour income are included in every regression. Standard errors are clustered by individual. The number of observations is 178,064.

Source: Statistics Canada, Longitudinal Administrative Databank.

In contrast, Table 4 shows that each 1% increase in total after-tax income reduces the likelihood that individuals are employed by 1.6 percentage points, on average. This finding indicates that older individuals do respond to tax incentives along the extensive margin. Since the probability that individuals are employed in the pre-reform period is 62.9%, as shown in Table 1, the implied elasticity of employment to total after-tax income is $\Delta \Pr\left(z_{it} > 0\right) / \Pr(z_{it} > 0) = -0.016 / 0.692 = -0.025$. As the model predicts, the change in after-tax income is the only relevant factor in explaining labour market participation, whereas the marginal net-of-tax share is statistically insignificant in the preferred model specification that controls for lagged labour income.

Table 4
Extensive margin—Employment responses to changes in the marginal net-of-tax share and total after-tax income

		Instrumental variables	
	Ordinary least squares	Reduced form	Two-stage least squares
		coefficient estimates	
Panel A: No lagged income controls			
Uncompensated effect			
Marginal net-of-tax share	-0.691 ***	0.177 ***	0.245 ***
Compensated effect			
Marginal net-of-tax share	-0.691 ***	0.057 ***	0.094 ***
Total after-tax income	0.011 ***	-0.001	0.009 **
Income effect			
Total after-tax income	0.050 ***	-0.004 ***	-0.006 ***
Panel B: 10-piece spline for the one-period lagged labour income			
Uncompensated effect			
Marginal net-of-tax share	-0.675 ***	0.149 ***	0.202 ***
Compensated effect			
Marginal net-of-tax share	-0.675 ***	0.011	0.009
Total after-tax income	0.007 ***	-0.011 ***	-0.014 ***
Income effect			
Total after-tax income	-0.045 ***	-0.011 ***	-0.016 ***

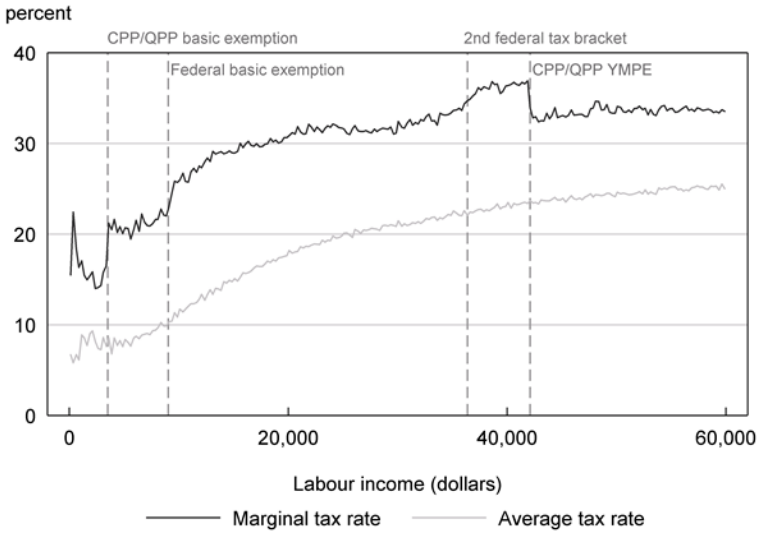
** significantly different from reference category (p < 0.01)
*** significantly different from reference category (p < 0.001)
Notes: The dependent variable is an indicator of whether the individual was employed in the reference year. The reduced-form model directly estimates how the predicted tax variables affect employment. The covariates listed in the notes of Table 2 and an indicator variable for whether the spouse was employed are included in every regression. Standard errors are clustered by individual. The number of observations is 527,286.
Source: Statistics Canada, Longitudinal Administrative Databank.

4.2 Average versus marginal net-of-tax shares

There are several reasons why workers' labour income may be unresponsive to a change in the marginal price of labour especially in the short run, such as inflexible employment contracts or work preferences. Since the demand for work diminishes as workers age, and retirement or partial retirement become viable substitutes for labour market participation, the *ex ante* expectation is for older workers to be at least as responsive as young and middle-aged workers to changes in tax rates. However, under-responsiveness may stem from behavioural factors including an imperfect understanding of the tax system. As Milligan (2009) shows, marginal income tax schedules in Canada are complex functions of taxfilers' province of residence, demographics, sources of income, and a plethora of other factors determined at the federal and provincial levels. For this reason, individuals may struggle to know their true marginal tax rates at the time of making labour decisions, especially when some sources of income are uncertain.

Liebman and Zeckhauser (2004) have posited that, when nonlinear price schedules are complex and knowing what marginal price is actually faced is difficult, individuals may use the average price as a proxy to help guide their decision-making. Figure 2 plots the typical marginal and average income tax schedules for the sample of individuals included in this study over a range of labour income from $0 to $60,000. The marginal tax rate exceeds the average tax rate due to progressivity, and the marginal tax rate has clear discontinuities at various points where specific features of the tax code and social programs start or stop taking effect, whereas the average tax rate is a smooth function of labour income.

