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On the Marginal Excess Burden of Taxation in an Overlapping Generations Model*

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Abstract

We quantify marginal excess burden, defined as the change in deadweight loss for an additional dollar of tax revenue, for different taxes. We use a dynamic general equilibrium, overlapping generations model featured with heterogeneous agents and a realistic structure of corporate finance and taxes. Our main results, based on an economy calibrated to Australian data, indicate that company taxes are more distorting than personal income and consumption taxes. Specifically, the marginal excess burden for the company income tax is 83 cents per dollar of tax revenue raised, compared to 34 cents and 24 cents for the personal income and consumption taxes, respectively. A broader analysis of more tax instruments confirm that the relatively larger excess burden of company taxes ultimately falls on households. Importantly, the marginal excess burden is distributed unevenly across skill types, generations and ages. This highlights political challenges when obtaining popular support for raising taxes. Hence, our analysis demonstrates that marginal excess burden can be an useful tool for evaluating both efficiency and distributional implications of a tax increase at the margin.

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Keywords: Taxation, fiscal distortion, overlapping generations, skill heterogeneity, corporate finance, deadweight loss, dynamic general equilibrium, welfare

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1 Introduction

The projections for many OECD economies indicate that they are heading into eras of fiscal stress with rising public debt relative to GDP (e.g., see IMF (2010) and Cecchetti, Mohanty and Zampolli (2010)). It is likely that governments will have to raise taxes to finance their existing spending commitments and to service increasing debt. A major concern of raising taxes is the distortions they create. This leads to a number of questions: How to assess welfare losses due to the adverse effects of tax increases on economic activities? Which tax results in the lowest welfare cost per dollar of additional revenue? And, who bears the welfare losses under different taxes?

In this paper we address these important questions by quantifying marginal excess burden (MEB), defined as the total welfare loss associated with one dollar of additional tax revenue, for different taxes in a dynamic general equilibrium, overlapping generations model with heterogeneous agents. We primarily examine three different taxes: company income tax, personal income tax and consumption tax. In our extension, we analyse a broader range of tax instruments imposed on households and firms. Our main goal is to better understand the deadweight loss of a tax increase at the point defined by the current tax system, and the distribution of deadweight loss across households and over time.

The marginal excess burden (MEB) analysis has been used extensively to evaluate the efficiency of the tax system in the public finance literature (see Auerbach and Hines (2002) for a review). In a static framework, the excess burden of taxation is commonly measured by the area of the associated 'Harberger triangle' (e.g., see Harberger (1964), Hausman (1981) and Hines (1999)). Intuitively, the base of the Harberger triangle measures the amount by which economic behaviour changes as a result of price distortions introduced by taxes. The MEB analysis computes the deadweight loss taken of a tax increase at the point defined by the current tax legislation. It therefore can provide local information; that is, welfare cost of a marginal tax increase. The MEB analysis is related to the theory of optimal taxation. However, it differs both in its approach and the underlying question it answers.

The theory of optimal taxation aims to characterize which tax system should be chosen to maximize a social welfare function subject to a set of constraints. The optimal taxation literature usually makes a normative choice on a social welfare function, which aggregates the utility of individual households. The optimality of a particular tax system depends on this choice of social welfare function (e.g., see Fehr and Kindermann (2015)). The optimal tax analysis provides global information on the "best" tax system. Conversely, MEB burden analysis measures the marginal welfare loss at current policy settings. Under MEB analysis each tax is examined in isolation. The optimal tax analysis provides limited information on current policy settings or the impacts of individual taxes. The MEB analysis can fill in this gap. A measure of the distortion of current policy settings can act as motivator of policy reform while optimal analysis provides insights of what a reform package should look like. Thus, the MEB and optimal tax analyses provide complementary information.

We depart from the previous literature and formulate a dynamic general equilibrium, overlapping generations (OLG) model with heterogenous agents. The model consists of different households, a perfectly competitive representative firm and a government sector. Households are of three skills types and enter the model at age 20 and potentially live to 100. They make decisions on consumption, labour supply and saving to maximise their lifetime utility. The households are forward looking and their decisions take into account flows of future after-tax incomes and the need for retirement savings. On the production side, there is a representative firm that produces output with its owned capital and labour rented from the labour market. The firm chooses investment to optimise its market value taking into account future profits and the structure of corporate finance and taxes. The firm can use retained profits or issue debt or equity to finance its investment plan. The firm pays returns to debt and equity holders. The government collects taxes to finance two government spending programs: government consumption and transfers to households.

We discipline the benchmark model to match data from Australia. Our model matches key patterns of life-cycle behaviour and essential features of the Australian macroeconomy in the 2010s. We first quantify the marginal excess burdens for three major taxes in Australia: Company Income Tax (CIT), Personal Income Tax (PIT) and Consumption Tax (CT).

Measuring marginal excess burden is more complex in a dynamic general equilibrium framework since the Harberger triangle is not well defined. To get around this issue we follow Judd (1987) and use Hicksian equivalent variation to measure the excess burden. More specifically, we compute it in two steps. We first compute the equivalent variation for all households over the transition path and in the new steady state. These specific excess burdens are a measure of welfare costs that individual households bear after raising taxes. Next, we construct a metric of the aggregate marginal excess burden in terms of the net present value of the excess welfare losses by all households normalised by dividing by the net present value of the change in net revenue. We call this metric the aggregate marginal excess burden (AMEB). In the baseline scenarios, only one tax rate is changed and the government budget is balanced by returning the additional revenue back to households via uniform lump sum transfers.[1] Technically, the AMEB measures the total

[1] It is important to note that the MEB analysis conducted here uses scenarios that each raise net revenue by the equivalent of one dollar per period in net present value terms. As the revenue change is uniform the impacts are directly comparable. Only one tax change is varied in each scenario which

distortion of the particular tax relative to a lump sum tax at the point defined by the current tax system. Moreover, in our heterogenous agents model it is straightforward to compute disaggregated MEB by household characteristics.

Our main results are as follows. First, we find that the marginal excess burden for the company income tax is 83 cents per dollar of tax revenue collected, which is much higher than 34 cents and 24 cents found for the personal income tax and the consumption tax, respectively. This finding indicates that the company income tax results in the largest aggregate deadweight loss. The main reason is that foreign capital is highly mobile and therefore responsive to the company tax in a small open economy model. An increase in the company income tax discourages investment and subsequently decreases the capital stock, productivity and wages.

We show that the welfare losses are not evenly distributed as the marginal excess burden varies significantly across skill types, ages and generations. We find that over-65s, on average, are the biggest losers from a company tax increase. They lose less from increases in the personal income tax or the consumption tax. Lower-income households would be, on average, largely unaffected by a company tax hike. This occurs as the model assumes any extra revenue generated is re-distributed evenly via the transfer system to balance the budget, the loss of income from lower wages is offset by higher transfer. Further, low income households would be 32 cents better off under an income tax rise and 16 cents better off if the consumption tax increased again due to the additional transfers.

Moreover, we consider other tax instruments, including investment tax credits (ITC), depreciation deductions (DD), personal labour income tax (PLT) and personal asset income tax (PAT). We find that the taxes which are broadly considered as falling on capital result in higher marginal excess burden than the taxes on labor and consumption in our framework. The overall ranking is that reducing investment tax credits results in the highest marginal excess burden, while raising consumption tax causes the lowest marginal excess burden. Interestingly, even though a reduction in the investment tax credits has the highest welfare cost at the aggregate level the households alive at the time of the policy change are better off.

Finally, we consider different model specifications and calibration assumptions, including the openness of the economy, alternative methods to allocate additional tax revenue, the foreign ownership share, the role of fixed factors, franking credits, capital adjustment speed, economic growth, the intertemporal elasticity of substitution and the elasticity of labor supply. We find that our main results are fairly robust.

Thus, we demonstrate that the marginal excess burden is an effective index for com-

isolates the impacts of individual taxes. If the revenue increase were used to fund a cut in another non-lump sum tax then the impacts would be due to two changes and disentangling the effects would be more difficult.

paring the distortion of different taxes at the margin. It can be used to facilitate the comparison of a large number of taxes both in terms of aggregate distortions and distributional impacts. We show that both the aggregate marginal excess burden and the group-specific marginal excess burden are useful for understanding the efficiency and distributional effects of tax increases. Our result has implications for evaluating alternative designs of a tax reform plan. It indeed provides essential information for public policy debates around the 'best' option to raise tax revenue. Furthermore, a better understanding of the distribution of marginal excess burdens allows policy makers to put together a more feasible package of tax increases required to close fiscal gaps. Indeed, the marginal excess burden approach is particularly suited to improve communication between academics and policy makers and to bridge the gap between academic research and policy making.

Related literature

Our work is connected to several branches of the macroeconomic/public finance literature. First, our paper extends the large literature analysing the excess burden of taxation. The early work studies excess burden in a static framework (e.g., see Feldstein (1978), King (1983), Feldstein (1995), Fullerton and Henderson (1989), and Hines (1999)). Note that, these micro and empirical estimates of excess burden do not take into account dynamic changes in the labour and capital markets and general equilibrium price adjustments in response to tax increases. Auerbach, Kotlikoff and Skinner (1983), Chamley (1981) and Ballard, Shoven and Whalley (1985) extend the excess burden approach to general equilibrium frameworks. They concentrate on approximating the total excess burden of large tax changes. Judd (1985*a*) and Judd (1987) analyses the marginal excess burden of taxation using a representative agent model. In particular, Ballard, Shoven and Whalley (1985) find MEB estimates in the range of 18 to 46 cents for industry level capital tax and a range of 12 to 23 cents for industry level labour taxes. Judd (1985*b*) finds a MEB of 12 cents for labour income tax, 98 cents for a tax on dividends and interest payments, and -16 dollars for an investment tax credit. We deviate from the previous studies and formulate a dynamic general equilibrium with heterogenous agents and a realistic structure of corporate finance and taxes. We also take into account both long-run steady state effects and dynamic effects along the transition path. As a result, we find our MEB estimates are relatively larger. More importantly, our new modelling approach allows us to map out the distribution of marginal excess burdens across households. We show that deadweight losses of raising one additional revenue are heterogenous across households and over time.

Our work links the literature on the marginal excess burdens of taxes to the literature on the dynamic effects of taxes. Since Auerbach and Kotlikoff (1987) there is a large literature analysing aggregate and welfare effects of various tax schemes, using a large scale overlapping generations (OLG) models. Auerbach and Kotlikoff (1987) show that while replacing income tax with wage tax reduces efficiency, replacing income tax with consumption tax increases efficiency. Imrohoroglu (1998) finds that a positive capital income tax rate maximizes steady state welfare. In a similar environment, Ventura (1999) shows that the elimination of capital income taxation positively affects capital accumulation. Fuster, Imrohoroglu and Imrohoroglu (2007) study the effects of different revenue-neutral tax reforms that eliminate capital income taxation and show that the majority of the population alive at the time of the reform benefit from it in the dynastic framework. Conesa, Kitao and Krueger (2009) find that the optimal capital income tax rate is strictly positive at 36 percent in an overlapping generations economy with incomplete markets and heterogeneous agents. The policy experiments in this literature involves raising some taxes while lowering others to maintain a balanced government budget. As such changes in welfare are due to multiple tax changes and disentangling the impacts of each taxes is more difficult. We follow a similar OLG modelling approach and explicitly model corporate tax policy and how a firm optimally finances its investment plan. Differently, we quantify the economic cost of only one tax change at the margin. We demonstrate that understanding the impacts of tax increases at current state of tax policy settings, especially the distributional consequences, is important for policy making.

Assessing the marginal economic impacts of taxation has parallels to the literature on dynamic scoring of tax cuts. Mankiw and Weinzierl (2006) studies the extent to which a tax cut pays for itself through increased activity. Leeper and Yang (2008) emphasize the role of tax financing instruments when calculating the tax scoring. That literature is motivated by President Bush's early 2000s tax cuts in the United States. In the dynamic scoring literature, the dynamic revenue estimate takes the behavioural responses and general equilibrium adjustments into account. Dynamic scoring of a tax rate computes the derivative of the dynamic tax revenue taken at the point defined by the current tax legislation. The MEB approach is analogous to the dynamic scoring approach as it measures the effects at the margin. However, it focuses more on the economic cost of raising taxes. In our analysis, we can compare the static revenue increase required to raise an additional net dollar once the dynamic responses of agents and general equilibrium channels are taken into account. Furthermore, we go beyond revenue implications and map out marginal welfare costs for different households at the point defined by the current tax system.

Our paper contributes to the analysis of the Australian tax system. Several policy papers including Cao et al. (2015) apply the marginal excess burden approach to evaluate the efficiency cost of tax reforms in Australia, using static multi-industry computable general equilibrium (CGE) models. However, the CGE modelling approach lacks many important features as it abstracts from microfoundations of inter-temporal behaviour. These CGE models exclude dynamics of investment and capital accumulation and fail to account for the transition dynamics. There is a growing literature using overlapping generations (OLG) models to analyse the dynamic effects of the Australian tax and transfer policies (e.g. see Tran and Woodland (2014), Kudrna, Tran and Woodland (2015) and Kudrna, Tran and Woodland (2017)). However, these papers do not assess the marginal distortions of taxes in Australia, which is the focus of our paper.

The paper is structured as follows. Section 2 describes the model. Section 3 provides details on the calibration of our model to the Australian economy and its fit to the data. In Section 4 we present the quantitative analysis. Section 5 includes extensions and sensitivity analysis. Section 6 concludes. The Appendix contains additional tables and figures. The derivation of the key equations and description of the computational methods is contained in an online technical appendix.

2 Model

The model is a discrete time dynamic general equilibrium model, which consists of overlapping households, a perfectly competitive representative firm, foreign investors with perfectly capital mobility and a government with full commitment technology.

2.1 Demographics

The model is populated by households of different ages between 20 and 100, $j \in \mathbb{J} = [20, \ldots, 100]$, and three different skill types $i \in \mathbb{I} =[1, 2, 3]$.

In each period a continuum of households aged 20 enters the model and live to at most age 100 . They face a stochastic probability of death every period, sp_j the age-dependent survival probability at age j. The unconditional probability of surviving from age 20 to age j, is given by $S_j = \prod_{s=21}^{j} sp_s$. The size of a new cohort entering the economy and the overall population both grow at the rate g^n. $M_{t,j,i}$ denotes the size of the cohort of skill type i in age j at time t, which evolves according to $M_{t+1,j+1,i} = sp_{j+1} M_{t,j,i} = M_{t,j+1,i}(1 + g^n)$.

