Fiscal consolidation and climate policy: An overlapping generations perspective*

Sebastian Rausch

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Ronald G. Prinn and John M. Reilly,
Program Co-Directors

For more information, contact the Program office:

MIT Joint Program on the Science and Policy of Global Change
Postal Address:
Massachusetts Institute of Technology
77 Massachusetts Avenue, E19-411
Cambridge, MA 02139 (USA)
Location:
Building E19, Room 411
400 Main Street, Cambridge
Access:
Tel: (617) 253-7492
Fax: (617) 253-9845
Email: ***globalchange@mit.edu***
Website: ***http://globalchange.mit.edu/***

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Sebastian Rausch *

Center for Economic Research at ETH Zurich (CER-ETH), ETH Zurich, Switzerland, and MIT Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology, Cambridge, USA

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ABSTRACT

This paper examines the distributional and efficiency impacts of public debt consolidation financed through a carbon tax employing a dynamic general-equilibrium model with overlapping generations of the U.S. economy. The numerical model features government taxes and spending and a multi-sectoral production structure including intermediate production, specific detail on the energy sector both in terms of primary energy carriers and energy-intensive industries, and sector- and fuel-specific carbon inputs. In contrast to revenue-neutral carbon tax swaps, using the carbon revenue for deficit reduction implies a relaxation of future public budgets as debt repayment results in lower future interest obligations. While intergenerational welfare impacts depend importantly on what tax recycling instrument is used, we find that combining public debt consolidation with a carbon policy entails the possibility of sustained welfare gains for future generations. If social discount rates are sufficiently low or if social preferences exhibit a large aversion with respect to intergenerational inequality, combining fiscal consolidation and climate policy may offer the chance for societal gains even without considering potential benefits from averted climate change.

1. Introduction

Putting a price on carbon—which is the most prevalent greenhouse gas—has the potential to address two long-term problems. One is the problem of growing debt in the United States with potentially detrimental implications for economic growth. The revenue from a carbon tax could be used to reduce the deficit or to finance reductions in marginal rates of existing taxes while holding the deficit constant (or a combination of both). The other problem is the build-up of carbon dioxide in the atmosphere–the principal anthropogenically sourced greenhouse gas–contributing to global climate change derived from burning fossil fuels. Leaving this environmental externality unaddressed is expected to create costly damages.

While an extensive literature has studied the interactions of environmental taxes and the broader fiscal system and the double-dividend (see e.g., Bovenberg and Goulder, 1996)—largely focusing on revenue-neutral carbon tax swaps to fund marginal rate cuts in distortionary taxes—the economic effects of using revenue-raising climate policy to reduce government debt have not been investigated widely. This paper presents an attempt to fill this gap by addressing a central question: in the light of weak political support for a greenhouse gas control policy in the United States, can a carbon pricing policy be socially desirable if combined with a fiscal policy aimed at reducing public debt? Using carbon revenues for deficit reduction implies a relaxation of future public budgets as debt repayment results in lower interest obligations. Recycling future budget surpluses by lowering distortionary taxes therefore entails the opportunity of positive and sustained welfare gains for future generations despite increased energy prices due to carbon pricing. Current young and subsequent generations, however, who do not live long enough to reap the benefits of relaxed future public budgets will likely have to bear the burden of deficit reduction raising potential concerns about intergenerational equity.

To shed light on the efficiency and intergenerational distributional effects of such a combined climate and fiscal consolidation policy, we develop a dynamic general-equilibrium overlapping generations (OLG) model for the U.S. economy that is uniquely well-suited to assessing the impacts of a carbon price on the macro-economy, its interactions with important fiscal tax distortions, and the public budget (including government spending and income from a range of different tax instruments). Our model setup is similar to Auerbach and Kotlikoff (1987) and Altig et al. (2001) where households with rational expectations live for a finite number of periods and maximize their lifetime utility by choosing optimal life-cycle consumption and savings behavior. A key difference is the disaggregated multi-sectoral production structure of the model including intermediate production, specific detail on the energy sector both in terms of primary energy carriers and energy-intensive industries, and sector- and fuel-specific carbon inputs. The model thus combines elements of a standard Auerbach and Kotlikoff (1987)-type OLG approach with those of energy-economy models typically employed to investigate climate policy issues (see e.g., Paltsev

* Department of Management, Technology, and Economics, ETH Zurich, Zürichbergstrasse 18, ZUE E7, 8032 Zurich, Switzerland. Tel.: +41 44 632 63 59.
E-mail address: srausch@ethz.ch.

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et al., 2005; Caron et al., 2012). Finally, the choice of an OLG over an infinitely-lived agent (ILA) framework to investigate the economic impacts of public debt reduction financed through carbon taxation is motivated by the Ricardian equivalence result: as consumers in the standard Ramsey (1928), Cass (1965), Koopmans (1965) ILA framework internalize the government's budget constraint, it does not matter whether a government finances its spending with debt or a tax increase.

With fiscal consolidation and climate policy as high-priority policy issues in the United States (and many European countries), it seems important to arrive at a better understanding of how the gains and losses from a jointly implemented climate and fiscal policy are determined. While different fiscal reform measures for debt consolidation are conceivable (including contraction in government spending, increases in average and marginal wage tax rates, and other taxes), we focus solely on debt consolidation through raising revenue from a policy that puts a price on carbon. We consider two sets of counterfactual policy scenarios. A first set of scenarios, following the setup typically found in the "double-dividend" literature, looks at the impact of revenue-neutral carbon tax swaps using either capital, labor, or consumption-based taxes as recycling instruments. A second set of scenarios uses the carbon revenue to repay government debt which in turn produces future budget surpluses as a result of reduced interest payment obligations. These public budget surpluses are then used to fund cuts in marginal tax rates of capital, labor, or consumption.