Figure 2
Marginal and average tax rate schedules, illustrated



Notes: The marginal and average tax rate schedules are shown for the relevant sample of taxfilers, among those earning from $1 to $60,000 in 2006. Individuals were binned according to income in $250 increments and the average values of the tax rates within each bin are shown. Several income thresholds are illustrated: the point where the Canada Pension Plan and Quebec Pension Plan (CPP/QPP) social program contributions begin ($3,500 in 2006); the federal basic income tax exemption ($9,039 in 2006); the start of the second federal income-tax bracket ($36,378 in 2006); and the CPP/QPP Year's Maximum Pensionable Earnings threshold ($42,100 in 2006) at which point the CPP/QPP marginal contribution rate falls to zero. These program features result in clear discontinuities in effective marginal tax rates, whereas average effective tax rates remain smooth through the income thresholds.
Source: Statistics Canada, Longitudinal Administrative Databank.

To determine whether individuals are more responsive to the average or marginal net-of-tax share along the intensive margin, the approach from Ito (2014) is used of performing an encompassing test of these alternative price measures. For each $j \in \{i, s\}$, denote τ_{jt}^{a} as the average net-of-tax share for individual j at time t. The change in the log of the average net-of-tax share is $\Delta \ln\left(1-\tau_{jt}^{a}\right) = \ln\left(1-T_{jt}/Y_{jt}\right) - \ln\left(1-T_{j,t-1}/Y_{j,t-1}\right)$, and the instrument for this endogenous regressor is given by:

$$\Delta \ln\left(1-\tau_{jt}^{a}\right)^{IV} = \ln\left(1-\frac{T\left(\hat{\Psi}_{jt};\pi_{t+1},\tilde{\Pi}_{t}\right)}{\hat{Y}_{jt}}\right) - \ln\left(1-\frac{T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)}{Y_{jt}}\right) \tag{9}$$

The estimating equation assesses the extent to which average and marginal net-of-tax shares independently affect labour income. Specifically, the statistical model for the intensive-margin analysis is given by:

$$\begin{aligned}\Delta \ln\left(z_{it}\right) = {} & \alpha_1 + \beta_1 \Delta \ln\left(1-\tau_{it}\right) + \beta_1^{a} \Delta \ln\left(1-\tau_{it}^{a}\right) + \gamma_1 \Delta \ln\left(Y_{it}-T_{it}\right) + \zeta_1 \Delta \ln\left(z_{st}\right) \\ & + X_{it}^{'}\theta_1 + f\left[\ln\left(z_{i,t-1}\right)\right] + \eta_{it}\end{aligned} \tag{10}$$

Note that $\Delta \ln\left(1-\tau_{it}\right)$, $\Delta \ln\left(1-\tau_{it}^{a}\right)$ and $\Delta \ln\left(Y_{it}-T_{it}\right)$ are separately identified in this environment because of tax progressivity and the fact that both Y_{jt} and T_{jt} are varying exogenously in the instruments due to the tax reform, as shown graphically in Figure 3 and derived

formally in the Appendix. To the extent that individuals understand the income tax schedule and the lack of response to the marginal net-of-tax share correctly indicates that labour income is unresponsive to changes in tax rates, the expectation is that $\hat{\beta}_1 = \hat{\beta}_1^a = 0$. In contrast, the schmeduling hypothesis predicts that $\hat{\beta}_1 = 0$ and $\hat{\beta}_1^a > 0$.

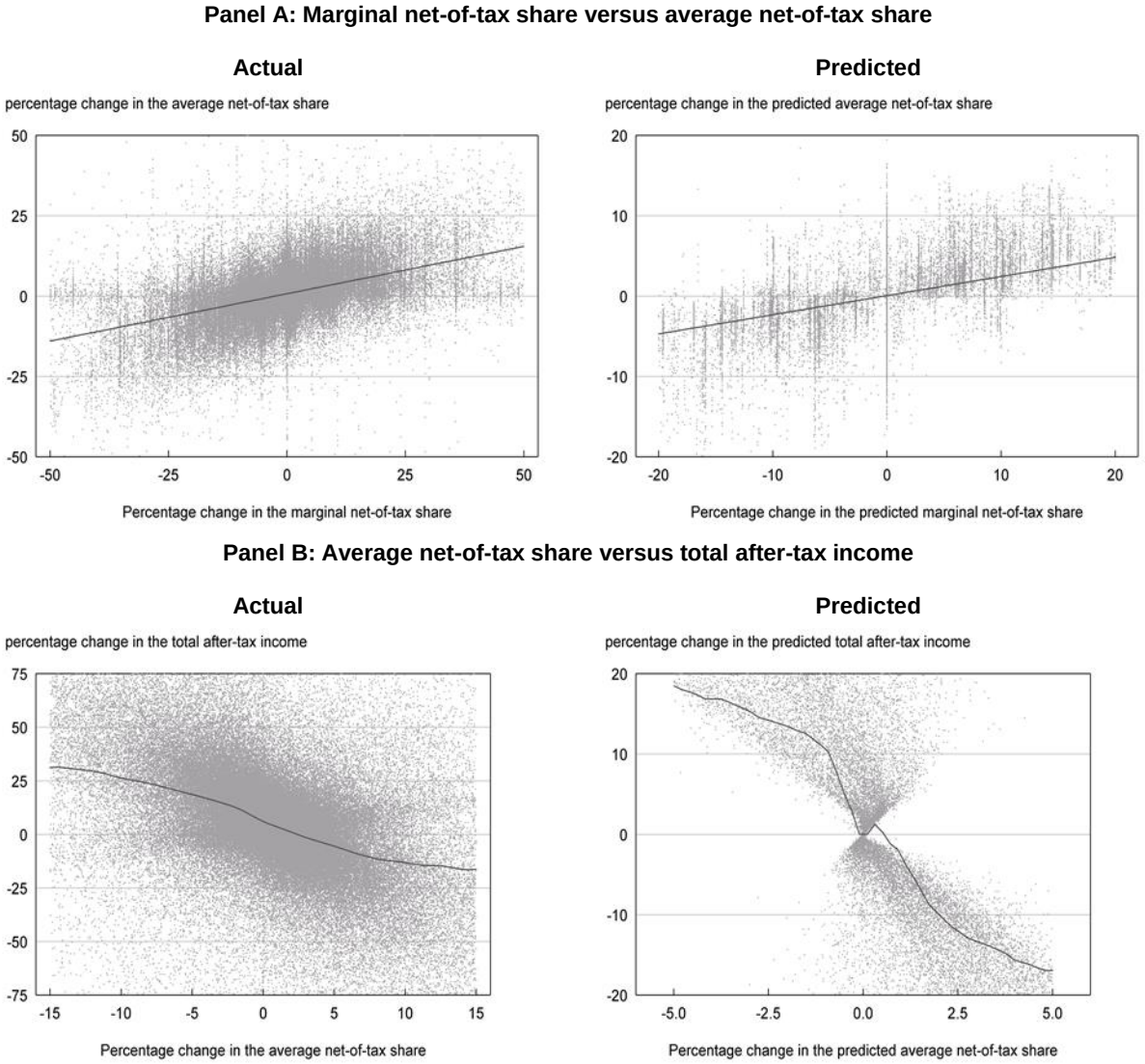
For expositional purposes, an encompassing test is also performed for the extensive-margin analysis. The corresponding statistical model in this case is the following:

$$\begin{aligned}\Delta 1\left(z_{it} > 0\right) = {} & \iota_1 + \vartheta_1 \Delta \ln\left(1-\tau_{it}\right) + \vartheta_1^a \Delta \ln\left(1-\tau_{it}^a\right) + \kappa_1 \Delta \ln\left(Y_{it} - T_{it}\right) + \mu_1 \Delta 1\left(z_{st} > 0\right) \\ & + X_{it}^{'} \phi_1 + f\left[\ln\left(z_{i,t-1}\right)\right] + \varrho_{it}\end{aligned} \tag{11}$$

The encompassing test of an extensive-margin response serves as a useful placebo test of whether individuals may respond to changes in their average tax rates as a proxy for their marginal rates, or whether this is simply due to an income effect of the tax reform given that $\Delta \ln\left(1-\tau_{it}^a\right)^{IV}$ and $\Delta \ln\left(Y_{it} - T_{it}\right)^{IV}$ are correlated. Since the theoretical framework predicts that individuals only respond meaningfully to changes in their total after-tax income along the extensive margin, the expectation is that $\hat{\vartheta}_1 = \hat{\vartheta}_1^a = 0$ and $\hat{\kappa}_1 < 0$. In contrast, if $\Delta \ln\left(1-\tau_{it}^a\right)^{IV}$ captures an income effect, the likely outcome in this case is $\hat{\vartheta}_1 = 0$ and $\hat{\vartheta}_1^a, \hat{\kappa}_1 < 0$.

The results from Equation (10) are shown in Panel A of Table 5. These findings indicate that individuals are very responsive to contemporaneous changes in their average—not their marginal—tax rates. For each 1% increase in the average net-of-tax share, labour income is estimated to increase by approximately 0.421% in the preferred model specification. In contrast, the marginal net-of-tax share and total after-tax income continue to be insignificant determinants of labour earnings, consistent with the previous section's findings. Ito (2014) posits for the case of domestic electricity consumption that individuals may initially respond to the average price, but then start to use the lagged marginal price as this information becomes available over time. In this setting, Table 5 finds no evidence of a delayed responsiveness in $\Delta \ln\left(z_{i,t+1}\right)$ to either the marginal or average net-of-tax share, although an increase in total after-tax income does (weakly) induce a reduction in labour earnings in the next period, which is consistent with the initial expectation that $\hat{\gamma}_0 < 0$ from the previous section.

Figure 3
The relationship between the changes in the actual and predicted tax variables



Notes: The relationship between the change in the marginal net-of-tax share relative to the change in the average net-of-tax share (Panel A) and between the change in the average net-of-tax share relative to the change in total after-tax income (Panel B) are shown, for both the actual and predicted tax variables. Each dot corresponds to a unique observation. The kernel-weighted local polynomial smoothing of these relationships are also shown. The predicted measures maintain the same basic relationships as the actual measures, but are less noisy.
Source: Statistics Canada, Longitudinal Administrative Databank.

Panel B of Table 5 shows the results from the extensive-margin analysis of Equation (11). Notably, in the preferred model specification that controls for income effects of the tax reform, changes in the marginal and average net-of-tax shares are both insignificant predictors of contemporaneous changes in labour market participation, as expected. This provides additional support for the notion that individuals respond to changes in their average tax rates along the intensive margin as a proxy for their marginal rates and not simply because of income effects resulting from the reform. The results for an initial response also continue to indicate that each 1% increase in total after-tax income reduces the likelihood of being employed, in this case by an average of 1.5 percentage points, the implied elasticity being -0.024%. However, the assessment of a delayed response shows that increases in the average net-of-tax share and total after-tax income both reduce the likelihood that individuals are employed in the next period, suggesting that

individuals may use the average tax rate as a measure of the reform's income effect in a lagged context. This finding partly supports modelling employment as a function of the average net-of-tax share, which is an approach that has been used in related studies (Eissa and Hoynes 2004; Gelber and Mitchell 2012).