2.2 Household

Preferences. Households maximise expected lifetime utility which is the sum of current and discounted future intra-temporal utility adjusted for the chance of death

$$U_{t,j,i} = \sum_{j'=j}^{100} S_j \hat{\beta}^{j'-j} u\left(C_{t+j'-j,j',i}, l_{t+j'-j,j',i}\right)$$

where $\hat{\beta}$ is the time discount factor and S_j is the unconditional probability of survival. Households have identical intra-temporal preferences over consumption, $C_{t,j,i} \geq 0$, and leisure, $0 \leq l_{t,j,i} \leq 1$. The intra-temporal utility is assumed to have the form

$$u\left(C_{t,j,i}, l_{t,j,i}\right) = \frac{\left(C_{t,j,i}^{\gamma} l_{t,j,i}^{1-\gamma}\right)^{1-\sigma}}{1-\sigma},$$

where σ is a parameter governing inter-temporal elasticity of substitution and γ is the consumption share of utility.

Endowments. Households are different by skill type and age in our model. New households enter the model with a specific income type that determines their labour productivity over their life cycle. Labour efficiency unit, denoted by $e_{j,i}$, is type and age dependent but time-invariant. In each period, households are endowed with one unit of time that can be allocated over labour market and leisure activities. As such, each household's before-tax labour income is given by $W_t\left(1 - l_{t,j,i}\right) e_{j,i}$ where W_t is the market wage rate in period t.

Household problem. Households begin with zero assets, $A_{t,20,i} = 0$, and choose consumption, labour supply and asset holdings to maximise their utility over their lifetime. In our inter-temporal setting, households are able to save to smooth consumption over the life cycle by buying/selling asset holdings, $A_{t,j,i}$, which yields a dividend r_t^a, at a market price p_t^a. Households are restricted to a no borrowing constraint at all times, $A_{t,j,i} \geq 0$.

There are several sources of income. Households receive incomes from supplying labor and holding assets, $W_t(1 - l_{t,j,i})e_{j,i} + r_t^a A_{t,j,i}$. Households receive transfers from the government to offset the company tax paid by the firm through a dividend imputation system. The amount of franking credits is given by $r_t^{FC} A_{t,j,i}$, where r_t^{FC} is the franking credit per asset unit. In addition, households receive lump-sum transfer from the government $T_{t,j,i}$ and accidental bequests, $BQ_{t,i}$.[2] Household are required to pay personal income tax at the rate of τ^p. A typical household's taxable income includes labor, asset

[2]We abstract from any intended bequests and all inter-generational transfers are accidental. Households face uncertain death and therefore may die with positive asset holdings. The assets of the deceased are redistributed equally to all surviving households of the same type.

and franking credit incomes. The household's disposable income is given by

$$\Upsilon_{t,j,i} = (1-\tau_t^p)\left[W_t(1-l_{t,j,i})e_{j,i} + r_t^a A_{t,j,i} + r_t^{FC} A_{t,j,i}\right] + p_t^a A_{t,j,i} + T_{t,j,i} + BQ_{t,i}.$$

The household's utility maximisation problem can be written in terms of a dynamic programming problem as

$$V_j(A_{t,j,i}) = \max_{\{C_{t,j,i}, l_{t,j,i}, A_{t+1,j+1,i}\}} \left\{u\left(C_{t,j,i}, l_{t,j,i}\right) + \hat{\beta} s p_{j+1} V_{j+1}\left(A_{t+1,j+1,i}\right)\right\} \tag{1}$$

subject to the household's budget constraint $p_t^a A_{t+1,j+1,i} + (1+\tau_t^c) C_{t,j,i} = \Upsilon_{t,j,i}$, the credit constraint, $A_{t+1,j+1,i} \geq 0$, and the positivity of leisure and consumption $C_{t,j,i} > 0$ and $1 \geq l_{t,j,i} > 0$.[3]

2.3 Firm

The production sector consists of one representative firm which owns capital and the fixed factor and chooses investment, dividends, debt and equity and to maximise its cum dividend share price.

Technology. Output is produced by combining capital, K_t, effective labour, N_t, and a fixed factor, Z_t, in a constant returns to scale Cobb-Douglas production,

$$Y_t = F_t\left(K_t, N_t\right) = Z_t K_t^{\alpha_k} (\Lambda_t N_t)^{\alpha_n}.$$

Capital's share of output is α_k and α_n is labour's share. Λ_t is the labour augmenting level of technology and grows at the constant rate g^{Λ}.[4]

Capital is accumulated according to the law of motion

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{2}$$

where I_t is investment and δ is the depreciation rate.

Investment is subject to a quadratic capital adjustments cost with the total cost of investment given by

$$I_t + 0.5\psi\left(\frac{I_t}{K_t}\right)^2 K_t.$$

Corporate finance. The firm is owned by equity holders. There are two channels

[3] Technically, the effective rate of return on holding assets is $\widetilde{r}_t = r_t^a + r_t^{FC}$.

[4] In our setting, output per capita grows by labour augmenting productivity in steady state. As such we define the effective fixed factor as $Z_t = (\Lambda_t^Z \bar{Z})^{1-\alpha_k-\alpha_n}$ where Λ_t^Z is the fixed factor augmenting level of technology and $\bar{Z}$ is the fixed factor. We assume fixed factor augmenting productivity grows by the compound sum of labour augmenting productivity and population growth, $g^Z = g^{\Lambda} + g^n + g^{\Lambda} g^n = g^{\Lambda n}$ implying it grows at the same rate as steady state output.

to finance the firm's investment plan: internal finance by retained incomes and external finance by issuing new equity and debt. For simplicity, we make two assumptions: (i) equity is set equal to capital, $\Theta_t = K_t$, which sets equity issuance equal to net investment; and (ii) debt is set at a constant fraction of real capital as in Poterba and Summers (1983), so that the level of debt is given by $B_t^f = \xi K_t$, where ξ is a fixed debt to real capital ratio.[5] This debt to capital assumption is used to cap debt holdings in the model. As debt receives preferential tax treatment the firm would be completely debt financed if there is no cap.[6]

Company tax and deductions. We model some key features of corporate tax structure. The firm pays company income tax (CIT) on its income which is revenue minus wages, $\tau^k (Y_t - w_t N_t)$. The firm can also deduct from its taxable income a fraction of its interest payments, investment and capital depreciation. The value of the tax deductions for interest paid is given by $\chi^\xi r_t^f B_t^f$, where r^f is an adjusted interest rate and χ^ξ is a deductible fraction of its interest payment.[7] The value of investment tax credits (expensing deductions) is given by $\chi^I I_t$, where χ^I is a deductible fraction of its investment cost. The value of depreciation deductions is equal to $\chi^\delta \delta K_t$, where χ^δ is a deductible fraction of depreciation cost. The total deduction is given by $\left(\chi^\xi r_t^f B_t^f + \chi^I I_t + \chi^\delta \delta K_t\right)$.

Firm problem. The firm maximises its own value which is given by its cum dividend price multiplied by the number of shares $V_t = p_t^* \Theta_t = (p_t + d_t)\Theta_t$. The value of the firm can be expressed in terms of dividend payments and new equity issuances as

$$V_{t_0} = \sum_{t=t_0}^{\infty} \frac{d_t \Theta_t + p_t(\Theta_{t+1} - \Theta_t)}{\prod_{s=t_0}^{t}(1 + r_s)}. \tag{3}$$

The firm's problem is to choose a sequence of $\left\{I_t, d_t, B_t^f, \Theta_{t+1}\right\}_{t=t_0}^{\infty}$ to maximize its market value and subject to its budget constraint

$$\begin{aligned} I_t + 0.5\psi \frac{I_t^2}{K_t} + d_t \Theta_t + r_t B_t^f = {} & (1 - \tau_t^k) \left[F_t (K_t, N_t) - W_t N_t\right] + p_t^k (\Theta_{t+1} - \Theta_t) \\ & + (B_{t+1}^f - B_t^f) + \tau_t^k \left(\chi^\xi r_t^f B_t^f + \chi^I I_t + \chi^\delta \delta K_t\right), \end{aligned} \tag{4}$$

taking account wage rate, interest rate and the company tax policy as given. The firm's problem is also subject to the capital accumulation equation (2). The stock of debt and equity are further subject to the simplifying assumptions discussed in the corporate

[5] The price of capital when calculating the value of debt is one.

[6] The equity to capital assumption is a simplifying assumption as the firm is indifferent between paying returns as capital gains or as dividends. This stems from Miller and Modigliani (1961) and our assumption that the marginal foreign investor pays neither dividend taxes nor capital gains taxes, or if they do that the rates are equal.

[7] The interest rate used for tax deductions, r^f, takes into account that firms are able to deduct nominal interest payments. See the technical appendix for further details.

finance section.

2.4 Government

The government collects revenue from taxing household and firm incomes and household consumption to finance government purchases and transfers.

Taxes. The government raises revenues from company income tax, personal income tax and consumption tax. The firm pays company income tax on its gross income with deductions. The full range of deductions is described in the firm section (2.3). Total revenue from the company income tax is given by

$$TAX_t^k = \tau_t^k \left[F_t \left(K_t, N_t \right) - W_t N_t - \chi^\delta \delta K_t - \chi^\xi r_t^f \xi K_t - \chi^I I_t \right].$$

A dividend imputation system to compensates resident households for the company income tax paid by firms. The value of the franking credit per share is computed by $r_t^{FC} = \chi^{FC} \frac{TAX^k}{\Theta_t}$, where χ^{FC} is the share of company income tax paid that firms distribute as franking credits.

Households labour and asset incomes are taxed at the rates of τ^p. However, they use franking credits against the value of their asset income, $r_t^{FC} A_{t,j,i}$. The sum of personal income taxes paid by all households is given by

$$TAX_t^p = \sum_{j \in \mathbb{J}} \sum_{i \in \mathbb{I}} M_{t,j,i} \left\{ \tau_t^p \left[\left(W_t (1 - l_{t,j,i}) e_{j,i} + \left(r_t^a + r_t^{FC} \right) A_{t,j,i} \right) \right] - r_t^{FC} A_{t,j,i} \right\}.$$

The government revenue from consumption tax, TAX_t^c, is given by

$$TAX_t^c = \tau_t^c C_t,$$

where τ_t^c is consumption tax rate and C_t is total private consumption.

Hence, the total tax revenue is a sum of three tax revenues: $TAX_t = TAX_t^p + TAX_t^k + TAX_t^c$.

Expenditures. The government has two spending programs: the purchase of goods for government consumption, G_t, and government transfers, T_t. Government consumption and transfers grow in line with productivity and population. Government transfers encompass pension payments and other social security transfers. The total amount of government transfers, T_t, is the sum of transfers to all households

$$T_t = \sum_{j \in \mathbb{J}} \sum_{i \in \mathbb{I}} M_{t,j,i} T_{t,j,i},$$

where $M_{t,j,i}$ is the measure of age j and type i households at time t and $T_{t,j,i}$ is the amount of transfers received by individual households which grow in line with labour augmenting productivity.

Budget balancing rule. How the government balances its budget depends on the scenario. In the baseline the government's budget is balanced in every year and the government starts with zero debt. When the government borrows or lends the evolution of government bonds, B_t^G, is given by

$$B_{t+1}^G = TAX_t - G_t - T_t - (1 + r_t) B_t^G. \tag{5}$$

We assume that the government can borrow and lend at the international interest rate and that all government debt is held by foreigners. In this case the government's budget is balanced by ensuring the net present value of revenue equals that of spending.

$$\sum_{t=0}^{\infty} \frac{TAX_t}{\prod_{s=0}^{t}(1 + r_s)} = \sum_{t=0}^{\infty} \frac{G_t + T_t}{\prod_{s=0}^{t}(1 + r_s)}. \tag{6}$$

2.5 Markets

The economy is small and open with perfect capital and goods mobility. The labour market is assumed to be perfectly competitive with the wage equal to the marginal product of labour. Labour is assumed to be internationally immobile implying workers can not migrate in response to economic conditions.

In the domestic financial market, there exists an asset combining agency that combines equity and debt issued by the firm into a single asset which is sold to both residents and foreigners. One unit of the combined asset is defined as one unit of equity plus the proportional share, ξ, of debt. As such the stock of assets equals the stock of equity which equals the capital stock and also the stock of firm bonds divided by the debt financing ratio

$$A_t = \Theta_t = K_t = B_t^f / \xi. \tag{7}$$

The price of the combined asset, p_t^a, is the price of equity plus the share of debt used in funding the firm and is given by $p_t^a = p_t^k + \xi$. The return on the combined asset is given by the return on debt plus the return on equity and is given by $r_t^a = \xi r_t + d_t$.

The domestic capital market is fully integrated into the world capital market. As such, foreigners are the marginal investors and the domestic interest rate, r_t, is exogenous and equal to the world interest rate, $r_t = r$. The domestic firm therefore uses the international interest rate in its maximisation problem. As such the rate of return on domestic assets must equal the international interest rate

$$\frac{r_{t+1}^a + p_{t+1}^a - p_t^a}{p_t^a} = r_t = r. \tag{8}$$

Foreign goods and domestic goods are perfect substitutes hence only net exports are tracked in the model. Net exports (NX_t) are determined by the balance of payments and are given by

$$NX_t = r_t^a A_t^{for} - p_t^a(A_{t+1}^{for} - A_t^{for}) + r_t D_t^G - (D_{t+1}^G - D_t^G), \tag{9}$$

where A_t^{for} is the total assets held by foreigners.

2.6 Competitive equilibrium

The solution to the model is given by prices and quantities that are consistent with the solutions to the households' and firm's problems, the government's budget constraint and foreigners' required rate of return.