Our model produces several results. First, in the context of a revenue-neutral carbon tax swap that employs either capital, labor, or consumption taxes to recycle the carbon revenue all generations incur welfare losses (an exception is the consumption-based tax recycling where current old households gain as they exhibit relatively large consumption shares). In contrast, if the carbon revenue is used to repay the principal public debt, the level of future tax rates can be reduced to a permanently lower level. We find that while elderly households and current young are worse off as compared to a revenue-neutral tax swap, that future generations stand the chance of sustained welfare gains. These gains are larger if future budget surpluses are used to fund rate cuts in marginal capital and labor taxes as compared to consumption-tax recycling as these positively impact savings and labor supply decisions of households. Second, when we evaluate these outcomes formally, using an explicit social welfare function, we find that revenue-neutral carbon tax swaps result in a negative societal assessment for virtually any combination of social discount rates and inequality aversion. The picture changes drastically if debt reduction is considered as an option to recycle the revenue from a carbon pricing policy: if social discount rates are sufficiently low or if social preferences place a large weight on intergenerational equity, we find that a combined fiscal consolidation and climate policy can be desirable from a social standpoint. Importantly, these results are derived without considering potential benefits from averted climate change.[1]

Finally, our analysis shows that the benefits from combining climate and debt consolidation policies are limited. While a more stringent carbon policy generates more revenue that can be used to repay government debt, and thus has the potential to result in large reductions of future interest obligations, an aggressive carbon policy at the same time reduces economic growth and brings about lower revenue from other tax sources. We find that moderate carbon policies (in combination with a debt consolidation program) starting with a carbon price of \$20 per ton of CO_2 yield societal welfare gains for annual social discount rates of around 2.5%. Much lower social discount rates are required to support more stringent carbon policies (that are part of a fiscal consolidation package).

Our analysis is closely related to Carbone et al. (2012) who also in the context of U.S. policy examine the welfare impacts of stabilizing the long-term debt-to-GDP ratio at 60%. While their analysis is also based on an OLG simulation model and considers using the revenues from a carbon policy to fund tax cuts—as part of a larger fiscal reform package that includes cutting government spending—they do not consider explicitly the option of debt repayments which results in lower interest payment obligations in the future. The scarce economic literature investigating the interactions between a carbon pricing and fiscal consolidation policy further comprises two recent papers by McKibbin et al. (2012) and Rausch and Reilly (2012). McKibbin et al. (2012) compare the economic costs of different ways of reducing the budget deficit and find that a carbon tax lowers GDP more (less) than a labor (capital) tax increase. Overall, and in line with Rausch and Reilly (2012) a key insight is that a carbon tax offers a way to help reduce the deficit and improve the environment with minimal disturbance to overall economic activity. Both studies, however, employ a representative-agent framework and are thus not able to investigate the intergenerational implications of fiscal and climate policies.

The remainder of this paper is structured as follows. Section 2 presents our analytical framework and discusses issues related to the numerical implementation of the model. Section 3 describes our scenarios and the welfare metric to assess efficiency and distributional considerations from a societal perspective. Section 4 presents and discusses our results. Section 5 concludes.

2. The model

2.1. Aggregate demand and government budget

Time is discrete and extends from $t = 0, \ldots, \infty$. There is no aggregate or household-specific uncertainty. The demand side of our aggregate economy in time period t is characterized by national account balances relating capital income (W_t), labor income (L_t), income from natural resources (Z_t),government transfers (T_t), private sector consumption (C_t), private sector net saving (S_t), public sector consumption (G_t), the government budget deficit (M_t), the trade deficit (E_t), investment (I_t), and tax rates on capital, labor, consumption, output, and carbon emissions. These include the aggregate income balance:

$$W_t + L_t + Z_t + T_t = C_t + S_t \tag{1}$$

and the savings-investment balance:

$$S_t - M_t + E_t = I_t. \tag{2}$$

The annual identity for the government budget states that the deficit run by the government through year t is equal to the change in the stock of debt (D_t) between (beginning-of-years) $t + 1$ and t:

$$p_t^G G_t + T_t - \Phi_t + rD_t = B_t - R_t = D_{t+1} - D_t, \tag{3}$$

where $p_t^G G_t$ is the value of public spending, Φ_t is the tax revenue, r is the real interest rate, B_t is the additional borrowing, and R_t is the repayment of the principal. Tax revenue is obtained from capital and labor income taxes, consumption taxes, and sector-specific ad-valorem output taxes.

Debt repayment affects the net public expenditures (N_t) in current and future periods according to the equation:

$$N_t = R_t + rD_t - B_t = R_t + r\left(D_0 - \sum_{\tau=0}^{t} (R_\tau - B_\tau)\right). \tag{4}$$

The public budget can then be written as:

$$p_t^G G_t + T_t + N_t = \Phi_t. \tag{5}$$

In period t, gross investments (I_t) add to the next periods capital stock (K_{t+1}) according to the standard accumulation equation:

$$K_{r,t+1} = (1-\delta)\, K_{r,t} + I_{r,t}, \tag{6}$$

[1] This paper is only concerned with assessing the cost side of the cost-benefit ledger, i.e., it focuses on economic costs or welfare gross of environmental benefits.

where δ is the constant depreciation rate and where I_t is a Leontief composite of inputs. For simplicity, the model abstracts from capital adjustment costs. Savings and labor are supplied as a result of intertemporal optimization decisions by the different generations of households.