Table 5
Encompassing tests—Labour income and employment responses to changes in the marginal versus average net-of-tax shares

	Initial timing of response, net-of-tax shares				Delayed timing of response, net-of-tax shares			
	Marginal	Average	Marginal and average	Marginal and average	Marginal	Average	Marginal and average	Marginal and average
	coefficient estimates							
Panel A: Intensive margin								
Marginal net-of-tax share	1.004 ***	…	0.573 ***	-0.112	-0.276 ***	…	-0.178	-0.122
Average net-of-tax share	…	1.838 ***	1.293 ***	0.421 **	…	-0.457 ***	-0.288 †	-0.208
Total after-tax income	…	…	…	0.028	…	…	…	-0.134 †
Panel B: Extensive margin								
Marginal net-of-tax share	0.202 ***	…	0.145 ***	0.011	-0.033 **	…	-0.018	-0.019
Average net-of-tax share	…	0.148 ***	0.104 ***	-0.005	…	-0.033 ***	-0.028 ***	-0.028 **
Total after-tax income	…	…	…	-0.015 ***	…	…	…	-0.006 *

… not applicable

* significantly different from reference category ($p < 0.05$)

** significantly different from reference category ($p < 0.01$)

*** significantly different from reference category ($p < 0.001$)

† significantly different from reference category ($p < 0.10$)

Notes: The covariates listed in the notes of Tables 2, 3 and 4 are included in every regression. Standard errors are clustered by individual. The number of observations is 178,064 for the intensive-margin analysis and 527,286 for the extensive-margin analysis.

Source: Statistics Canada, Longitudinal Administrative Databank.

5 Intra-household effects

The extent to which changes in the tax liabilities of spouses have spillover effects on the employment and labour income decisions of individuals is investigated in this section. More precisely, based on the comparative statics of Equations (2) and (3) derived in the theoretical framework, this section estimates whether individuals respond directly to: 1) changes in their spouses' total after-tax income, which affect the household budget set (a cross-spouse income effect); and 2) changes in their spouses' employment and labour income decisions (a cross-spouse labour effect). This analysis is important because the labour supply decisions of older workers may be codependent, and the pension income splitting reform is known to have had different effects on the tax liabilities of individuals and spouses.

5.1 Test of cross-spouse income effects

This analysis estimates whether individuals respond equally to changes in their own total after-tax income and to the after-tax income of their spouses, as predicted by the unitary model. To this end, variants of Equations (5) and (6) are estimated, given by:

$$\begin{aligned}\Delta \ln\left(z_{it}\right) = {} & \alpha_2 + \beta_2^a \Delta \ln\left(1-\tau_{it}^a\right) + \gamma_2 \Delta \ln\left(Y_{it}-T_{it}\right) + \delta_2 \Delta \ln\left(Y_{st}-T_{st}\right) + \zeta_2 \Delta \ln\left(z_{st}\right) \\ & + X_{it}^{'}\theta_2 + f\left[\ln\left(z_{i,t-1}\right)\right] + \varepsilon_{it}\end{aligned} \tag{12}$$

$$\begin{aligned}\Delta 1\left(z_{it}>0\right) = {} & \iota_2 + \kappa_2 \Delta \ln\left(Y_{it}-T_{it}\right) + \lambda_2 \Delta \ln\left(Y_{st}-T_{st}\right) + \mu_2 \Delta 1\left(z_{st}>0\right) \\ & + X_{it}^{'}\phi_2 + f\left[\ln\left(z_{i,t-1}\right)\right] + \varphi_{it}\end{aligned} \tag{13}$$

Intuitively, the test for a cross-spouse income effect is carried out by directly inserting the variable for the change in the spouse's log of total after-tax income into the estimating equation to determine its significance. As before, to credibly identify the effects of the endogenous regressors, the instruments $\Delta \ln\left(1-\tau_{it}^a\right)^{IV}$, $\Delta \ln\left(Y_{it}-T_{it}\right)^{IV}$ and $\Delta \ln\left(Y_{st}-T_{st}\right)^{IV}$ are used in a 2SLS approach. While pension income splitting mechanically shifts the total after-tax incomes of individuals and spouses in opposite directions, these effects are separately identified within couples since the percentage changes in total after-tax income depend on the initial (pre-reform) levels of pension and total income. Note that the average rather than the marginal net-of-tax share is used in Equation (12) based on the results in the previous section. The unitary model predicts that individuals respond equally to changes in their own as well as their spouses' tax liabilities, hence the expectation is that $\hat{\gamma}_2 = \hat{\delta}_2$ from Equation (12), and $\hat{\kappa}_2 = \hat{\lambda}_2$ from Equation (13).

The results of this analysis are shown in Table 6 based on the OLS and IV (reduced-form and 2SLS) estimators. Notice that this analysis is carried out separately across individuals (Panel A) and their spouses (Panel B), where "individuals" are the taxfilers observed in the data and "spouses" are the taxfilers matched to those individuals with whom they are married or in a common-law relationship. Since the unit of taxation in Canada is the individual, and taxfilers are randomly selected into the LAD dataset, individuals and spouses should exhibit roughly symmetric cross-spouse responses to the tax reform despite the fact that the reform is known to have had opposite effects on each spouse's total after-tax income, as shown in Charts 1 and 2.