For a given model calibration an equilibrium is defined by a set of household decisions $\{C_{t,j,i},\ l_{t,j,i}, A_{t+1,j+1,i}\}_{t\in\mathbb{T},j\in\mathbb{J},i\in\mathbb{I}}$; a set of firm decisions including labour demand, capital stock, investment, equity and debt $\{N_t, K_{t+1}, I_t, \Theta_{t+1}, B_t^f,\}_{t\in\mathbb{T}}$; a set of relative prices for wages, assets and returns on assets $\{W_t, p_t^a, r_t^a,\ r_t^{FC}\}_{t\in\mathbb{T}}$; accidental bequests $\{BQ_{t,i}\}_{t\in\mathbb{T}}$; government policy settings $\{\tau_t^c, \tau_t^p,\ \tau_t^k, \chi^\xi, \chi^I, \chi^\delta, G_t, T_t\}_{t\in\mathbb{T}}$; and foreign assets and net exports $\{A_t^{for}, NX_t\}_{t\in\mathbb{T}}$ such that the following hold:

1. the choice of leisure, asset accumulation and consumption are consistent with the solutions to household's problem given in equation (1),

2. the investment, capital stock, dividends, firm debt and the stock of equity are consistent with the solution firm's problem given in equation (3),

3. the return to assets and the price of assets are consistent with return required by foreign investors as given in equation (8),

4. the government's budget balances as given in equation (6),

5. the sum of individual consumption, labour supply, and asset holdings equals aggregate consumption, labour demand, and aggregate domestically owned assets,

$$\begin{aligned}
C_t &= \sum_{j\in\mathbb{J}}\sum_{i\in\mathbb{I}} M_{t,j,i}C_{t,j,i}, \\
N_t &= \sum_{j\in\mathbb{J}}\sum_{i\in\mathbb{I}} M_{t,j,i}(1-l_{t,j,i})e_{j,i}, \\
A_t^{dom} &= \sum_{j\in\mathbb{J}}\sum_{i\in\mathbb{I}} M_{t,j,i}A_{t,j,i}
\end{aligned}$$

6. the capital stock equals the total stock of assets as in equation (7), with total assets equal to the sum of domestic assets plus foreign owned assets

$$A_t = A_t^{dom} + A_t^{for}, \tag{10}$$

7. the aggregate resource constraint holds, with total production equalling the total use of output as given below

$$K_t^{\alpha_k}(\Lambda_t N_t)^{\alpha_n}(\Lambda_t^Z Z)^{1-\alpha_k-\alpha_n} = C_t + G_t + I_t + 0.5\psi\left(\frac{I_t}{K_t}\right)^2 K_t + NX_t, \tag{11}$$

where net exports are given by equation (9) with government bonds evolving according to equation (5),

8. bequests are equal to the deceased's assets, including returns, evenly distributed amongst the remaining agents of that type as given by

$$BQ_{t,j,i} = \frac{\sum_{j\in\mathbb{J}}(M_{t-1,j,i} - M_{t,j+1,i})(p_t^a + r_t^a)A_{t,j+1,i}}{\sum_{j\in\mathbb{J}} M_{t,j,i}}. \tag{12}$$

3 Calibration

This section describes how parameters of the model are calibrated. The majority of the parameters are calibrated so that the model matches Australian macroeconomic aggregates. Other parameters are calibrated so that household variables match microeconomic data from the Household, Income and Labour Dynamics in Australia (HILDA) survey or taken from the literature.[8] The frequency of the model is annual and the unit of the model is an individual who represents a household. As a basis of the calibration, we first compute a benchmark steady state economy that approximates the economy of 2010. We summarize these external parameters in Table 4. Internally selected parameters to match a given set of targets from Australian data are presented in table 5.

3.1 Demographics

The population dynamics are calibrated to match the Australian Bureau of Statistic's (ABS) release 3222.0 Population Projections. The population dynamics are set to match

[8]This paper uses unit record data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey. The HILDA Project was initiated and is funded by the Australian Government Department of Families, Housing, Community Services and Indigenous Affairs (FaHCSIA) and is managed by the Melbourne Institute of Applied Economic and Social Research (Melbourne Institute). The findings and views reported in this paper, however, are those of the author and should not be attributed to either FaHCSIA or the Melbourne Institute.

the evolution of the cohort of persons aged 20 in 2013-14. Defining $Pop_{20,2014}$ to be the population of persons aged 20 at 1 June 2014 the conditional survival probability is calculated as $sp^*_{21} = Pop_{21,2015}/Pop_{20,2014}$. Due to positive net migration the projected size of some age cohorts increases but we set the conditional survival probability to a maximum value of one.

The three skill levels are defined by three education levels. Let $\mathcal{P}_i$ denote the share of the population with skill type i. The share of the population with skill type i at age j is given by $m_{j,i} = \mathcal{P}_i \frac{S_j(1+g^n)^{j-20}}{\sum_{j=20}^{100} S_j(1+g^n)^{j-20}}$.

The growth in the population is also calibrated to the ABS's release 3222.0 Population Projections. Growth in the population of persons aged 20 and over is projected to average 1.7 per cent from now to 2050 and we use this value for g^n.

3.2 Household

The consumption share of utility γ is set to 0.25 so that the share of hours spent at work in the model matches HILDA data. The inter-temporal elasticity $1/\sigma$ is set to 0.4 as in Kudrna, Tran and Woodland (2015).

The labour efficiency endowments are estimated from HILDA data. The skill type levels are matched to education levels as reported in HILDA. The shares from in HILDA give the populations shares of the skill types in our calibration.

3.3 Firm

The labour share of output, α_n, is set at 0.59, so that the labour share of output matches the average ratio of gross operating surplus to compensation of employees from 1990 to 2014 as in ABS 5204.006.[9] Further, the capital share of output, α_k, is set at 0.39, so that the fixed factors share of output matches the 2 per cent contribution of non-residential land to GDP as in Cao et al. (2015). The depreciation rate, δ, is set at 5.6 per cent to match the investment to capital stock ratio in the data. We use the steady state relationship $\delta + n + g + n * g = I/K$ and target the average ratio of gross fixed capital formation to the end of year net capital stock from 1990 to 2014, in both cases excluding dwelling.

The capital adjustment cost ψ is set to 3.33 to target the steady state q-ratio of 1.14 from Oliner, Rudebusch and Sichel (1995). Labour augmenting productivity growth, g^{Λ}, is set to 1.7 per cent to match growth in per capita GDP from 1990 to 2014.

We follow Cao et al. (2015) to assume that the firm issues franking credits for 36.8 per cent of the tax they pay meaning $\chi^{FC} = 0.368$. The firm is 24 per cent debt funded

[9] We assume that the capital share of gross mixed income matches the capital share in gross operating surplus and compensation of employees.

and is able to deduct 100 per cent of its interest payments, $\chi^{\xi} = 1.0$. The firm receives investment tax credits for 5 per cent of its investment, $\chi^{I} = 0.05$, and is able to claim the remaining 95 per cent as depreciation deductions $\chi^{d} = 0.95$.

3.4 Government

Tax rates are set to match revenue to GDP ratios as from ABS 5506. The company income tax (CIT) rate τ^{k} is set to 33.0 per cent to match the CIT to GDP ratio of 5.4 per cent. The personal income tax (PIT) rate τ^{p} is set to 16.1 per cent to match PIT to GDP ratio of 10.4 percent. The consumption tax (CT) rate τ^{c} is set to 6.2 per cent to achieve the consumption tax revenue to GDP ratio of 3.6 per cent.

Transfers are calibrated based on data from Australian Bureau of Statistics: ABS 5204.030 and ABS 6537 where aggregate pensions average 2.7 per cent of GDP from 1990 to 2014. Other social assistance payments excluding pensions average 5.2 percent of GDP. Beyond matching the social transfers to GDP an attempt is made the match the income quintiles in ABS 6537 in the model.

Government purchases of goods are set to 11.5 per cent of GDP, so that the budget balances in the baseline.

3.5 Markets

The world interest rate r is set to target the capital stock to GDP ratio. The capital stock to GDP target is calculated from 1990 to 2014.[10] The target capital output ratio equal to 3.1 implies a world interest rate, r, equal to 3.8 per cent in the model.

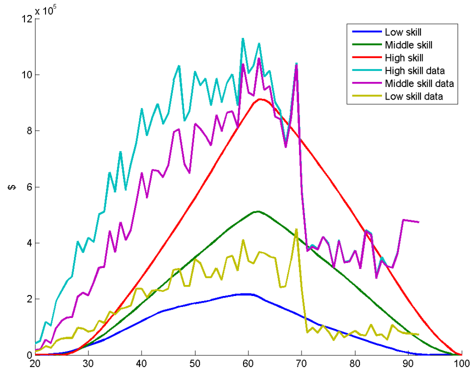
The discount rate β is used to target the domestic ownership of the capital stock. The discount rate determines agent's time preference and therefore their savings and asset accumulation. As there is no concise closed form solution for asset accumulation and β is solved iteratively. In the model β equals 0.978 giving net foreign ownership of 17 per cent in line with the average net international investment position relative to the total capital stock from 1990 to 2015.

3.6 Benchmark model

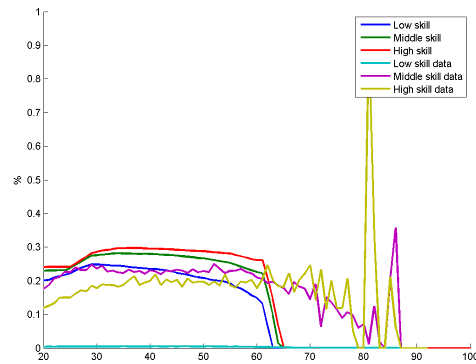
Our benchmark model matches the macroeconomic data. In addition, it can replicate the life cycle patterns of Australian households. Figure 1 depicts the asset holdings and labor supply over the life cycle. Figure 1 presents the asset accumulation in the model, compared to that in HILDA. In the model households save for retirement but are bound

[10] The relationship between the interest rate and the capital output ratio is given in the technical appendix.

by the borrowing constraint in the early part of their lives when their labour productivity is lower. Figure 1(b) shows the broad similarities between the labour supply profiles in the model and in the HILDA data.



(a) Asset accumulation



(b) Share of time spent in labour

Figure 1: Asset holdings and labour supply over the life cycle: Model vs. HILDA data

4 Quantitative analysis

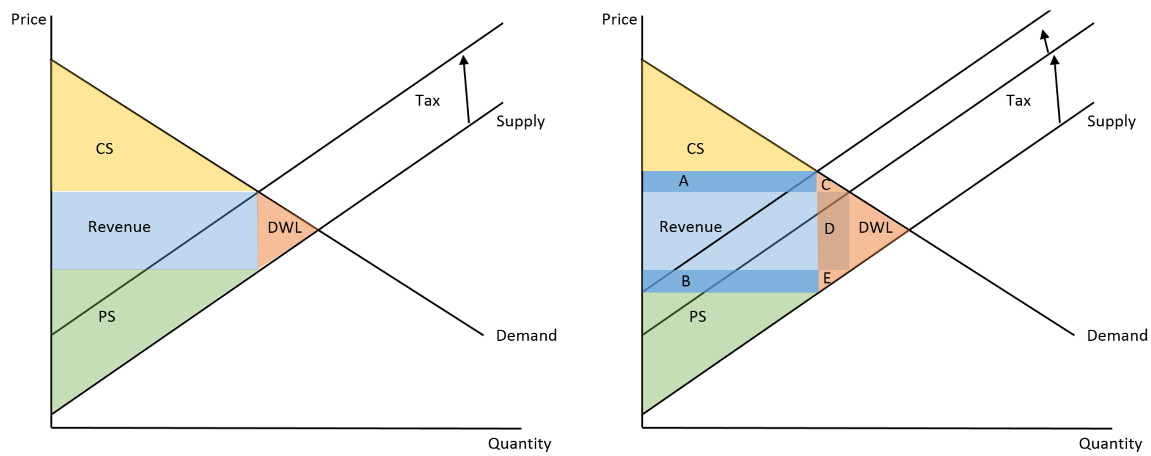
We quantify marginal excess burden associated with various taxes using the model described in the previous section.

4.1 Marginal excess burden

In a simple static framework, the excess burden of taxation can be measured by the area of the associated 'Harberger triangle' (e.g., see Harberger (1964)). Figure 2 demonstrates how excess burden and marginal excess burden can be measured using a demand and supply framework. In a dynamic general equilibrium framework, the excess burden of taxation is more complex since the Harberger triangle is not well defined. Instead, we follow the approach in Judd (1987) that uses Hicksian equivalent variation to measure the excess burden.

In particular we consider an experiment in which the government raises an additional dollar of revenue through one of its tax instruments. The tax instrument is permanently adjusted to meet the targeted net present value (NPV) revenue increase. Specifically, the revenue increase target is equal, in NPV terms, to one dollar per household per year adjusted for growth.[11] The revenue increase is the net additional revenue change taking into account other tax bases.

[11] In terms of numerically modelling these scenarios we model a small, permanent tax increase and scale the results. The further details on the scaling of the results can be found in the technical appendix.



(a) Excess burden (b) Marginal excess burden (MEB)

Figure 2: The marginal excess burden of an increase in a tax imposed on suppliers. CS is consumer surplus. PS is producer surplus. Revenue is tax revenue. DWL is the deadweight loss/exess burden of a tax. MEB is the marginal excess burden of a tax increase, $MEB = \frac{C+D+E}{D-A-B}$.

We calculate the equivalent variation of the policy change for each household and use this as each household's MEB. The excess burden measures the distortion of a tax relative to a non-distortionary lump sum tax. We construct the core scenarios so that the welfare change faced by each household equals the MEB they bear. In the core scenarios the additional government revenue is spent through uniform lump sum transfers to households.[12] When revenue is returned uniformly, levying a uniform lump sum tax is simply taking money from households and immediately returning it. As such, a uniform lump sum tax does not cause any changes in welfare or other variables and therefore no distortion. Therefore, when the additional revenue is returned uniformly the welfare change of households can be interpreted as their burden of the tax relative to a non-distortionary lump sum tax, their excess burden. We measure each household's welfare change through a per period equivalent variation transfer and use this as the household's MEB.

Finally, we construct an aggregate metric of marginal excess burdens of all households. The aggregate MEB is defined by the net present value of the marginal excess burdens of all households normalised by dividing by the net present value of the change in net revenue.[13] Our aggregate MEB is an index that measures the total distortion of the particular tax relative to a lump sum tax. In addition, we construct group-specific MEBs for different cohorts and skill types.[14] These group MEBs allow us to more easily

[12]The transfer is equal across households and periods adjusting for labour augmenting productivity growth.

[13]The formula of the aggregate marginal excess burden (AMEB) is provided in the technical appendix.

[14]The MEB for different productivity types is constructed in the same way as the total aggregation. The MEB grouped across old, young and future generations is calculated as a simple average. Old is

compare the impacts across households and generations.