2.2. Overlapping generations households

The economy is populated by overlapping generations. A household of generation g is born at the beginning of year $t = g$, lives for $N + 1$ years, and is endowed with $\omega_{g,t} = \omega\,(1+\gamma)^g$ units of time in each period $g \le t \le g + N$.[2] In each period over the life cycle households are endowed with units of time that they allocate between labor and leisure.[3] Households are assumed to be forward-looking individuals that form rational point expectations (perfect foresight) over their finite lifetime. γ denotes the exogenous steady-state growth rate of the economy. This can be thought of as a combined growth rate representing population growth and (exogenous) labor-augmenting technological progress. Leisure time, $\ell_{g,t}$, enters in a constant-elasticity-of-substitution (CES) function with consumption, $c_{g,t}$, to create full consumption, $z_{g,t}$. Lifetime utility of generation g in region r, $u_{g,r}$, is additively separable over time and is of the constant-intertemporal-elasticity-of-substitution form (CIES). The representative agent of each generation and type chooses optimal consumption and leisure paths over his life cycle subject to lifetime budget and time endowment constraints. The optimization problem for generation g in region r is given by:

$$\begin{aligned}
&\max_{c_{r,g,t},\ \ell_{r,g,t}} u_{r,g}\left(z_{r,g,t}\right) = \sum\nolimits_{t=g}^{g+N}\left(\frac{1}{1+\hat{\rho}}\right)^{t-g}\frac{z_{r,g,t}^{1-1/\sigma}}{1-1/\sigma}\\
&s.t.\quad z_{r,g,t}\quad \left(\alpha c_{r,g,t}^{\nu}+(1-\alpha)\ell_{r,g,t}^{\nu}\right)^{\frac{1}{\nu}}\\
&\sum_{t=g}^{g+N} p_{r,a,t}\ c_{r,g,t} \le p_{r,k,t}\ \bar{k}_{r,g,g}+\sum_f p_{r,f,t}\bar{z}_{r,f,g}+\sum_{t=g}^{g+N} p_{r,l,t}\ \pi_{g,t}\ \left(\omega_{r,g}-\ell_{r,g,t}\right)+p_{r,a,t}\ \zeta_{r,g,t}\\
&\qquad \ell_{r,g,t} \le \omega_{r,g}\\
&\qquad c_{r,g,t} \ge 0\quad ,\quad \ell_{r,g,t} \ge 0.
\end{aligned} \tag{7}$$

Here, σ is the intertemporal elasticity of substitution, $\sigma_{cl} = 1/(1-\nu)$ is the elasticity of substitution between consumption and leisure, and α determines the relative importance of material consumption vis-à-vis leisure consumption. $\hat{\rho}$ is the subjective utility discount factor, and $p_{r,x,t}$, $x = \{a,k,l,f\}$, denote the price for the output good, the purchase price of capital, the wage rate, and the price for the fuel-specific natural resource $f(f = \{Coal, Natural\ Gas, Crude\ Oil\}$, respectively. $\pi_{g,t}$ is an index of labor productivity over the life cycle. $\bar{z}_{r,f,g}$ denotes the endowment with natural resource f by generation g. Households first decide how to allocate their lifetime income over time. Given the expenditure for z, households decide in a second stage how much to spend on consumption and leisure.[4]

We assume throughout our analysis that endowments of natural resources grow exogenously at the steady-state growth rate, and that income from natural resource accrues to households in proportion to their capital income.

Similarly, government transfers to households are assumed to be exogenous, also grow at the steady-state growth rate, and are allocated to each generation according to its share in the total population, where $\zeta_{r,g,t} = (1+\gamma)^g / \sum_{i=t-N}^{t} (1+\gamma)^i\ T_t$. This implies that transfer payments are constant over the life-cycle.

The present value of total consumption expenditure over the lifetime cannot exceed the present value of lifetime income. This rules out that households die in debt. In each period of the life cycle, time allocated to leisure consumption cannot exceed the total time endowment. Choices for material and leisure consumption are restricted to be nonnegative.[5] Material consumption c is a CES composite of individual commodities shown in Table 1. We assume that each generation uses an identical consumption technology, i.e. we abstract from age-specific preferences. The nested CES structure for private consumption is depicted in Fig. A.15 in Appendix A.

$\bar{k}_{r,g,g}$ denotes the capital holdings of generation g at the beginning of life $t = g$. Initial old generations, i.e. generations born prior to period zero, are endowed with a non-zero amount of capital. The initial distribution of capital across these generations is selected such that the economy is on a balanced growth path (for details on the calibration procedure see Section 2.7). We assume that newborn households enter with zero capital, i.e. we rule out intergenerational bequests: $\bar{k}_{r,g,g} = 0,\ \forall\ g \ge 0$.

2.3. Production

For each industry ($i = 1, \ldots, I,\ i = j$) in each region ($r = 1, \ldots, R$) gross output (Y_{ir}) is produced in each period using inputs of labor (L_{ir}), capital (K_{ir}), natural resources including coal, natural gas, crude oil, and land (R_{ir}), and produced intermediate inputs (X_{jir})[6]:

$$Y_{ir} = F_{ir}(L_{ir}, K_{ir}, R_{ir}; X_{1ir}, \ldots, X_{Iir}). \tag{8}$$

We employ constant-elasticity-of-substitution (CES) functions to characterize the production technologies and distinguish five types of production activities in the model: fossil fuels (indexed by f); refined oil, electricity, agriculture, and non-energy industries (indexed by n). All industries are characterized by constant returns to scale (except for fossil fuels, agriculture and renewable electricity, which are produced subject to decreasing returns to scale) and are traded in perfectly competitive markets. Nesting structures for each type of production system are depicted in Figs. A.10–A.14 in Appendix A.

Fossil fuel f, for example, is produced according to a nested CES function combining a fuel-specific resource, capital, labor, and intermediate inputs:

$$Y_{fr} = \left[\alpha_{fr}\ R_{fr}^{\rho_{fr}^R} + \nu_{fr}\ \min\left(X_{1fr}, \ldots, X_{Ifr}, V_{fr}\right)^{\rho_{fr}^R}\right]^{1/\rho_{fr}^R} \tag{9}$$

where α, ν are share coefficients of the CES function and $\sigma_{fr}^R = 1/(1-\rho_{fr}^R)$ is the elasticity of substitution between the resource and the primary-factors/material composite. The primary factor composite is a Cobb–Douglas function of labor and capital:

$$V_{fr} = L_{fr}^{\beta_{fr}} K_{fr}^{1-\beta_{fr}}$$

where β is the labor share.