Table 6
Tests of cross-spouse income effects

	Ordinary least squares	Instrumental variables: Reduced form	Instrumental variables: Two-stage least squares
		coefficient estimates	
Panel A: Responses of individuals to changes in the couples' total after-tax incomes			
Intensive margin			
Individual's average net-of-tax share	-1.537 ***	0.336 *	0.409 *
Individual's total after-tax income	0.497 ***	-0.007	0.031
Spouse's total after-tax income	-0.052 ***	-0.041 †	-0.076 *
Extensive margin			
Individual's total after-tax income	0.044 ***	-0.018 ***	-0.023 ***
Spouse's total after-tax income	-0.002 ***	-0.014 ***	-0.018 ***
Panel B: Responses of spouses to changes in the couples' total after-tax incomes			
Intensive margin			
Spouse's average net-of-tax share	-3.215 ***	0.468 †	0.913 *
Spouse's total after-tax income	0.408 ***	0.013	0.121
Individual's total after-tax income	-0.032 ***	-0.052 *	-0.117 **
Extensive margin			
Spouse's total after-tax income	0.044 ***	-0.016 ***	-0.021 ***
Individual's total after-tax income	-0.001 †	-0.013 ***	-0.017 ***

* significantly different from reference category (p < 0.05)
** significantly different from reference category (p < 0.01)
*** significantly different from reference category (p < 0.001)
† significantly different from reference category (p < 0.10)

Notes: The covariates listed in the notes of Tables 2, 3 and 4 are included in every regression, as well as a 10-piece spline in the one-period lagged value of the log of the spouse's labour income. Standard errors are clustered by individual. The number of observations is 178,064 for the intensive-margin analysis and 527,286 for the extensive-margin analysis.
Source: Statistics Canada, Longitudinal Administrative Databank.

The findings indicate, first, that individuals' and spouses' labour incomes respond meaningfully to exogenous changes in their own average net-of-tax shares, but not to changes in their own total after-tax incomes, consistent with the results presented in Section 4. In addition, large cross-spouse responses are observed: each 1% increase in total after-tax income leads to a decrease in the other spouse's labour earnings of approximately 0.076% to 0.117% on average. Hence, older workers' intensive-margin decisions are influenced by changes in their own average tax rates, and by changes in disposable income at the household level brought on by their spouses. These results are quite robust given that they are qualitatively similar across panels, as expected.

Table 6 also shows that there are large cross-spouse effects of a tax reform along the extensive margin. For individuals, a 1% increase in their own and their spouses' total after-tax incomes reduces the likelihood of being employed by 2.3 and 1.8 percentage points; implied elasticities are -0.037 and -0.029, respectively. These findings are again similar for spouses. Importantly, while the own elasticity is only approximately 20% larger than the cross-spouse elasticity for both individuals and spouses, a test of equality rejects that they are equal (p=0.014 in Panel A, and p=0.022 in Panel B). As a result, the prediction of income pooling based on the unitary model is rejected (this finding is consistent with that of Gelber [2014]), although it is interesting to note that the own and cross-spouse elasticities are at least qualitatively similar.

5.2 Test of cross-spouse labour effects

The comparative statics in Subsection 2.2 show that a spouse's marginal net-of-tax share is a valid excluded instrument for estimating how a change in the labour income of the spouse affects an individual's employment and labour income decisions, provided that the spouse's tax rate varies exogenously. This is true because the marginal income tax rate of each spouse is only levied on that spouse's income, since the unit of taxation in Canada is the individual. With this in mind, the following variants of Equations (5) and (6) are estimated:

$$\begin{aligned}\Delta \ln\left(z_{it}\right) = \alpha_3 + \beta_3^a \Delta \ln\left(1-\tau_{it}^a\right) + \gamma_3 \Delta \ln\left(Y_{it}-T_{it}\right) + \delta_3 \Delta \ln\left(Y_{st}-T_{st}\right) + \zeta_3 \Delta \ln\left(z_{st}\right) \\ + X_{it}^{'}\theta_3 + f\left[\ln\left(z_{i,t-1}\right)\right] + \omega_{it}\end{aligned} \tag{14}$$

$$\begin{aligned}\Delta 1\left(z_{it}>0\right) = \iota_3 + \kappa_3 \Delta \ln\left(Y_{it}-T_{it}\right) + \lambda_3 \Delta \ln\left(Y_{st}-T_{st}\right) + \mu'_3 \Delta \ln\left(z_{st}\right) \\ + X_{it}^{'}\phi_3 + f\left[\ln\left(z_{i,t-1}\right)\right] + \chi_{it}\end{aligned} \tag{15}$$

To obtain causal estimates of the effects of interest, namely ζ_3 and μ'_3, the change in the spouse's predicted net-of-tax share is used as the instrumental variable for $\Delta \ln\left(z_{st}\right)$ in a 2SLS approach. While the theory indicates that the marginal tax rate should be used, the encompassing test of Subsection 4.2 suggests the average tax rate should be used in its place. Thus, the results will be shown using both $\Delta \ln\left(1-\tau_{st}\right)^{IV}$ and $\Delta \ln\left(1-\tau_{st}^a\right)^{IV}$ as the excluded instrument, although the results do not differ meaningfully in either case. Based on the model, the expectation is that individuals compensate for an exogenous decline in their spouses' labour income by working more, and vice versa, such that $\hat{\xi}_3, \hat{\mu}_3^{'} < 0$.