4.2 Three main taxes

In this section, we quantify marginal excess burdens for three main taxes: company income tax (CIT), personal/individual income tax (PIT) and consumption tax (CT). Table 1 presents the marginal excess burdens (MEB) for different taxes by different groups of households.[15]

	CIT	PIT	CT
Aggregate	\$0.83	\$0.34	\$0.24
Old: 65+	\$1.32	-\$0.64	\$0.01
Young: 20 to 64	\$0.54	\$0.09	\$0.23
Future: -100	\$0.96	\$0.44	\$0.25
Type 1: low income	-\$0.02	-\$0.32	-\$0.16
Type 2: medium income	\$0.73	\$0.27	\$0.18
Type 3: high income	\$1.75	\$1.04	\$0.70

Table 1: **Marginal excess burdens (MEB) of raising extra revenue from the company income tax (CIT), the personal income tax (PIT) and the consumption tax (CT).**

Our main results indicate that raising the company income tax is more distorting than raising the personal income tax and the consumption tax. As shown in the first row of Table 1, the aggregate MEB for the company income tax is 83 cents per dollar of tax revenue raised, compared to 34 cents and 24 cents for the personal income tax and the consumption tax, respectively. Our MEB estimates are relatively larger than estimates from previous studies using more simplified models abstracted from lifecycle behaviour and transition dynamics. Ballard, Shoven and Whalley (1985) find MEB estimates in the range of 18 to 46 cents for industry level capital tax and a range of 12 to 23 cents for industry level labour taxes. Judd (1985*b*) finds a MEB of 12 cents for labour income tax. It is important to note that we use a more comprehensive model in which we fully account for dynamic general equilibrium effects in steady state and along transition path.

The company income tax is the least preferred tax as it results in highest MEB at the aggregate level. However, when the welfare impacts are further disaggregated this does not hold for all households as presented in rows from 2 to 6 in Table 1. There is significant variation in the MEB across generations and income types. The marginal excess burden

defined as those 65 and over at the time of the policy change, young are those alive and below 65 at the policy change and the future generation shows the MEB in the long run steady state.

[15] The results presented are normalised for population and productivity growth with the population measure normalised to one. In this setting one dollar per household equals one dollar in total. Changes in aggregate variables, such as GDP and the capital stock, can be thought of as the change per dollar of net revenue. At the same time changes in households variables, such as welfare, can be thought of as the change per dollar of revenue per household.

for each tax is unevenly distributed. In particular, old households are the biggest losers from a company tax increase, but suffer less from increases in the personal income tax or the consumption tax. Lower-income households would be largely unaffected by tax hikes. This occurs as the model assumes any extra revenue generated is re-distributed evenly via the transfer system to balance the budget, the loss of income from lower wages is offset by higher transfer. Low-income households indeed would be 32 cents and 16 cents better off under income tax and consumption tax increases, respectively. Conversely, high-income households would be worse off as they bear most MEB.

We next examine each individual tax and analyse the underlying mechanisms through which it distorts economic activity and welfare.

Company income tax (CIT)

Figure 3 displays the dynamic effects of the company income tax (CIT) increase on four key variables: excess burden, tax revenue, capital stock and labour income. Figure 6 in Appendix presents further information on other variables including interest and dividend payments, after tax asset incomes, labor supply and asset holdings over the life cycles.

The CIT increase distorts the firm's incentive to invest. Higher company income tax rate lowers dividends, which subsequently lowers the value of capital and investment, as seen in Panel 3 of Figure 3. As the capital stock decreases the marginal product of capital increases ensuring dividends meet the foreign investors required rate of return. However, resident's returns are higher in the long run as they receive franking credits which increase in value. A lower capital stock decreases the marginal product of labour and therefore wages.

Household's responses to these changes can be understood in terms of both income and substitution effects of lower wages, higher transfers, reduced asset prices and changing rates of return. Panel 4 of Figure 3 shows labour supply decreasing as the substitution effect from lower wages is larger than the accompanying income effect, especially given the offsetting impact of higher transfers. Households also shift the timing of labour supply forward across their life in response to higher asset returns created for residents. This is matched by increased domestic saving.

The magnitude of the aggregate welfare loss per dollar of revenue is largely explained by the fall in wages relative to the change in revenue. Increasing company income tax to raise one dollar of net revenue reduces long run labour income by \$3.44 of which \$2.02 is due to the decline of wages. The decline in wages comes from the lower capital stock and the magnitude of this change is driven by the assumption that capital is internationally perfectly mobile.

The welfare loss to residents mainly comes through lower wages and the initial fall in the capital price. Panel 1 of Figure 3 presents the marginal excess burdens by skill

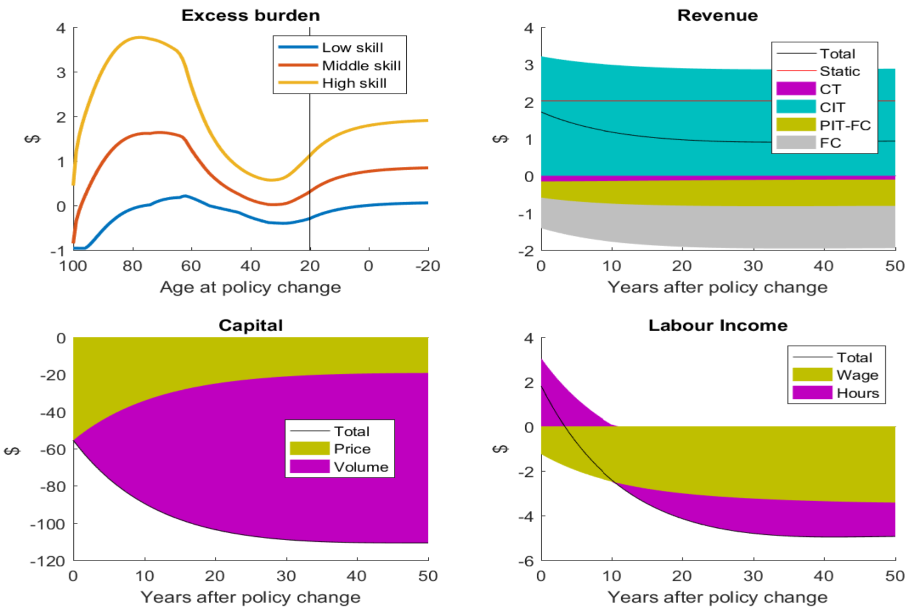


Figure 3: **The impacts of a company income tax (CIT) increase.** Note that, the CIT is permanently adjusted to raise the targeted net present value (NPV) revenue increase by $1.

and age. In the long run lower wages drive welfare decreases for the top two income groups while welfare is almost unchanged for the bottom income group as the increase in transfers offsets their fall in wages. Most of the oldest households have few remaining assets and are therefore not particularly negatively affected by the decline in asset values. Retired households who hold more assets, determined both by type and age, are more negatively affected by the asset price decrease and also the decline in returns. The welfare loss of households aged 20 to 60 is smaller than that of future generations or of recently retired older households. These households work while wages have not fully declined, are able buy assets while they are cheaper and experience higher returns later in life.

The tax revenue must initially increase more than $3 in order to raise one dollar of net revenue, as shown in Panel 2 of Figure 3. Such large revenue increase is to offset the increase in franking credit and the decreases in personal income tax (PIT) and consumption tax (CT) revenue. Declining output causes revenue to fall further over time. To raise the equivalent of $1 per period in NPV terms the CIT must raise as high as $1.80 in the first period. It then settles down to only $0.94 once the capital stock has fully adjusted. If changes in quantities and factor prices were not taken into account the tax increase would be projected to raise $2.01.[16] We refer to this projection, that does not take into account changes in quantities and prices, as the static projection. In terms of tax scoring this implies a one dollar increase in static revenue projection raises only $0.50 in net revenue when accounting for dynamic responses.

[16]The static revenue figure does include the change in franking credit use.

Personal income tax (PIT)

Figures 4 and 7 present the dynamic effects of the personal income tax (PIT) increase.

The personal income tax increase results in lower after-tax wages and realised returns on assets for residents. As such households substitute towards leisure and away from saving. Households not only reduce labour supply over their life but also shift labour supply from earlier to later in life as they value saving less. When the policy change is brought in households shift labour supply to later in life causing aggregate labour supply to decline by more in the medium term than in the long run, as shown in Panel 4 of Figure 4.

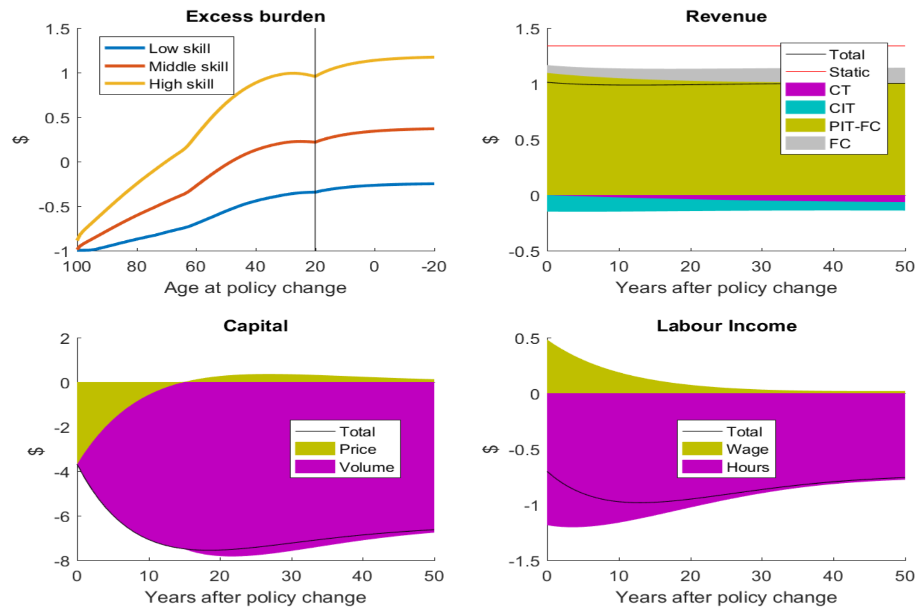


Figure 4: **The impacts of a personal income tax (PIT) increase.** Note that, the PIT is permanently adjusted to raise the targeted net present value (NPV) revenue increase by $1.

The decline in labour supply reduces the marginal product of capital and the return on assets. As such the firm invests less and the capital stock declines. The distortions to the household labour supply decision and the savings decision drives the welfare losses. The tax collects revenue in line with earnings which means lower income and older households pay less additional tax. As such, the oldest households and those with the lowest labour productivity are better off from the policy change due to the increased transfers. Future high labour productivity households are the most negatively affected as they work with a lower capital stock.

The aggregate marginal excess burden is smaller than that for the company income tax with welfare losses largely reflecting income patterns. The smaller aggregate distortion can also be observed in small capital stock and labour supply changes. The difference between the static revenue estimate and the dynamic estimate is also smaller for the PIT than the CIT. In terms of tax scoring a PIT increase that is projected to raise one dollar of static revenue raises \$0.73 once the dynamic effects are taken into account. There are limited changes in the other tax bases in response to the PIT increase.

Consumption tax (CT)

Figures 5 and 8 display the dynamic effects of the consumption tax (CT) increase.

A consumption tax increase raises the cost of consumption and causes substitution towards leisure. However, unlike the personal income tax, this increase does not significantly affect the inter-temporal savings decision. Households decrease labour supply more uniformly over their life cycle.

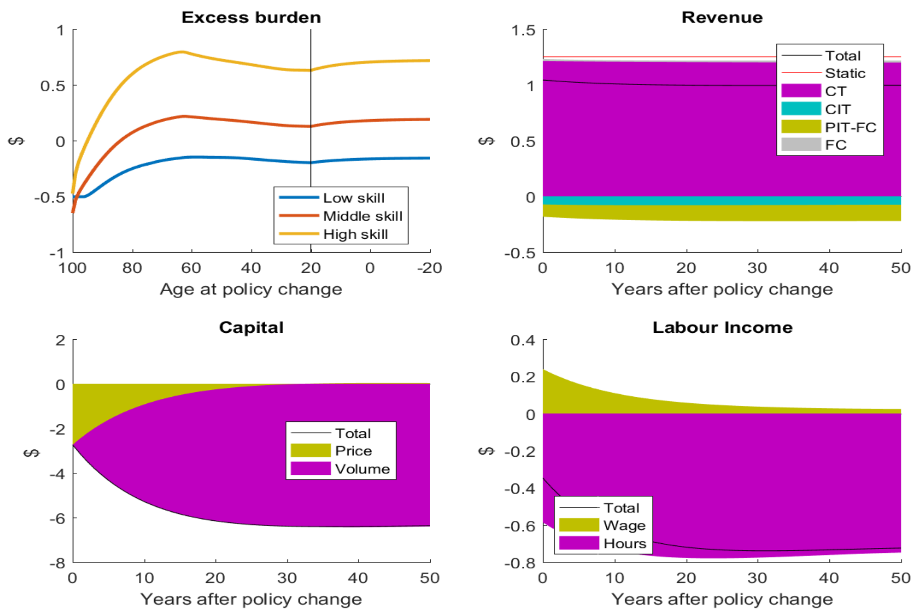


Figure 5: **The impacts of consumption tax (CT) increase.** Note that, the CT is permanently adjusted to raise the targeted net present value (NPV) revenue increase by \$1.

The welfare impacts of the CT increase largely mirror the consumption patterns in the model, as shown in Figure 5. Older households consume less. Younger and future generations will work with a lower capital stock and are therefore more negatively affected. The change in asset prices also causes a small variation of welfare impacts across generations.

The aggregate marginal excess burden from raising the CT is smaller than the personal income tax. The reason is that the CT is collected over a larger base and does not distort inter-temporal decisions. The older households largely do not pay the personal income tax; however, they pay the consumption tax. This implies that consumption tax revenue is collected from a bigger pool of households. The consumption tax on retired households is effectively a lump sum tax as the intra-temporal trade off between consumption and leisure is eliminated. This implies no distortion. The tax revenue collected from working households is relatively smaller; and therefore leads a smaller distortion. A consumption tax increase to raise one dollar using a static model can only raise \$0.80 in our dynamic setting, as shown Panel 3 of Figure 5.

4.3 Other taxes

In this section we demonstrate that the MEB approach can be used to facilitate the comparison of a wide range of taxes. We consider other tax instruments that the government can use to raise revenue from taxing firm or households, including reducing investment tax credits (ITC), reducing depreciation deductions (DD), raising personal labour income tax (PLT), and raising personal asset income tax (PAT).

Table 2 reports the marginal excess burden of different taxes. To ease comparison we also include the marginal excess burdens of the company income tax (CIT) and the consumption tax (CT). We classify different taxes into two groups: one imposing on the firm side and one imposing on the household sides.