[2] ω is a constant income scaling factor which is determined in the initial calibration procedure to reconcile household behavior with the aggregate benchmark data. For more details see Section 2.7.

[3] The size of the generation born at the beginning of year zero is normalized to unity. Note that there is no growth in time endowments over the life cycle. Thus, while the number of households across generations increases over time, the size of a cohort over its life cycle remains constant.

[4] The assumption of multi-stage budgeting is innocuous if and only if the utility function u is weakly separable and the sub-utility functions z are homothetic. Both conditions are satisfied in this model.

[5] Note that due to the convex structure of CES-preferences the nonnegativity constraints on c and l are never binding in the optimum.

[6] For simplicity, we abstract from the various tax rates that are used in the model. The model includes ad-valorem output taxes, corporate capital income taxes, payroll taxes (employers' and employees' contribution), and import tariffs. We also suppress the time index here.

Table 1
Model details.

Regions	Primary factors of production	Commodities (GTAP code)
USA	Capital	Agriculture (*aggr.*)
Rest of the World	Labor	Coal mining (COA)
	Coal	Natural gas extraction (GAS)
	Natural gas	Crude oil (OIL)
	Crude oil	Electricity* (ELY)
	Land	Refined oil* (P_C)
		Paper products, publishing* (PPP)
		Chemical, rubber, plastic products* (CRP)
		Ferrous metals* (I_S)
		Metals* (NFM)
		Non-metallic minerals* (NMM)
		Transportation (*aggr.*)
		Other energy-intensive industries (*aggr.*)
		Services (*aggr.*)
		Manufacturing (*aggr.*)

Note: "*aggr.*" denotes an aggregation of original GTAP sectors.

2.4. Supplies of final goods

With the exception of crude oil, which is modeled as a homogeneous good, intermediate and final consumption goods are differentiated following the Armington (1969) assumption. Our Armington specification differentiates goods domestic and international origin. For each demand class, the total supply of good i is a CES composite of a domestically produced variety and an imported one:

$$X_{ir} = \left[\psi^z ZD_{ir}^{\rho_i^D} + \xi^z ZM_{ir}^{\rho_i^D}\right]^{1/\rho^D{}_i} \tag{10}$$

$$\hat{C}_{ir} = \left[\psi^c CD_{ir}^{\rho_i^D} + \xi^c CM_{ir}^{\rho_i^D}\right]^{1/\rho^D{}_i} \tag{11}$$

$$I_{ir} = \left[\psi^i ID_{ir}^{\rho_i^D} + \xi^i IM_{ir}^{\rho_i^D}\right]^{1/\rho^D{}_i} \tag{12}$$

$$G_{ir} = \left[\psi^g GD_{ir}^{\rho_i^D} + \xi^g GM_{ir}^{\rho_i^D}\right]^{1/\rho^D{}_i} \tag{13}$$

where Z, $\hat{C}$, I, and G are inter-industry (intermediate) demand, consumer demand, investment demand, and government demand of good i, respectively; and ZD, CD, ID, and GD are domestic components and ZM, CM, IM, and GM imported components of each demand class. The ψ's and ξ's are the CES share coefficients and the Armington substitution elasticity between domestic and the imported varieties in these composites is $\sigma_i^D = 1/(1-\rho_i^D)$.

The internationally imported varieties are represented by nested CES functions. The imported variety of good i is represented by the CES aggregate:

$$\hat{M}_{ir} = \left[\sum_t \varphi_{isr}\; y_{isr}^{\rho_i^M}\right]^{1/\rho_i^M} \tag{14}$$

where y_{isr} are imports of commodity i from region s to r. π and φ are the CES share coefficients, and $\sigma_i^M = 1/(1-\rho_i^M)$ is the implied substitution elasticity across foreign origins.

2.5. Emissions

Carbon emissions are generated according to the stoichiometry of fossil fuel combustion, which occurs in fixed proportions to the consumption of fossil fuels by industry and final demand sectors. The carbon emissions in region r are defined by the expression:

$$\text{Emissions}_r = \sum_f \kappa_f \left(X_{ifr} + \hat{C}_{fr}\right) \tag{15}$$

where κ_f is the carbon content of fuel f. While endogenous efficiency improvement is governed by the possibility to substitute capital and labor for energy in response to changing relative prices, our model abstracts—for simplicity—from any autonomous energy efficiency improvements.

2.6. Infinite-horizon approximation and numerical solution

To approximate the underlying infinite horizon economy by a finite-dimensional complementarity problem, we choose a "state variable targetting" approach as proposed by Lau et al. (2002). The infinite horizon economy can be decomposed into two distinct problems where one runs from 0, …, T and the other runs from $T+1$, …, ∞, where T denotes the last period of the numerical model.[7] Both subproblems are linked through the post-terminal capital stock in period $T+1$. The level of post-terminal capital is computed endogenously by requiring that investment grows at the same rate as output (or any other "stable" quantity in the model):

$$I_{r,T}/I_{r,T-1} = 1+\gamma. \tag{16}$$

To compute a transition path to a new steady state of an infinite horizon economy, it is necessary to account for the special characteristics of generations alive in the post-terminal years (indexed by $\hat{g}$). We adopt the approach described in Rasmussen and Rutherford (2004) and impose two additional constraints on the model. Whereas assets held at the start of the initial period are exogenous, a shock to the model may change the demand and supply for savings at a given interest rate and consequently the profile of asset holdings and the trade deficit in the new steady state. Assets held in year T are therefore computed as endogenous variables chosen to ensure that the model is on a steady-state growth in T. This implies that the percentage change in welfare, as measured by the equivalent variation $(ev_{\hat{g}})$ of each of the generations living beyond the terminal period is of equal magnitude:

$$ev_{\hat{g}} = ev_{\hat{g}-1} \qquad \text{for } T-N < \hat{g} \le T. \tag{17}$$

The second constraint ensures that consumption profiles of households living beyond T are held at the steady-state level. This requires that given the post-terminal consumption demands by these generations, the price path for consumption goods declines with the interest rate consistent with a steady-state projection of the price of consumption in period T.