Several features of these model specifications are important to mention. In Equation (14), the preferred specification uses the average net-of-tax share, although the marginal tax rate is used when $\Delta \ln\left(1-\tau_{st}\right)^{IV}$ is used as the excluded instrument. As before, this analysis conditions on observations where both individuals and their spouses have strictly positive labour income. In Equation (15), the parameter μ'_3 captures the effect of a change in the labour income of the spouse on the individual's labour market participation, and is conditional on the spouse being employed. This restriction is necessary to ensure the spouse's net-of-tax share is a valid excluded instrument based on the prediction from the theoretical framework. Lastly, as in Subsection 5.1, the analysis is repeated to assess whether there is symmetry of the findings across individuals and spouses, in this case using $\Delta \ln\left(1-\tau_{it}\right)^{IV}$ as the excluded instrument.

The results of this analysis are shown in Table 7, for both individuals (Panel A) and spouses (Panel B). In both cases, the OLS regressions indicate that there is a significant positive correlation between the labour incomes of individuals and their spouses, which likely occurs as a result of positive assortative matching. In contrast, the intensive-margin 2SLS regressions indicate that each 1% change in one spouse's labour income induces the other spouse to reduce their labour income by approximately 1.008% to 1.567%, a finding that is quite robust both across spouses and the choice of excluded instrument. The sign and magnitude of this result are both consistent with expectations from the model. Moreover, the extensive-margin analysis indicates that there are large cross-spouse income effects of a tax reform on the labour market participation decisions of individuals—the implied elasticity of employment to the spouse's labour income is approximately -0.636% to -0.196%.

Table 7
Tests of cross-spouse labour effects

Excluded instrument	Ordinary least squares	Two-stage least squares: Marginal net-of-tax share	Two-stage least squares: Average net-of-tax share
		coefficient estimates	
Panel A: Responses of *individuals* to changes in spouses' labour income			
Intensive margin			
Spouse's labour income	0.114 ***	-1.152 ***	-1.567 ***
Extensive margin			
Spouse's labour income	0.007 ***	-0.388 ***	-0.123 ***
Panel B: Responses of *spouses* to changes in individuals' labour income			
Intensive margin			
Individual's labour income	0.107 ***	-1.008 ***	-1.506 ***
Extensive margin			
Individual's labour income	0.007 ***	-0.398 ***	-0.206 ***

*** significantly different from reference category (p < 0.001)

Notes: The covariates listed in the notes of Tables 2, 3 and 4 are included in every regression, as well as a 10-piece spline in the one-period lagged value of the log of the spouse's labour income. For the two-stage least squares regressions, the estimates in the second column have been derived using the marginal net-of-tax share as the excluded instrument, and the estimates in the third column have been derived using the average net-of-tax share. Standard errors are clustered by individual. The number of observations is 178,064 for the intensive-margin analysis, and the numbers of observations are 259,915 and 265,470 for the extensive-margin analyses in Panels A and B, respectively. In Panel A, the F- statistics of excluded instruments from the first-stage instrumental variables regressions are: 1) 111.51 and 210.34 for the intensive margin using the marginal and average net-of-tax shares as excluded instruments, respectively; and 2) 198.43 and 503.07 for the extensive margin using the marginal and average net-of-tax shares. The corresponding F-statistics in Panel B are 1) 157.19 and 40.72 for the intensive margin using the marginal and average net-of-tax shares; and 2) 343.52 and 142.33 for the extensive margin using the marginal and average net-of-tax shares.
Source: Statistics Canada, Longitudinal Administrative Databank.

Lastly, Table 8 carries out the tests of cross-spouse income and labour effects for various subsamples to test for heterogeneity by sex, income, and family composition. Several findings are noteworthy. In the intensive-margin analysis of Panel A, men appear more responsive than women to changes in their tax rates and the tax liabilities of their spouses, whereas women respond more to changes in the labour income of their spouses. Tax responses are also robust across income groups and appear to be primarily driven by the middle of the income distribution, whereas cross-spouse labour responses are the largest among high-income households. Couples without children residing in the household are the most responsive to changes in their average tax rates, whereas those with children exhibit the largest cross-spouse income and labour effects. This finding may arise because households without children are less financially constrained and are, therefore, able to adjust their labour supply in response to price incentives, whereas those with children make labour decisions in a manner that is most consistent with the model.

Along the extensive margin shown in Panel B, the results continue to indicate that women are more responsive than men to cross-spouse labour effects. In this case, however, income effects of a tax reform have the largest effect on the labour market participation of older workers from high-income households, which may arise because these workers are the most likely to be able to afford to retire early. The results are also similar across couples with and without children. Overall, the results of this heterogeneity analysis are generally consistent with the primary findings, and are quite robust and symmetric across both individuals and spouses.