	Firm			Household			
	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	\$0.83	\$1.30	\$1.08	\$0.34	\$0.48	\$0.30	\$0.24
Old	\$1.32	-\$1.86	\$0.00	-\$0.64	-\$0.13	-\$0.79	\$0.01
Young	\$0.54	-\$1.28	-\$0.13	\$0.09	\$0.77	-\$0.11	\$0.23
Future	\$0.96	\$2.19	\$1.51	\$0.44	\$0.45	\$0.45	\$0.25
Type 1	-\$0.02	\$0.23	\$0.12	-\$0.32	-\$0.29	-\$0.32	-\$0.16
Type 2	\$0.73	\$1.18	\$0.97	\$0.27	\$0.41	\$0.24	\$0.18
Type 3	\$1.75	\$2.46	\$2.13	\$1.04	\$1.29	\$0.97	\$0.70

Table 2: **Marginal excess burdens (MEB) of raising extra revenue from different taxes on the firm and households.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

Overall, we find that the taxes legally incident on firms, including company income tax, investment tax credit and depreciation deductions result in a higher level of AMEB than the taxes legally incident on households, including personal income tax, personal labour income tax, personal asset income tax and consumption tax. Our ranking points out that an reduction in investment tax credits has the highest AMEB, while raising the consumption tax has the lowest AMEB. Overall, our results indicate that the marginal excess burdens of the taxes on the firm side dominate that of the taxes on the household side.

Next, we discuss the underlying mechanism behind the excess burden of each tax separately.

Investment tax credits (ITC)

We consider an experiment where that the share of investment is no longer claimed immediately, but can then be claimed as depreciation deductions later. Reducing investment tax credits (ITC) lowers the share of investment the firm can immediately claim as a tax deduction. This means the reduction in the ITC is offset by increases in depreciation deductions later, $\Delta\chi^I = -\Delta\chi^\delta$.

The dynamic effects of a reduction in ITC are reported in Figure 9. Reducing ICT raises the cost of investment and results in less investment occurring. The price of assets also increases but is held down in the near term due to lower capital adjustment costs from lower investment. In the medium term the price of assets continues to rise consistent with increasing dividends from the decreasing capital stock and the increasing marginal product of capital.

Unlike raising the company income tax, reducing the ITC is a boon to retired households as the price of their assets increases. The welfare of older households increases through both the asset price increases and increased transfers. It is younger households and future generations whose welfare is reduced through lower wages due to the lower capital stock.

The aggregate distortion caused by a reduction in the ITC is larger than for the company income tax because of the windfall gains to foreigner investors and older households. Auerbach and Kotlikoff (1987) note that, in a closed economy, decreasing the ITC is similar to moving from a consumption tax to a labour income tax. That is, decreasing investment incentives shifts the burden of taxation from the old to the young. Reducing the ITC increases asset prices and acts as a transfer to older households and foreign investors. The reduction in the ITC only affects new capital raising the overall distortion relative to the company income tax. The net revenue raised falls significantly over time as reducing the ITC leads to higher depreciation deductions in the future.

Interestingly, while the reduction in the ITC results in largest aggregate welfare losses many households alive at the time of the policy change are better off.

Depreciation deductions (DD)

We model a reduction in depreciation deductions (DD) by reducing the share of depreciation deductions claimable, χ^δ. The dynamic effects are reported in Figure 10.

This reduction raises the effective tax rate on capital. Lowering depreciation deductions has similar impacts to an increase in the company income tax (CIT) with investment, the capital stock and wages all falling over time. However, the change in depreciation deductions only affects variable capital and therefore causes a larger aggregate distortion per dollar of revenue. As the depreciation deductions only affects variable capital the value of assets falls by less than under a CIT increase.

The larger per dollar distortion from the depreciation deductions, compared with the CIT, can be seen in the larger aggregate welfare loss. However, the welfare loss is smaller for asset rich households at the time of the policy change.

Lastly it is worth noting that the way debt deductions have been modelled here means that a decrease in debt deductibility has the identical impact to lower depreciation deductions. We have assumed that debt can only be held against variable capital and not against the value of the fixed factor. Under this assumption lowering debt deductions only directly affects the return to variable capital. If debt were also held against the fixed factor then lowering debt deductions would be more like a company income tax increase.

Personal labour income tax (PLT)

We consider an experiment where the government introduces a personal labour income tax (PLT). In the model, the PLT this is equivalent to a broad payroll tax. The dynamic effects in Figure 11. The PLT decreases the take home wage of households. The impacts of increasing PLT display characteristics of both the personal income tax (PIT) and consumption tax (CT) increases. As with the consumption tax, the PLT directly distorts the consumption leisure trade off. The tax base of the PLT is relatively smaller than that of the consumption tax as it only collects taxes from working households.

The aggregate marginal distortion caused by the PLT is lower than the personal income tax but higher than the consumption tax. It is lower than the personal income tax because it does not affect inter-temporal decisions. It is higher than the consumption tax because it does not collect revenue from older households whose expenditure is inelastic. Retired households prefer an the PLT increase to either personal income tax or consumption tax increases while future households prefer a consumption tax increase.

Personal asset income tax (PAT)

We consider an experiment where the government introduces a personal asset income tax (PAT) to raise revenue. This tax effectively reduces the returns to assets held by domestic households. The impacts of the PAT increase is equivalent to a decrease in franking credit deductibility. The MEB for the PAT is equivalent to the MEB of a reduction in dividend imputation.

Increasing the PAT distorts households' incentives to work and save and lead to decreases in saving and labour supply. The dynamic effects are reported in Figure 12. In our small open economy model with perfect capital mobility, the decrease in domestic saving is perfectly offset by increased foreign investment. However, changes in aggregate labor supply affect the demand for the aggregate capital stock.

The PAT causes the largest aggregate welfare loss among taxes directly imposed on the households. In addition, the PAT is more distorting than the personal labour income tax. The PAT is the least preferred tax for the high productivity households because they hold the most assets and are most negatively affected. Meanwhile, the low productivity households prefer the PAT over the personal labour income tax.

5 Sensitivity analysis

In this section we check the robustness of the main results. We consider different model specifications and calibrations: alternative methods to allocation additional tax revenue, foreign ownership share, the role of fixed factors, franking credits, capital adjustment speed, economic growth, intertemporal elasticity of substitution and elasticity of labor supply. Table 3 presents the results from different modelling assumptions.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Benchmark model	$0.83	$1.30	$1.08	$0.34	$0.48	$0.30	$0.24
Lump sum redistributive authority	$0.82	$1.46	$1.14	$0.36	$0.48	$0.32	$0.24
Revenue spent by government	$0.54	$0.94	$0.76	$0.13	$0.24	$0.09	$0.04
Closed economy	$0.63	$0.89	$0.75	$0.41	$0.75	$0.29	$0.24
Decreased foreign ownership	$1.13	$1.57	$1.41	$0.34	$0.43	$0.32	$0.24
Increased foreign ownership share	$0.55	$1.02	$0.79	$0.31	$0.53	$0.28	$0.23
Increased fixed factors	$0.33	$1.32	$1.05	$0.32	$0.38	$0.29	$0.22
No fixed factors	$1.11	$1.34	$1.17	$0.33	$0.45	$0.30	$0.24
No franking credit use	$0.70	$1.02	$0.86	$0.42	$0.84	$0.33	$0.25
Increased franking credit use	-$1.03	-$3.35	-$1.35	$0.20	$0.09	$0.26	$0.21
Faster capital adjustment	$0.52	$0.97	$0.78	$0.34	$0.54	$0.29	$0.23
No growth	$0.13	$2.09	$0.31	$0.39	$0.78	$0.29	$0.21
Debt tied to equity	$0.86	$1.33	$1.10	$0.34	$0.47	$0.30	$0.24
Lower intertemporal elasticity	$1.03	$1.45	$1.30	$0.29	$0.29	$0.29	$0.23
Lower consumption weight in utility	$0.85	$1.41	$1.13	$0.43	$0.63	$0.37	$0.29

Table 3: **Marginal excess burdens (MEB) of raising extra reveue from different taxes under different model specifications and assumptions.** Note that, CIT: Company income tax; ITC: Investment tax credit; DD: Depreciation deductions; PIT: Personal income tax; PAT: personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

Lump Sum Redistributive Authority

The hypothetical Lump Sum Redistributive Authority (LSRA) distributes the additional revenue so that all households undergo the same welfare change as measured by their equivalent variation. Unlike the LSRA of Auerbach and Kotlikoff (1987) the per period equivalent variation of all households is equal, not just future households. As all households experience the same welfare change, the policy causes either a Pareto improvement or deterioration. The magnitude of the welfare change can be used to assess the efficiency of the taxes at the margin.

Compared row 1 and row 2 of Table 3, we find that the LSRA changes are generally slightly larger than the AMEBs under the benchmark specification. The difference is in part due to the slightly larger decline in labour supply and output with the LSRA transfers. Effective labour supply generally declines further under the LSRA as the households who benefit most from the LSRA transfers are higher skill types and those with more time left in the labour market. This positive income effect causes these households to partake in more leisure and total effective labour supply to decline further. The corresponding decline in output reduces revenue meaning the welfare loss per dollar of net revenue is slightly larger.

Additional revenue to increase government consumption

In this exercise, we assume that the government allocates additional tax revenue to increase government spending instead of household transfers. The marginal excess burden in this experiment is taken as the equivalent variation minus the revenue change. As seen in row 2 of Table 3, the marginal excess burdens of all taxes are consistently smaller, compared to the baseline scenarios. The main reason is that there is no income effect from the additional transfers in this setting. Without the additional transfers household supply more labour and revenue increases. As such the distortions per dollar of revenue are relatively smaller. However, the ranking of tax distortions remains unchanged. The distributional effects are reported in Table 6.

Closed Economy

In the standard model specification the economy is modelled as small and open with perfect capital mobility. Foreigners are the marginal investor and the firm maximises it's value in line with these assumptions. In this sensitivity we instead specify a closed economy where the stock of assets equal the stock of savings. The firm is externally financed and maximises it's cum dividend value taking into account taxes paid by households on dividends and bonds and also the franking credits households receive.[17]

As seen in row 4 of Table 3, The AMEB for firm taxes are lower in the closed economy as the supply of capital is less elastic. As such taxes on capital create less of a distortion. Further in the closed economy taxing capital at the firm or the household

[17]The interest rate and capital to output ratios vary between the open and close economies. In moving to a closed economy we maintain household parameters such as the discount rate. As the foreign capital is not available in the closed economy the capital to output ratio is lower and the interest rate is higher.

level create similar distortions. PAT is most similar in its marginal impacts to decreasing depreciation or debt deductions.[18] CIT creates less of a distortion than PAT because the PAT allows for no deductions for variable capital which reduce the burden of the tax. We present the effects on skill types and ages in Table 7.

Foreign ownership

In the benchmark calibration we assume that foreigners own 17 per cent of assets. In this sensitivity analysis, we consider different foreign ownership rates.

We first lower the initial share of foreign ownership to zero while continuing to assume perfect capital mobility.[19] Table 8 indicates that the AMEB of the firm taxes is larger when there is less foreign ownership. The firm taxes raise less net revenue per unit of assets when the assets are owned by residents rather than foreigners because of the dividend imputation system. As a direct result, the distortion per dollar of net revenue is the higher when foreign ownership is lower. Furthermore, the company income tax (CIT) raises revenue from the fixed factor which is effectively a lump sum transfer from foreigners to residents. When foreign ownership is lower this transfer is smaller and the welfare loss from the CIT is larger.

Conversely, we consider an increase in the share of foreign ownership from 17 per cent to 50 per cent. As seen in Table 9 this has the opposite impact to lowering foreign ownership. The aggregate distortion from the firm taxes decreases. The alternate foreign ownership specifications change the magnitude of the MEBs but ordering of the aggregate distortions is preserved. However, the preferences over different tax instruments of households changes. With increased foreign ownership young household prefer the CIT to the PIT, PAT and CT.

Fixed factors

In the standard calibration the fixed factor of production contributes 2 per cent of output calibrated to the contribution of non-residential land. Cao et al. (2015) assume that natural resources and other fixed factors contribute a further 6 per cent of output. In this sensitivity analysis, we increase fixed factors contribution to 8 per cent of output and then decrease it to zero. We summarized the results of the sensitivity analysis with fixed factors in Tables 11 and 10.

We find that the AMEB is lower for the firm taxes when fixed factors contribute a

[18] The personal asset income tax is a tax on both dividends and interest received but no capital gains. While we could examine the impacts of dividend, interest and capital gains taxes individually a model such as Gourio and Miao (2011) is far better suited to looking at these.

[19] The foreign ownership share is lowered by adjusting the assets held by residents. This is done by lowering the households discount rate by changing the parameter β from 0.987 to 0.990.

larger share of output. Taxing the fixed factor of production is essentially a lump sum tax. As such when there are more fixed factors the firm taxes are less distortionary. Further taxing the fixed factor is partially a transfer from foreigners to residents, this raises domestic welfare. More fixed factors means there is a larger transfer from foreigners to residents to offset the welfare losses due to the distortions of the taxes. While the ordering of the AMEB for the different taxes is again preserved the impacts on different groups vary. Under the increased fixed factor specifications future households prefer company income tax over the other taxes as it delivers a welfare increase on average.

Without the fixed factor the asset price decrease from an increase in the company income tax is less than in the benchmark model. As such the welfare loss of households alive at the time of the policy change is less. When there are no fixed factors distortion is larger in aggregate due to a more flexible production sector. However, household alive at the of the policy change would, on average, prefer a consumption tax increase over a company income tax increase. The consumption tax increase immediately makes their consumption more expensive while the company income tax increase mainly lowers future wages.

Franking credits

In the benchmark calibration households are allowed to deduct 37 per cent of franking credits. In this experiment, we consider two extreme cases: (*i*) no franking credit use; and (*ii*) 100 per cent franking credit use. The results are reported in Tables 12 and 13.

We find that in the no franking credit case an increase in the CIT raises more net revenue. The increase in the CIT is not fully offset by the franking credit use in the personal tax system. As a result, the distortion per dollar of revenue is lower. Conversely, in a setting where 100 per cent franking credit can be used an increase in the CIT results in a net revenue decrease. The increase in CIT revenue is more than offset by increased franking credit use and the decline in the other tax bases. With 100 per cent franking credit use the CIT is beyond the peak of the Laffer curve at that rate. The AMEB is negative as the revenue change is negative.