Numerically, the equilibrium is formulated as a mixed complementarity problem (MCP) (Mathiesen, 1985; Rutherford, 1995).

Our complementarity-based solution approach comprises two classes of equilibrium conditions: zero profit and market clearance conditions.

The former condition determines a vector of activity levels and the latter determines a vector of prices. We formulate the problem using the General Algebraic Modeling System (GAMS) and use the Mathematical Programming System for General Equilibrium (MPSGE) (Rutherford, 1999) and the PATH solver (Dirkse and Ferris, 1995) to solve for non-negative prices and quantities.

[7] Note that this method for approximating the infinite horizon relies on the assumption of time-separable utility functions.

2.7. Data and calibration

This study makes use of social accounting matrices (SAMs) that are based on data from the Global Trade Analysis Project (GTAP, 2008). The GTAP dataset provides consistent global accounts of production, consumption, and bilateral trade as well as consistent accounts of physical energy flows and energy prices. Version 8 of the database, which is benchmarked to 2007, identifies 113 countries and regions and 57 commodities. Table 1 shows the five energy and ten non-energy commodities which are distinguished in the model, and which are aggregations of commodities in the GTAP data. Primary factors in the dataset include labor, capital, and fossil-fuel resources (these make up natural resource income, R, in Eq. (1)). Model regions include the United States and an aggregate region representing the Rest of the World.[8]

In addition to the GTAP data, further information is required to parameterize the model. To describe the evolution of labor productivity over the life-cycle, we use an age-related productivity profile according to:

$$\pi_{gt} = \exp\left(\lambda_0 + \lambda_1(t-g+21) + \lambda_3(t-g+21)^2 + \lambda_3(t-g+21)^3\right),$$

where the parameters of this function are selected to minimize the difference from the profile arising by taking the average of multiple income groups as discussed in Altig et al. (2001). The coefficients used are: $\lambda_0 = 1.0785$, $\lambda_1 = 0.0936$, $\lambda_2 = -0.0015$, and $\lambda_3 = 7 \times 10^{-6}$.

Our estimate for the benchmark budget deficit is based on a long-run projection of 3% of GDP by Congressional Budget Office (2012). The initial level of publicly-held debt is also based on the Congressional Budget Office estimate that existing debt represents approximately 70% of GDP in 2011. Benchmark expenditures on government services and the trade deficit are directly taken from the GTAP data. We calibrate the benchmark marginal labor tax rate to a value of 35.8% (Barro and Redlick, 2011) and the marginal capital tax rate to a value of 39.9% (Babiker et al., 2003).

As customary in applied general equilibrium analysis, we use economic value flows (=quantity × price; where all prices in the first year are normalized to one) of the dataset to calibrate the value share and level parameters for the base year of the model. Response parameters in the functional forms which describe production technologies and consumer preferences are determined by exogenous elasticity parameters, the values of which are shown in Table 2. Symbols used in Table 2 to denote elasticity parameters correspond with those used in Figs. A.10 to A.15 in Appendix A.

We calibrate the model to a steady-state baseline extrapolated from the set of 2007 social accounting matrices using exogenous assumptions on the growth rate of output (γ), the interest rate ($\bar{r}$), and the capital depreciation rate (δ). This ensures that solving the model without any shock gives a solution that replicates a balanced growth path. The steady-state assumption requires that benchmark investment expenditure covers growth plus depreciation on the capital stock and that the gross return to capital covers interest plus depreciation: $I(\bar{r}+\delta) = W(\gamma+\delta)$.

The choice of the annual interest rate is important for the results of a long-term analysis like the present one. We use a value of $\bar{r} = 0.04$ for the net of tax return.[9] The annual capital depreciation rate is set to 7%, but in contrast to $\bar{r}$ this parameter has little impact on the results. γ is set to 2% reflecting roughly an average of the U.S. economic growth experience between 2004 and 2012. We solve the model for 150 years ($T = 150$) and assume that the deterministic lifespan of households is 50 years ($N = 49$).[10] We assume that households are born into the model at age 20; thus households live until the age of 70.

Table 2
Reference values of substitution elasticities for production and consumption technologies.

Parameter	Substitution margin	Value
σ_{en}	Energy (excluding electricity)	1.0[a]
σ_{enoe}	Energy—electricity	0.5[a]
σ_{eva}	Energy/electricity—value-added	0.5[a]
σ_{va}	Capital—labor	1.0[a]
σ_{klem}	Capital/labor/energy—materials	0[a]
σ_{cog}	Coal/oil—natural gas in ELE	1.0[a]
σ_{co}	Coal—oil in ELE	0.3[a]
σ_{rnw}	Resource—Capital/labor/energy materials in renewable ELE	0.5
σ_{nr}	Resource—Capital/labor/energy /materials in nuclear ELE	0.5
σ_{am}	Materials in AGR	0[a]
σ_{ae}	Energy/electricity—materials in AGR	0.3[a]
σ_{er}	Energy/materials—land in AGR	0.6[a]
σ_{erva}	Energy/materials/land—value-added in AGR	0.7[a]
σ_{rklm}	Capital/labor/materials—resource in primary energy	0[a]
σ_{gr}	Capital/labor/materials—resources	0.5
σ_{govinv}	Materials—energy in government and investment demand	0.5[a]
σ_{ct}	Transportation—Non-transport in private consumption	1.0[a]
σ_{ec}	Energy—Non-energy in private consumption	0.25[a]
σ_{c}	Non-energy in private consumption	0.25[a]
σ_{ef}	Energy in private consumption	0.4[a]
σ_i^D	Foreign—domestic	GTAP, version 8
σ_i^M	Across foreign origins	GTAP, version 8
σ	Intertemporal elasticity of substitution	0.35
σ_{cl}	Leisure—material consumption	0.8
α	Weight on material consumption in full consumption	0.75

Note:
[a] Parameter values are taken from Paltsev et al. (2005).