Table 8
Heterogeneous responses

	Individuals' cross-spouse effect on				Spouses' cross-spouse effect on			
	Income			Labour	Income			Labour
Endogenous regressor	Individual's average net-of-tax share	Individual's total after-tax income	Spouse's total after-tax income	Spouse's labour income	Spouse's average net-of-tax share	Spouse's total after-tax income	Individual's total after-tax income	Individual's labour income
	coefficient estimates							
Panel A: Intensive margin								
Sex								
Female	0.186	0.121 *	0.184 †	-1.900 ***	-0.343	0.079	0.234 *	-2.011 ***
Male	2.068	0.260	-0.221 ***	-1.496 ***	3.696 *	0.441	-0.328 ***	-1.269 ***
Household income								
Top 50 percent	-0.526	-0.136	-0.053	-2.208 ***	-1.522	-0.342	-0.089	-1.670 ***
Top 75 percent	0.546 *	0.062	-0.101 *	-1.710 ***	0.412	0.039	-0.113 *	-1.539 ***
Top 90 percent	0.529 *	0.044	-0.100 **	-1.565 ***	0.944 †	0.135	-0.105 *	-1.518 ***
Exclude top 5 percent	0.425 *	0.042	-0.069 †	-1.501 ***	0.981 *	0.131	-0.119 **	-1.539 ***
Exclude top 10 percent	0.426 **	0.011	-0.086 **	-1.482 ***	1.315 **	0.173 *	-0.150 ***	-1.538 ***
Family composition								
Has children	0.104	-0.167 †	-0.168 **	-1.840 ***	-0.337	-0.111	-0.202 **	-1.264 ***
No children	0.666 **	0.136 †	-0.048	-1.476 ***	1.293 **	0.179 †	-0.083	-1.629 ***
Panel B: Extensive margin								
Sex								
Females	…	-0.014 ***	0.023 **	-0.267 ***	…	-0.016 ***	0.010	-0.378 ***
Males	…	-0.013	-0.019 ***	-0.038 †	…	-0.026 **	-0.021 ***	-0.129 ***
Household income								
Top 50 percent	…	-0.023 ***	-0.037 ***	-0.035	…	-0.026 ***	-0.040 ***	-0.125 ***
Top 75 percent	…	-0.025 ***	-0.022 ***	-0.108 ***	…	-0.025 ***	-0.022 ***	-0.193 ***
Top 90 percent	…	-0.024 ***	-0.018 ***	-0.125 ***	…	-0.022 ***	-0.017 ***	-0.210 ***
Exclude top 5 percent	…	-0.023 ***	-0.017 ***	-0.126 ***	…	-0.021 ***	-0.016 ***	-0.216 ***
Exclude top 10 percent	…	-0.022 ***	-0.016 ***	-0.139 ***	…	-0.022 ***	-0.015 ***	-0.232 ***
Family composition								
Has children	…	-0.024 ***	-0.024 ***	-0.047 ***	…	-0.027 ***	-0.022 ***	-0.057 ***
No children	…	-0.022 ***	-0.016 ***	-0.073 ***	…	-0.019 ***	-0.015 ***	-0.066 ***

… not applicable

* significantly different from reference category ($p < 0.05$)

** significantly different from reference category ($p < 0.01$)

*** significantly different from reference category ($p < 0.001$)

† significantly different from reference category ($p < 0.10$)

Notes: The covariates listed in the notes of Tables 2, 3 and 4 are included in every regression, as well as a 10-piece spline in the one-period lagged value of the log of the spouse's labour income. Standard errors are clustered by individual. The bottom column headers show the endogenous regressors being instrumented. The number of observations is 178,064 for the intensive-margin analysis and 527,286 for the extensive-margin analysis.

Source: Statistics Canada, Longitudinal Administrative Databank.

6 Conclusion

This paper assesses the extent to which the labour decisions of older workers respond to policy-induced variation in effective income tax rates, in Canada. To credibly identify these effects, the analysis exploits exogenous variation in tax rates following a recent reform that reduced the income tax liabilities of older couples by permitting pensioners to split this income with their spouses, using an instrumental variables design. The results show that older workers are very responsive to changes in taxes in terms of both their employment and labour income adjustments. However, in contrast with standard predictions, workers respond to changes in their average—not their marginal—tax rates. The compensated elasticities of taxable labour income with respect to the average and marginal net-of-tax shares are estimated to be 0.421 and -0.112, respectively, of which only the former is statistically significant.

An explanation for this result is that the individuals use the average price of labour as a proxy for the marginal price given that the income tax schedule in Canada is complex and may be difficult to understand (Liebman and Zeckhauser 2004). Given that the marginal tax rate generally exceeds the average tax rate due to progressivity, this finding suggests that workers oversupply labour at older ages because of tax illiteracy as they are not taking their true marginal costs of working into account properly. This finding also raises questions about the extent to which the weak responsiveness to income taxes found in related studies of young and middle-aged workers can also be explained by low tax salience, this being an important issue for future research.

In addition, individuals appear responsive to variation in household income resulting from changes in the tax liabilities and earnings of their spouses following a tax reform. This result is sensible in the context of this study given that income splitting necessarily involves some collaboration and tax planning between spouses. While the test of cross-spouse income effects rejects the income pooling prediction of the unitary model of labour supply, individuals and spouses nonetheless still take changes in each other's incomes into account when making their own employment decisions, which is qualitatively consistent with expectations. These findings provide new insight into intra-household labour supply.

Appendix

Derivations of $\frac{dz_i^*}{d\left(1-\tau_i\right)}$ and $\frac{dz_i^*}{d\left(1-\tau_s\right)}$

The optimal levels of income $\left\{z_i^*, z_s^*\right\}$ are given by:

$$z_i^*, z_s^* \in \arg\max_{z_i, z_s} \lambda u^i\left(c, z_i, z_s; \psi_i\right) + \left(1-\lambda\right) u^s\left(c, z_i, z_s; \psi_s\right) \tag{16}$$

where $c = z_i\left(1-\tau_i\right) + z_s\left(1-\tau_s\right) + R$. Given z_s, the first-order condition to this optimization problem with respect to z_i is:

$$\lambda\left(u_c^i\left(1-\tau_i\right) + u_{z_i}^i\right) + \left(1-\lambda\right)\left(u_c^s\left(1-\tau_i\right) + u_{z_i}^s\right) = 0 \tag{17}$$