Debt to equity ratio

Under the standard model specification we assume a constant share of capital is financed through debt. In this sensitivity we allow the firm to borrow a fixed share of the value of its equity. Note that, as the price of equity is greater than the value of capital we decrease the ratio of debt to equity, so that the overall level of firm debt is held constant in both the benchmark model and in this sensitivity analysis. Table 14 displays the result of this experiment. In this setting when changes in the value of firm equity result in changes in the firm's borrowing capacity. However, the effect through this channel is rather small. There is only a marginal increase in the distortion of the firm taxes.

Faster capital adjustment

In our benchmark economy, half of the capital stock adjustment in response to a tax change is completed within approximately 9 years. We adjust the parameters so that half of capital stock adjustment is completed in 4 years. In particular, we lower the capital adjustment cost parameter ψ from 3.3 to 0.25. When the firm responds more quickly to tax changes the distortion of taxation is higher. However, the model also assumes firms are not able to deduct adjustment costs from taxable revenue which means adjustment costs raise the distortion of firm taxes. As shown in Table 15, under the calibration used here the second effect dominates. A lower adjustment cost leads to a lower distortion for firm taxes.

No economic growth

We assume that productivity and populations grow by 1.7 per cent per year in our benchmark calibration. We now check our results with a no growth assumption. That is, both population and productivity growth are set to zero, while the risk free interest rate is maintained. We report the results in Table 16. We find that lower growth decreases the NPV of future revenue and welfare. Distortions that manifest in the future are given lower weight when growth is lower. When there is no growth the company income tax (CIT) has the lowest AMEB.

Decreased inter-temporal elasticity of substitution

In the benchmark calibration the inter-temporal elasticity of substitution is 0.4. We test an inter-temporal elasticity of substitution of 0.2. We report the results in Table 17. We find that reducing the elasticity of inter-temporal substitution reduces the distortion to saving from the personal income tax (PIT) and the personal asset tax (PAT).

Increased elasticity of labour supply

We conduct a sensitivity analysis with the consumption share of utility. We consider a lower consumption share of 0.125, compared to 0.25 in the benchmark model. Our simulation results are summarized in Table 18. We find that a reduction in the consumption share of utility increases the uncompensated elasticity of labour supply. The distortions from taxes that predominantly affect the labour supply decision increase.

6 Conclusion

We assess the economic costs of distortionary taxes through the lens of marginal excess burden in a dynamic general equilibrium, overlapping generations model calibrated to Australian data. We quantify the aggregate marginal excess burden for different taxes on the firm and household sides. We find that taxes which are broadly considered as falling on capital income are more distorting than the taxes on labour income and consumption. This confirms the findings in the literature that the overall efficiency of the tax system can be improved by relying less on capital income taxes with high marginal excess burden and more on consumption taxes with low marginal excess burden. More importantly, we are able to map out the distribution of excess burdens. The uneven distribution of excess burdens across households and generations implies political challenges when obtaining popular support for the tax reforms. Those who benefit the most will likely have to compensate those who do not benefit as much.

Our work demonstrates that the marginal excess burden approach can be extended to a dynamic general equilibrium model filled with overlapping generations and firms with realistic financial policy. Moreover, it provides policy makers with a simple but informative index for assessing the direction of tax policy change as it allows for clear comparison between different taxes.

The magnitudes of the distortions of the taxes hinge on our modelling assumptions including market structures and heterogeneity. The core model assumes perfect capital mobility and using an assumption of imperfect capital mobility would make company income tax less distorting. The model also assumes a homogeneous good but allowing for multiple goods and imperfect substitution between domestic and international production would introduce further rigidities and lower the measures of distortions. The set-up of household sector is simplified. While allowing for household heterogeneity by age and skill we abstract from exogenous income shocks. There is no precautionary savings motive. Furthermore, we abstract from firm heterogeneity and firm financing. Our model can be extended to examine the accuracy of marginal analysis. We leave these issues for future research.

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7 Appendix

7.1 Calibration tables

Parameters:		Explanation/Source:
- Periods working	$J_1 = 45$	
- Periods retired	$J_2 = 35$	
- Population growth rate	$n = 0.017$	ABS data in 2014
- Labor productivities by skill	$\{e_j\}_{j=1}^{J_1}$	Calculated from HILDA data
- Total factor productivity	$Z = 1$	Normalization
- Labour augmenting productity growth	$g^{\Lambda} = 0.017$	Average GDP growth 1990-2014
- World interest rate	$r = 0.37$	
- Labor income share	$\alpha_n = 0.59$	Calculated from ABS data
- Capital income share	$\alpha_k = 0.39$	Calculated from ABS data
- Capital depreciation	$\delta = 0.056$	Calculated from ABS data
- Debt to equity ratio	$\xi = 0.27$	
- Franking credit share	$\chi^{FC} = 0.368$	Cao et al (2015)
- Debt deduction share	$\chi^{\xi} = 1.0$	Cao et al (2015)
- Investment tax credit share	$\chi^{I} = 0.05$	Cao et al (2015)
- Depreciation deduction share	$\chi^{d} = 0.95$	Cao et al (2015)

Table 4: External Parameters

Parameters:		Explanation/Source:
- Relative risk aversion	$\sigma = 2.5$	to match $\frac{K}{Y}$ and R
- Preference on consumption vs. leisure:	$\gamma = 0.25$	to match labor supply
- Discount factor	$\beta = 0.978$	to match 17% net foreign ownership
- Capital adjustment cost	$\psi = 0.33$	to match q-ratio
- Company Income tax	$\tau^k = 0.294$	to match revenue/ GDP (ABS 5204)
- Personal income tax	$\tau^p = 0.252$	to match revenue/ GDP
- Consumption tax	$\tau^c = 0.064$	to match revenue/ GDP
- Residual Government spending	G	to match size of tax revenue

Table 5: Internal parameters used to match a set of target moments in the data.

7.2 Additional result tables and figures

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	\$0.54	\$0.94	\$0.76	\$0.13	\$0.24	\$0.09	\$0.04
Old	\$0.84	-\$1.86	-\$0.28	-\$0.82	-\$0.39	-\$0.95	-\$0.27
Young	\$0.28	-\$1.27	-\$0.29	-\$0.10	\$0.47	-\$0.28	\$0.02
Future	\$0.66	\$1.70	\$1.12	\$0.22	\$0.22	\$0.22	\$0.05
Type 1	-\$0.18	\$0.04	-\$0.06	-\$0.43	-\$0.40	-\$0.43	-\$0.30
Type 2	\$0.46	\$0.84	\$0.66	\$0.07	\$0.18	\$0.04	-\$0.01
Type 3	\$1.33	\$1.92	\$1.65	\$0.72	\$0.94	\$0.67	\$0.44

Table 6: **Marginal excess burdens (MEB) with additional tax revenue allocated to general government consumption.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	GST
Aggregate	\$0.63	\$0.89	\$0.74	\$0.41	\$0.75	\$0.29	\$0.24
Old	\$0.15	-\$1.36	-\$0.50	-\$0.52	-\$0.51	-\$0.53	\$0.06
Young	\$0.74	-\$0.06	\$0.43	\$0.13	\$0.43	\$0.03	\$0.29
Future	\$0.76	\$1.83	\$1.18	\$0.68	\$1.21	\$0.50	\$0.25
Type 1	-\$0.16	-\$0.02	-\$0.09	-\$0.27	-\$0.09	-\$0.33	-\$0.16
Type 2	\$0.55	\$0.80	\$0.66	\$0.34	\$0.67	\$0.22	\$0.18
Type 3	\$1.47	\$1.87	\$1.65	\$1.13	\$1.66	\$0.95	\$0.71

Table 7: **Marginal excess burdens (MEB) in a closed economy.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	$1.13	$1.57	$1.41	$0.34	$0.43	$0.32	$0.24
Old	$2.41	-$2.24	$0.45	-$0.59	-$0.17	-$0.75	$0.11
Young	$1.03	-$1.79	-$0.05	$0.11	$0.69	-$0.11	$0.28
Future	$1.22	$2.75	$1.93	$0.45	$0.41	$0.47	$0.25
Type 1	$0.12	$0.35	$0.26	-$0.30	-$0.26	-$0.31	-$0.16
Type 2	$1.02	$1.44	$1.28	$0.28	$0.36	$0.25	$0.19
Type 3	$2.23	$2.90	$2.65	$1.03	$1.17	$0.99	$0.71

Table 8: **Marginal excess burdens (MEB) with lower foreign ownership share.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	$0.55	$1.02	$0.79	$0.31	$0.53	$0.28	$0.23
Old	$0.19	-$1.40	-$0.46	-$0.74	-$0.06	-$0.85	-$0.19
Young	$0.01	-$0.68	-$0.22	$0.04	$0.94	-$0.11	$0.13
Future	$0.75	$1.61	$1.15	$0.42	$0.49	$0.42	$0.27
Type 1	-$0.14	$0.12	-$0.01	-$0.36	-$0.48	-$0.34	-$0.18
Type 2	$0.48	$0.93	$0.70	$0.25	$0.45	$0.22	$0.17
Type 3	$1.30	$2.00	$1.65	$1.03	$1.59	$0.94	$0.69

Table 9: **Marginal excess burdens (MEB) with higher foreign ownership share**. Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	$0.33	$1.32	$1.05	$0.32	$0.38	$0.29	$0.22
Old	$4.63	-$0.71	$1.18	-$0.46	-$0.20	-$0.60	$0.42
Young	$2.27	-$1.01	$0.29	$0.15	$0.61	-$0.09	$0.41
Future	-$0.26	$2.18	$1.37	$0.40	$0.37	$0.43	$0.17
Type 1	-$0.31	$0.19	$0.05	-$0.28	-$0.22	-$0.31	-$0.16
Type 2	$0.26	$1.20	$0.95	$0.26	$0.32	$0.23	$0.16
Type 3	$1.03	$2.54	$2.14	$0.98	$1.04	$0.95	$0.67

Table 10: **Marginal excess burdens (MEB) with increased fixed factors.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	$1.11	$1.34	$1.17	$0.33	$0.45	$0.30	$0.24
Old	-$0.28	-$2.34	-$0.39	-$0.72	-$0.12	-$0.86	-$0.13
Young	-$0.28	-$1.43	-$0.32	$0.05	$0.79	-$0.13	$0.16
Future	$1.60	$2.28	$1.68	$0.44	$0.41	$0.45	$0.28
Type 1	$0.19	$0.30	$0.22	-$0.34	-$0.39	-$0.33	-$0.17
Type 2	$1.01	$1.23	$1.06	$0.26	$0.37	$0.24	$0.19
Type 3	$2.12	$2.46	$2.20	$1.04	$1.34	$0.98	$0.72

Table 11: **Marginal excess burdens (MEB) with no fixed factors.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	$0.70	$1.02	$0.86	$0.42	$0.84	$0.33	$0.25
Old	$0.64	-$1.03	-$0.09	-$0.65	-$0.01	-$0.80	$0.00
Young	$0.63	-$0.30	$0.26	$0.13	$1.13	-$0.10	$0.24
Future	$0.78	$1.51	$1.11	$0.54	$0.83	$0.48	$0.27
Type 1	-$0.13	$0.04	-$0.05	-$0.29	-$0.15	-$0.32	-$0.15
Type 2	$0.62	$0.92	$0.76	$0.35	$0.75	$0.26	$0.19
Type 3	$1.61	$2.08	$1.84	$1.18	$1.89	$1.02	$0.72

Table 12: **Marginal excess burdens (MEB) with no franking credit.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	-$1.03	-$3.35	-$1.35	$0.20	$0.09	$0.26	$0.21
Old	-$2.29	$5.01	-$0.84	-$0.61	-$0.26	-$0.77	$0.02
Young	-$0.27	$5.55	$0.49	$0.03	$0.37	-$0.12	$0.23
Future	-$1.21	-$6.24	-$1.89	$0.29	$0.05	$0.40	$0.22
Type 1	-$1.04	-$2.31	-$1.21	-$0.37	-$0.44	-$0.33	-$0.19
Type 2	-$1.02	-$3.22	-$1.32	$0.14	$0.03	$0.20	$0.15
Type 3	-$1.04	-$4.51	-$1.53	$0.82	$0.65	$0.90	$0.67

Table 13: **Marginal excess burdens (MEB) with increased franking credits.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	GST
Aggregate	$0.86	$1.33	$1.11	$0.34	$0.47	$0.30	$0.24
Old	$1.28	-$1.95	$0.01	-$0.64	-$0.13	-$0.79	$0.01
Young	$0.54	-$1.28	-$0.10	$0.09	$0.76	-$0.11	$0.23
Future	$1.01	$2.22	$1.54	$0.44	$0.45	$0.45	$0.25
Type 1	-$0.00	$0.24	$0.13	-$0.32	-$0.29	-$0.32	-$0.16
Type 2	$0.77	$1.21	$1.00	$0.27	$0.40	$0.24	$0.18
Type 3	$1.81	$2.50	$2.17	$1.04	$1.29	$0.97	$0.70

Table 14: **Marginal excess burden with debt tied to equity.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	$0.52	$0.97	$0.78	$0.34	$0.54	$0.29	$0.23
Old	$0.84	-$2.45	-$0.77	-$0.72	-$0.20	-$0.86	-$0.07
Young	$0.49	-$1.26	-$0.26	$0.10	$0.86	-$0.11	$0.22
Future	$0.51	$1.66	$1.08	$0.44	$0.51	$0.43	$0.24
Type 1	-$0.18	$0.07	-$0.04	-$0.32	-$0.27	-$0.33	-$0.17
Type 2	$0.44	$0.87	$0.69	$0.28	$0.46	$0.23	$0.17
Type 3	$1.28	$1.95	$1.67	$1.06	$1.41	$0.96	$0.69

Table 15: **Marginal excess burdens (MEB) with faster capital adjustment.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	$0.13	$2.09	$0.31	$0.39	$0.78	$0.29	$0.21
Old	$0.10	-$4.53	-$0.30	-$0.60	$0.06	-$0.78	-$0.07
Young	-$0.34	-$1.56	-$0.43	$0.27	$1.01	$0.07	$0.20
Future	$0.91	$9.47	$1.60	$0.80	$0.88	$0.78	$0.29
Type 1	-$0.46	$0.67	-$0.36	-$0.23	$0.01	-$0.29	-$0.19
Type 2	$0.08	$1.96	$0.25	$0.32	$0.68	$0.23	$0.15
Type 3	$0.74	$3.59	$1.01	$1.07	$1.63	$0.92	$0.67

Table 16: **Marginal excess burdens (MEB) with no economic growth.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	$1.03	$1.45	$1.30	$0.29	$0.29	$0.29	$0.23
Old	$1.85	-$1.90	$0.28	-$0.64	-$0.24	-$0.78	$0.05
Young	$0.66	-$1.31	-$0.07	$0.04	$0.54	-$0.13	$0.21
Future	$1.19	$2.43	$1.79	$0.39	$0.26	$0.44	$0.25
Type 1	$0.08	$0.32	$0.23	-$0.33	-$0.36	-$0.32	-$0.16
Type 2	$0.93	$1.33	$1.18	$0.22	$0.22	$0.23	$0.17
Type 3	$2.05	$2.68	$2.45	$0.96	$0.99	$0.95	$0.69

Table 17: **Marginal excess burdens (MEB) with lower intertemporal elasticity.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

	CIT	ITC	DD	PIT	PAT	PLT	CT
Aggregate	$0.85	$1.41	$1.13	$0.43	$0.63	$0.37	$0.29
Old	$1.18	-$1.91	-$0.08	-$0.58	$0.01	-$0.76	$0.04
Young	$0.61	-$1.29	-$0.08	$0.17	$0.96	-$0.06	$0.29
Future	$0.99	$2.33	$1.57	$0.54	$0.61	$0.53	$0.31
Type 1	-$0.06	$0.23	$0.09	-$0.30	-$0.23	-$0.32	-$0.15
Type 2	$0.76	$1.29	$1.03	$0.36	$0.55	$0.31	$0.23
Type 3	$1.83	$2.67	$2.25	$1.20	$1.55	$1.11	$0.80

Table 18: **Marginal excess burdens (MEB) with smaller consumption weight in utility.** Note that, CIT: Company income tax; ITC: Investment tax credits; DD: Depreciation deductions; PIT: Personal income tax; PAT: Personal asset income tax; PLT: Personal labour income tax; and CT: Consumption tax.