To calibrate the steady-state model to the SAM, it is necessary that the solution to the OLG household individual maximization problems is consistent with the base-year value for aggregate private consumption and income. We employ a steady-state calibration procedure for OLG models put forward by Rasmussen and Rutherford (2004). More specifically, we impose two additional constraints on individuals' maximization problems by endogenously solving for the time endowment parameter ω and the utility discount rate $\hat{\rho}$.[11]

Fig. 1 shows the calibrated income, consumption, and savings profiles for each generation along the baseline steady-state growth path. In the first period of the life-cycle, capital income is zero and consumption and savings are financed through labor income and exogenous transfers. The desire to increase consumption over the life-cycle (as is implied by the Euler equation) means that capital income is growing over the first 35 years of the life-cycle and then falls back to zero reflecting positive saving while young and subsequent dissaving. Labor income, as well as time devoted to labor, is increasing for the first decades of the life cycle and is then decreasing consistently with the humped-shaped productivity profile and the tendency of leisure to increase with a constant productivity level.

3. Evaluating fiscal consolidation with climate policy

To evaluate the efficiency and distributional effects of fiscal consolidation with climate policy we consider two sets of scenarios. The first one

[8] The exact aggregation scheme and the aggregate benchmark SAM data are available on request from the author.

[9] Altig et al. (2001) argue for using a value around 7–8% based on the historical real rate of return to capital, while others (e.g., Fullerton and Rogers, 1993) use a much smaller rate around 3–4%. With no account for risk in this model it is not clear which value should be used. Also it should be kept in mind that with these kinds of models there is no "correct" value.

[10] Solving the model for a longer time horizon does not produce different results thus indicating that the model has been given enough time to settle on a new balanced growth path. To reduce computational complexity, we solve the model with a 10-year time step.

[11] Note that ω is a simple scaling factor with no economic significance. $\hat{\rho}$ is selected as the second calibration parameter as there is little evidence on what would constitute an appropriate value. The calibrated value for $\hat{\rho}$ is 1.22.

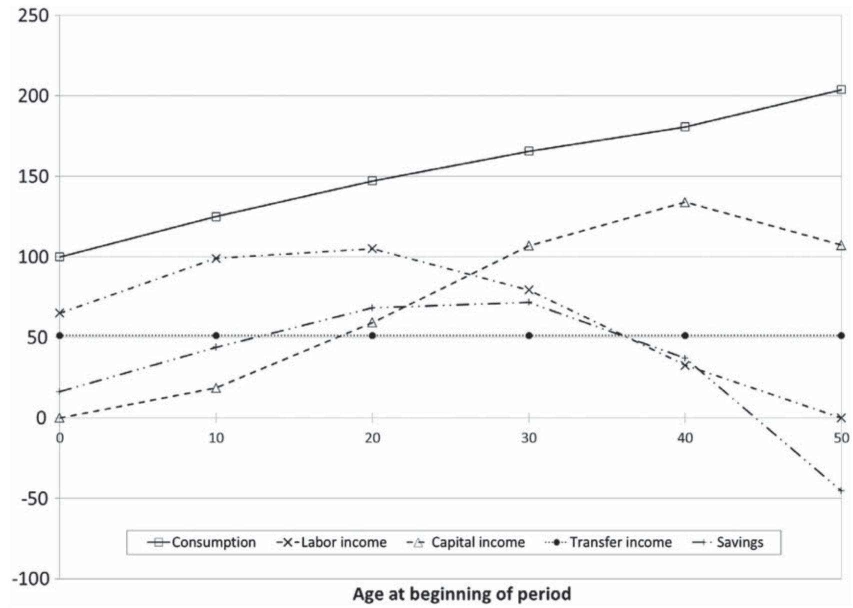

Fig. 1. Baseline income, consumption, and savings profiles for each generation (first period consumption = 100).

recycles the revenue from a carbon pricing policy through lowering marginal tax rates on capital, labor, and consumption. The level of the respective tax recycling instrument is determined endogenously in equilibrium by the public budget (see Eq. (5)), while the other tax instruments are held fixed at their benchmark level. Here Φ_t denotes all tax receipts including the revenue from a carbon tax. A second set of scenarios considers using the carbon revenue to repay the principal debt. Deficit reduction implies a relaxation of future public budgets as debt repayment results in lower interest obligations (as can be seen from Eq. (4)). Lower interest obligations are recycled through reductions in future marginal tax rates on capital, labor, and consumption. In each period the level of the endogenous tax instrument is determined by Eq. (5). This means that whenever there is a budget deficit (surplus) relative to the baseline budget in a given period, the level of the respective tax instrument in that period is higher (lower) than in the benchmark.

In the baseline growth path, we have calibrated the model such that there are no repayments on the principal, nor is there additional borrowing. In the fiscal consolidation scenarios, the carbon revenue raised in each period is recycled via R_t therefore impacting current and future net public expenditures. Throughout our analysis we assume that government expenditure (G) and government transfers (T) grow exogenously with the steady-state growth rate. This assumption helps us to isolate the impacts of tax rate changes due to a carbon tax swap with or without fiscal consolidation.