To derive the effect of a change in the marginal net-of-tax share on the taxable labour income of the individual, totally differentiate Equation (17) with respect to $\left(1-\tau_i\right)$ and evaluate at $\left\{z_i^*, z_s^*\right\}$ per the envelope condition, then solve for $dz_i^* / d\left(1-\tau_i\right)$ to obtain:

$$\begin{aligned}\frac{dz_i^*}{d\left(1-\tau_i\right)} = &-\frac{1}{\upsilon\left(1-\tau_i\right)+\psi}\left(\lambda u_c^i + \left(1-\lambda\right)u_c^s\right) - \frac{\upsilon}{\upsilon\left(1-\tau_i\right)+\psi}\left(z_i^* + \frac{dR}{d\left(1-\tau_i\right)}\right) \\ &- \frac{\upsilon\left(1-\tau_s\right)+\omega}{\upsilon\left(1-\tau_i\right)+\psi}\left(\frac{dz_s^*}{d\left(1-\tau_i\right)}\right)\end{aligned} \tag{18}$$

and,

$$\upsilon = \lambda\left(u_{cc}^i\left(1-\tau_i\right) + u_{z_i c}^i\right) + \left(1-\lambda\right)\left(u_{cc}^s\left(1-\tau_i\right) + u_{z_i c}^s\right)$$

$$\psi = \lambda\left(u_{cz_i}^i\left(1-\tau_i\right) + u_{z_i z_i}^i\right) + \left(1-\lambda\right)\left(u_{cz_i}^s\left(1-\tau_i\right) + u_{z_i z_i}^s\right)$$

$$\omega = \lambda\left(u_{cz_s}^i\left(1-\tau_i\right) + u_{z_i z_s}^i\right) + \left(1-\lambda\right)\left(u_{cz_s}^s\left(1-\tau_i\right) + u_{z_i z_s}^s\right)$$

denote $\Gamma = \upsilon / \left(\upsilon\left(1-\tau_i\right)+\psi\right)$, $\Theta = \left(\upsilon\left(1-\tau_s\right)+\omega\right) / \left(\upsilon\left(1-\tau_i\right)+\psi\right)$, and $\Omega = -1 / \left(\upsilon\left(1-\tau_i\right)+\psi\right)$. Based on the assumptions imposed on the utility function, $\Gamma > 0$, $\Theta > 0$, and $\Omega > 0$. Substituting these terms into Equation (18) gives Equation (2), as desired.

To solve for Equation (3), totally differentiate Equation (17) with respect to $\left(1-\tau_s\right)$ and solve for $dz_i^* / d\left(1-\tau_s\right)$. The derivation is the same as above, except that the first term on the right-hand side of Equation (18) is not present.

Separately identifying $\Delta\ln\left(1-\tau_{jt}\right)$, $\Delta\ln\left(1-\tau_{jt}^{a}\right)$ and $\Delta\ln\left(Y_{jt}-T_{jt}\right)$

The predicted marginal tax rate, $\left(1-\tau_{jt}\right)^{IV}$, is separately identified from the other two predicted tax variables given the nonlinearity (convexity) of the tax schedule, due to progressivity. For the remaining two variables, note that the percentage change in the predicted total after-tax income, $\left(Y_{jt}-T_{jt}\right)^{IV}$, can be expressed algebraically as follows:

$$\%\Delta\left(Y_{jt}-T_{jt}\right)^{IV}=\frac{\left(\hat{Y}_{jt}-T\left(\hat{\Psi}_{jt};\pi_{t+1},\tilde{\Pi}_{t}\right)\right)-\left(Y_{jt}-T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)\right)}{\left(Y_{jt}-T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)\right)}$$

$$=\frac{\left(\frac{\hat{Y}_{jt}}{Y_{jt}}-\frac{T\left(\hat{\Psi}_{jt};\pi_{t+1},\tilde{\Pi}_{t}\right)}{Y_{jt}}\right)-\left(\frac{Y_{jt}}{Y_{jt}}-\frac{T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)}{Y_{jt}}\right)}{\left(\frac{Y_{jt}}{Y_{jt}}-\frac{T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)}{Y_{jt}}\right)}$$

$$=\frac{\left(\frac{\hat{Y}_{jt}}{Y_{jt}}-\frac{T\left(\hat{\Psi}_{jt};\pi_{t+1},\tilde{\Pi}_{t}\right)}{Y_{jt}}\right)-\left(1-\frac{T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)}{Y_{jt}}\right)}{\left(1-\frac{T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)}{Y_{jt}}\right)}$$

The percentage change in the predicted average net-of-tax share, $\left(1-\tau_{jt}^{a}\right)^{IV}$, is expressed algebraically as follows:

$$\%\Delta\left(1-\tau_{it}^{a}\right)^{IV}=\frac{\left(1-\frac{T\left(\hat{\Psi}_{jt};\pi_{t+1},\tilde{\Pi}_{t}\right)}{\hat{Y}_{jt}}\right)-\left(1-\frac{T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)}{Y_{jt}}\right)}{\left(1-\frac{T\left(\Psi_{jt};\pi_{t},\tilde{\Pi}_{t}\right)}{Y_{jt}}\right)}$$

Hence, $\%\Delta\left(1-\tau_{it}^{a}\right)^{IV}\neq\%\Delta\left(Y_{jt}-T_{jt}\right)^{IV}$ on average. These two predicted variables are separately identified in this environment, as desired.

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