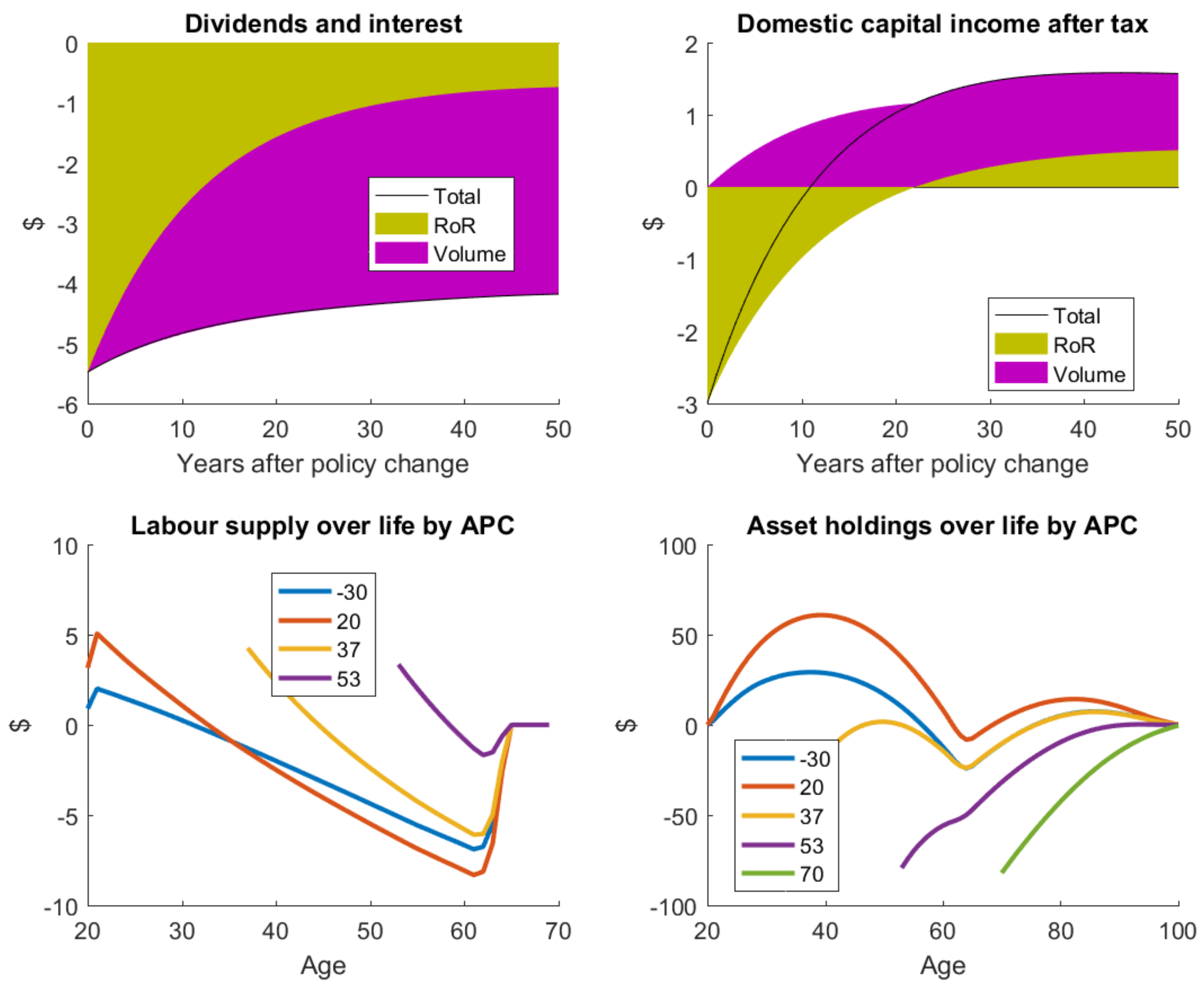

Figure 6: **The impacts of company income tax (CIT) increase.** Note that, the CIT is permanently adjusted to raise the targeted net present value (NPV) revenue increase by $1.

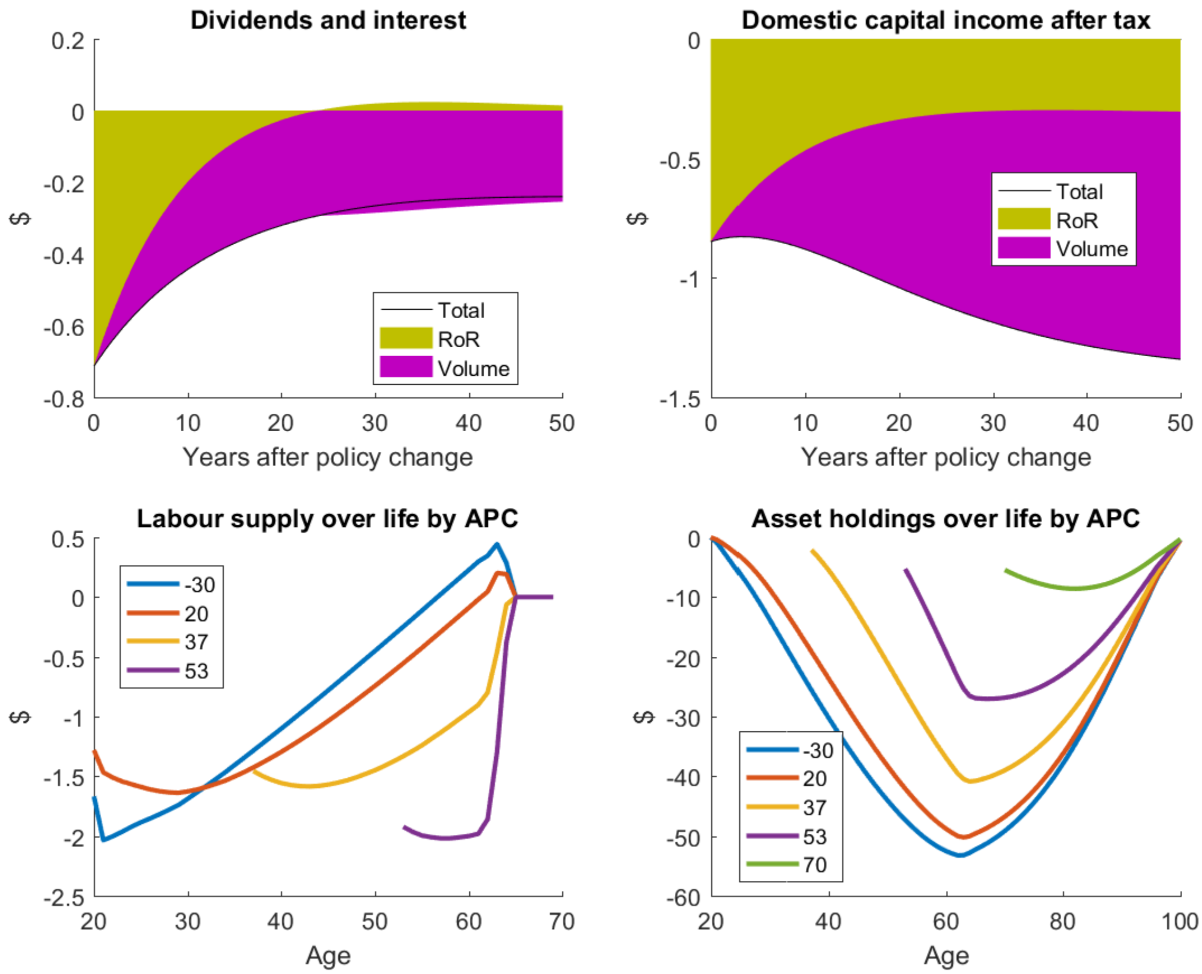

Figure 7: **The impact of personal income tax (PIT) increase.** Note that, the PIT is permanently adjusted to raise the targeted net present value (NPV) revenue increase by $1.

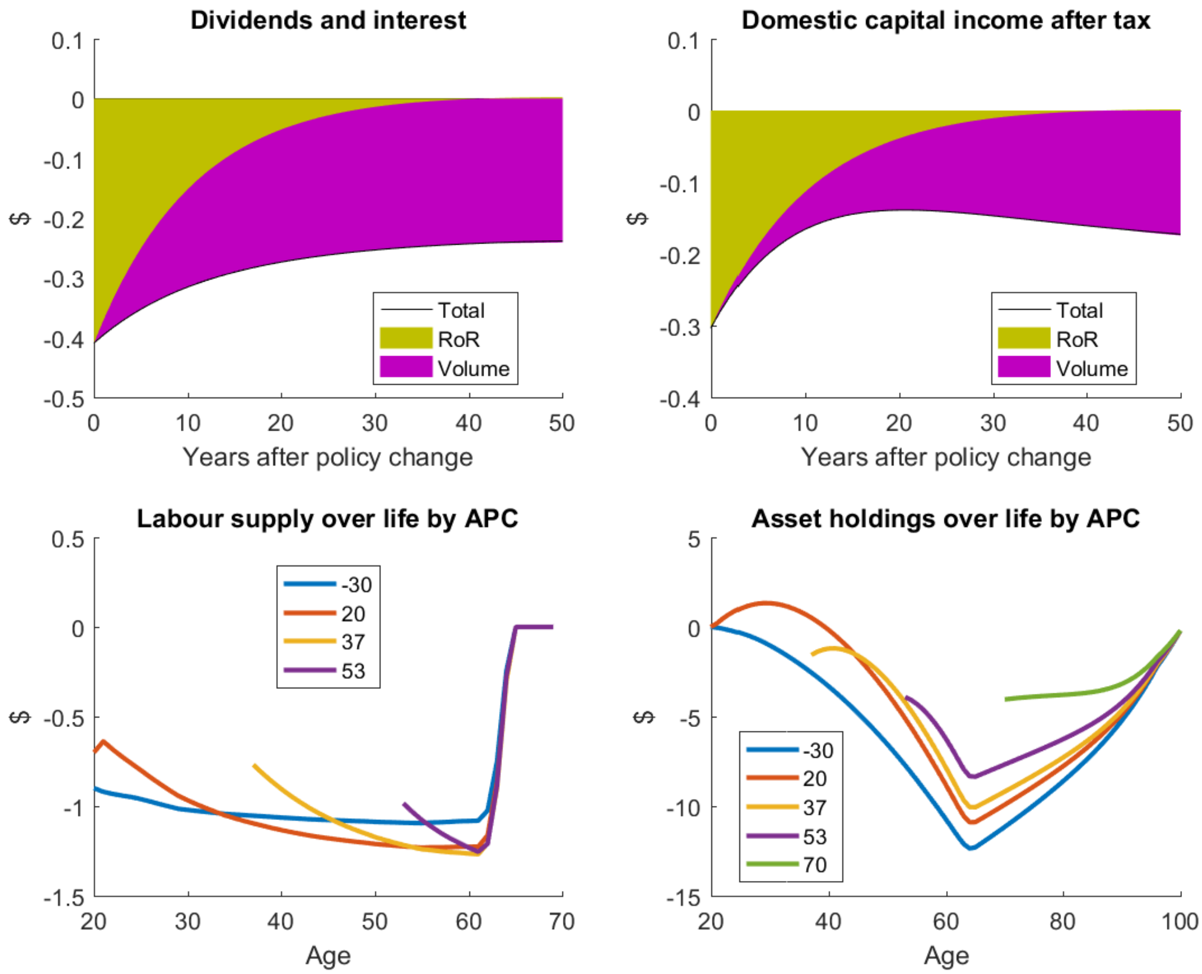

Figure 8: **The impacts of consumption tax (CT) increase.** Note that, the CT is permanently adjusted to raise the targeted net present value (NPV) revenue increase by $1.