We limit our analysis of climate policy to a carbon pricing scheme that imposes a carbon price of \$20 per ton of CO_2 in the first period of the model and assume that the carbon price rises at 4% per year.[12] The carbon policy is restricted to a period of 50 years after which carbon emissions are allowed to increase without further policy constraints, i.e. the carbon tax drops to zero. Our scenario design is motivated by the following considerations. First, limiting the carbon policy to a finite number of periods helps us to obtain a clearer picture of the intergenerational impacts of the policy as the economy gradually returns to a steady-state equilibrium in periods after the policy is discontinued. Second, based on the current political debate in the United States surrounding the issue of fiscal reform and the potential contribution of a carbon tax, such a setup does not seem implausible (see, for example, Congressional Budget Office, 2012; McKibbin et al., 2012). Third, a (binding) carbon policy continuing for an infinite number of periods is not consistent with a situation in which the economy converges towards a balanced growth path. A final steady state of the model, however, is necessary to apply the above-mentioned methods for approximating the infinite-horizon economy.

Our analysis enables us to quantify the intergenerational welfare impacts of climate policy with and without fiscal consolidation. As fiscal consolidation involves trading-off short-term costs with potential long-term welfare gains from reduced future levels of public debt, we are also interested in evaluating the welfare impacts using "social" preferences. To this end, and following Jensen and Rutherford (2002), we apply a direct social welfare function (SWF) approach assuming that aggregate welfare can be measured as:

$$\mathrm{EV}_{\mathrm{SWF}} = \left(\sum_g \theta_g u_g^{\rho}\right)^{1/\rho} \tag{18}$$

where $\epsilon = 1/(1-\rho)$ is an index of the elasticity of substitution across welfare gains for different households, and θ_g is a weighting factor that accounts for population and discounting:

$$\theta_g = N_g(1-\Delta)^g. \tag{19}$$

N_g is the number of households represented by the generation g, and Δ is a parameter that discounts the contribution of future generations to aggregate social welfare.

When Δ is larger, then the welfare of future generations plays a smaller role in defining social welfare.

Social welfare is also influenced by the inter-household substitution elasticity which captures trade-offs in welfare for households born at different times. is related to the inequality aversion parameter ρ. $\rho = 1$ represents the utilitarian (Bentham) social welfare function corresponding to no inequality aversion in which the societal equivalent variation is a weighted sum of equivalent variations over all households. Lower values for ρ imply larger a societal concern for inequality. If $\rho \to 0$, Eq. (18) represents the Nash social welfare function, and $\rho \to -\infty$ represents the Rawlsian case where the society is solely concerned with maximizing the utility of the household with the smallest welfare.

[12] There are, at least, two motivating arguments for such an assumption. First, it represents a carbon policy with increasing stringency that is typically considered as a possible policy scenario in the U.S. context (Paltsev et al., 2009). Second, a carbon price rising at the rate of interest can be viewed as an optimal Hotelling price that would be borne out by a cap-and-trade regulation with unlimited banking and borrowing provisions.

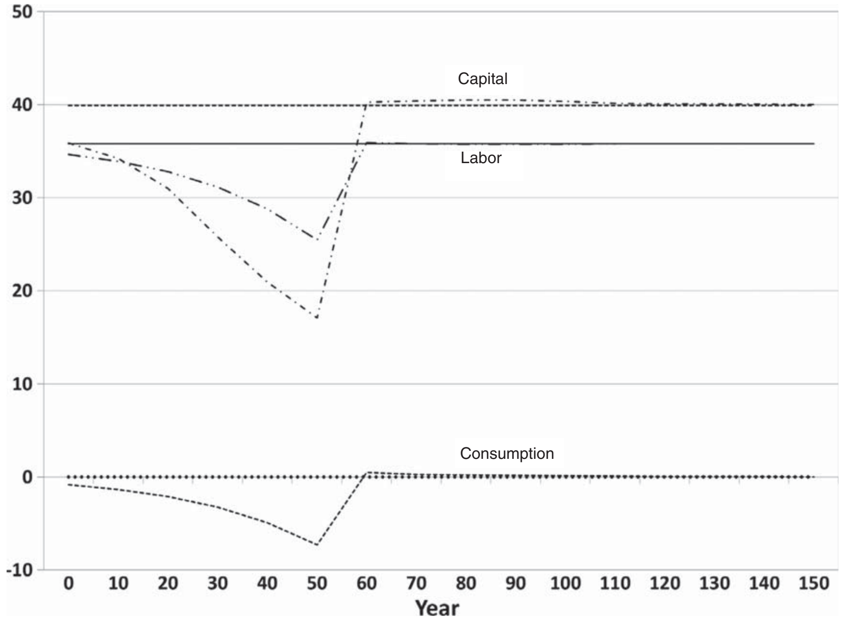

Fig. 2. Model tax rates for revenue-neutral carbon tax swap cases (%).

4. Results

4.1. Revenue-neutral carbon tax swaps

We begin our analysis by investigating the impacts of using the carbon revenue for cutting marginal tax rates on capital, labor, and consumption (without reducing government debt). The corresponding scenario labels are *Tax_Capital*, *Tax_Labor*, and *Tax_Consum*, respectively. Fig. 2 shows the benchmark tax rates (horizontal lines) and the required tax level to satisfy the government budget constraint defined in Eq. (5). In all three cases, the government budget allows for substantial reductions in tax rates for periods in which the carbon policy is active and revenue is generated. In the year 50 when the carbon tax is removed from the economy, the tax rates jump back to the irrespective benchmark level. In fact they slightly and temporarily increase above the benchmark level to raise sufficient revenue as the growth in the tax base has been slowed down due to the carbon policy in preceding periods; in the long-term the rates converge back to their benchmark level. Differences in the magnitudes of reductions reflect the width of the tax base for each instrument.