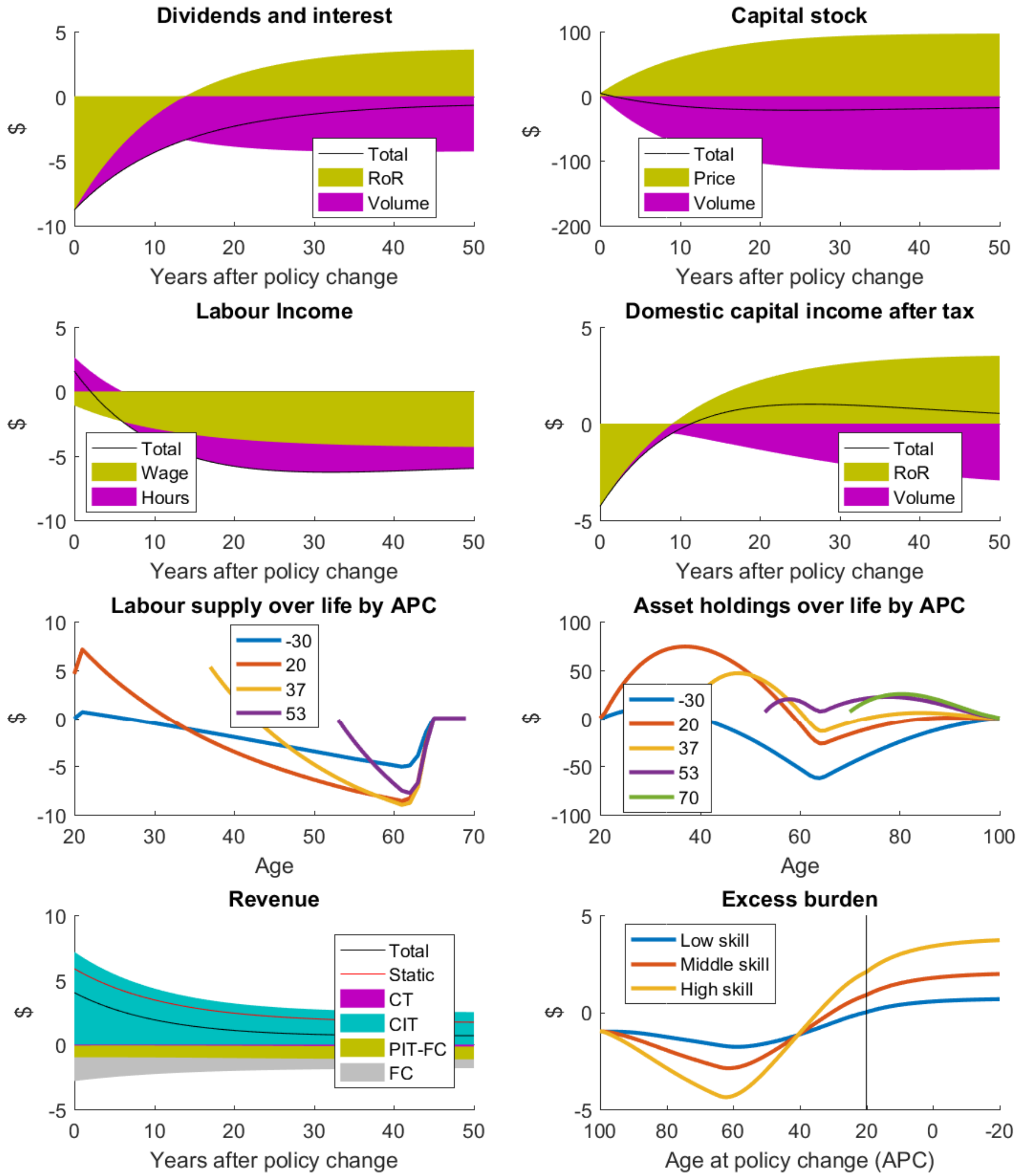

Figure 9: **The impact of investment tax credit (ITC) reduction.**

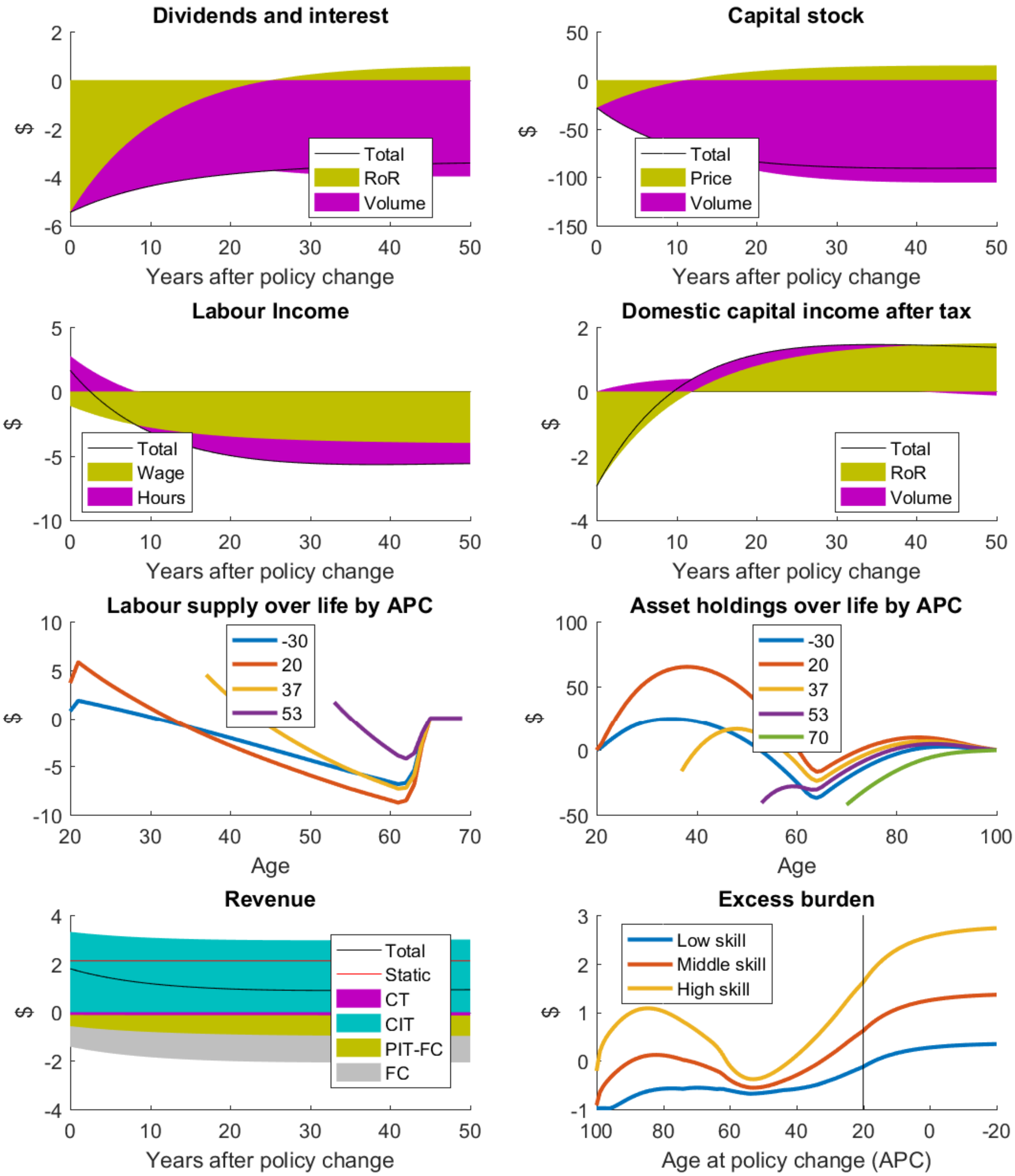

Figure 10: **The impacts of debt deduction (DD) reduction.**

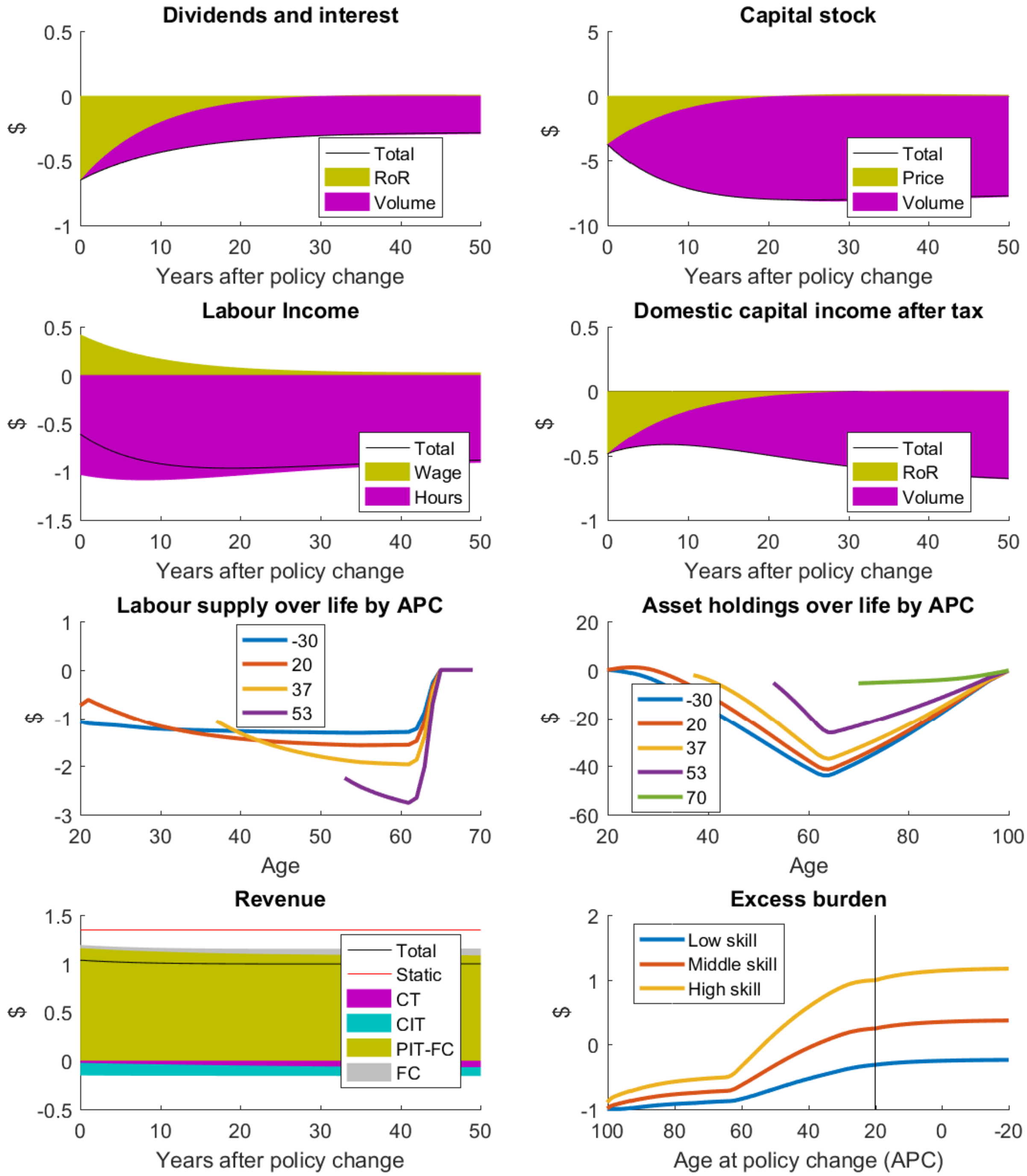

Figure 11: **The impacts of personal labour income tax (PLT) increase.**

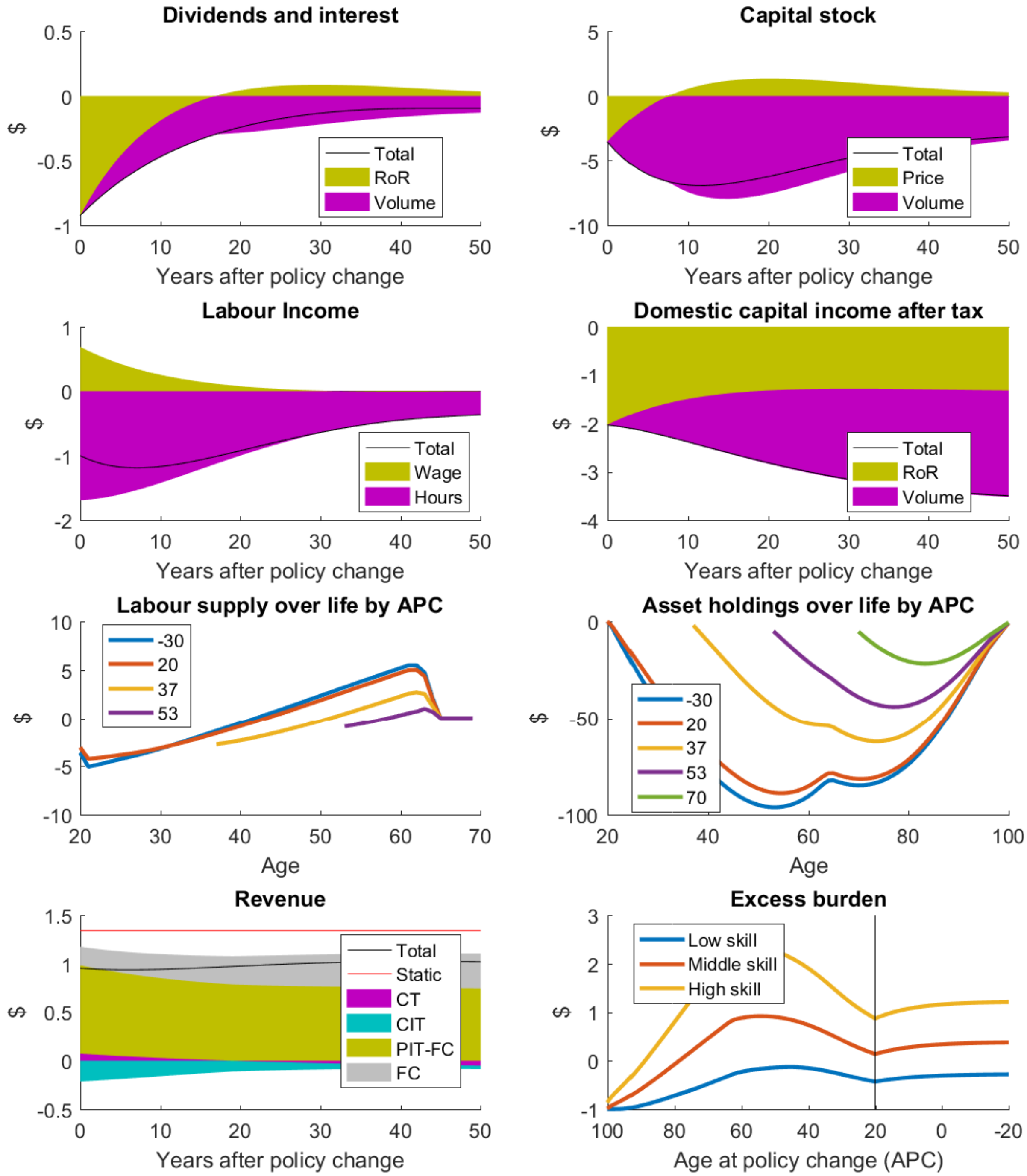

Figure 12: **The impacts of personal asset income tax (PAT) increase.**