Fig. 3 shows the utility changes for the different generations as measured by the equivalent variation.[13] Recycling the carbon revenue through reductions in consumption taxes generates welfare gains for the current old generations, i.e. those born before year 0, as they spend a relatively large share of their income on consumption. For these households, the positive effect of lower consumption taxes dominates the increased (direct and indirect) cost of consumption goods due to the carbon tax. Lowering labor or capital taxes makes all generations worse off. Using the carbon revenue to lower capital tax rate produces smaller welfare losses as compared to using the labor tax instrument. This result can be explained by the relatively large share of capital income of current old households. As the carbon tax increases over time, current young and future generations are first made progressively worse off up to a point where welfare losses for future generations begin to decrease as these households increasingly live into future periods without a carbon policy.[14]

As is evident from Fig. 3, different tax instruments have different implications in terms of both efficiency and intergenerational equity. Recycling carbon revenues through lower consumption tax rates produces the largest difference in utility across generations with elderly households benefiting and future generations incurring substantial welfare losses. At the same time, lowering consumption taxes forgoes positive efficiency gains from increasing labor and capital supply as is achieved in the cases where either marginal tax rates on labor or capital are cut. Comparing the capital and labor tax recycling options, the latter one turns out to produce a more equitable outcome across generations while also being more efficient vis-à-vis a cut in capital taxes. Current generations benefit immediately from lower labor taxes by increasing labor supply with positive effects on savings and lifetime income whereas lower capital taxes do not benefit them as asset holdings are lower than labor income over the first half of the life-cycle (compare with baseline household choices in Fig. 1).

4.2. Combining public debt reduction and climate policy

Efficiency and intergenerational distributional impacts are altered substantially if the carbon revenue is used to reduce the public debt. A lower stock of public debt implies a relaxation of future public budgets and basically acts as an intergenerational redistribution mechanism. We consider three cases that differ with regard to how the receipts from deficit reduction—in the form of lower interest payments—are recycled. A scenario labeled *Debt_Capital* assumes that the budget deficit or surplus in each period has to be balanced by changing the marginal tax rates on capital. Similarly, scenarios *Debt_Labor* and *Debt_Consum* consider changing marginal labor tax and consumption tax rates, respectively.

Fig. 4 shows the percentage-point difference for each model tax rate under debt repayment relative to the corresponding revenue-neutral carbon tax swap case. If the carbon revenue is used to

[13] For generations alive when the abatement policy is introduced in period zero, the equivalent variation measures the change in the value of remaining lifetime utility as opposed to total lifetime full consumption.

[14] Note that as we do not fix CO_2 emissions but rather the carbon price, emission reductions differ slightly across scenarios. The observed differences are, however, negligible which allow us to compare the welfare results from different scenarios.

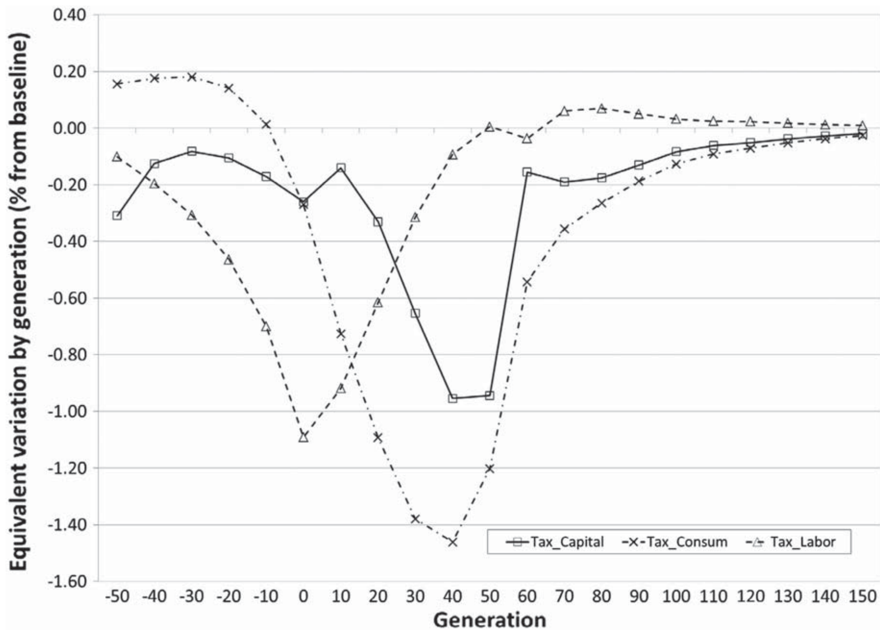

Fig. 3. Equivalent variation by generation for revenue-neutral carbon tax swaps (% change from baseline).

repay the principal debt, tax rates in all cases are higher throughout almost all periods for which the carbon policy is active (i.e., until $t = 50$). The percentage-point differences turn negative from year 40 and onward as cumulative receipts from lower interest obligations relax public budgets beginning to produce public budget surpluses. Importantly, in each of the three cases the respective tax rate converges eventually to new steady-state level that is below the benchmark tax rate.

The pattern of initially higher but then lower long-term tax rates suggests a different pattern in terms of the intergenerational incidence of burdens from a combined climate and fiscal policy as compared to the revenue-neutral carbon tax swap cases (Fig. 5). Elderly households, current young generations, and all future generations born before the last period of the climate policy incur welfare losses, whereas subsequent future generations born after the year 50 are made better off as they enjoy sustained and lower levels of the respective tax rate for all periods after the fiscal consolidation. Not surprisingly, comparing the debt reduction with the tax swap cases shows that the costs of fiscal consolidation are borne by the elderly and current young households, while subsequent generation enjoys welfare gains (or smaller losses under debt reduction as compared to the tax swap cases if measured against the no-policy baseline).

Like for the tax swap cases, labor-tax recycling has the most immediate impact on welfare for current old generations who incur welfare losses as these households finance a large fraction of their consumption by drawing down savings. On the other hand, current young and subsequent generations incur increasingly smaller welfare losses due to increasingly lower taxes on labor. Relative to current old generations, higher after-tax wages are beneficial for these households as they exhibit relatively high labor productivity allowing them to increase

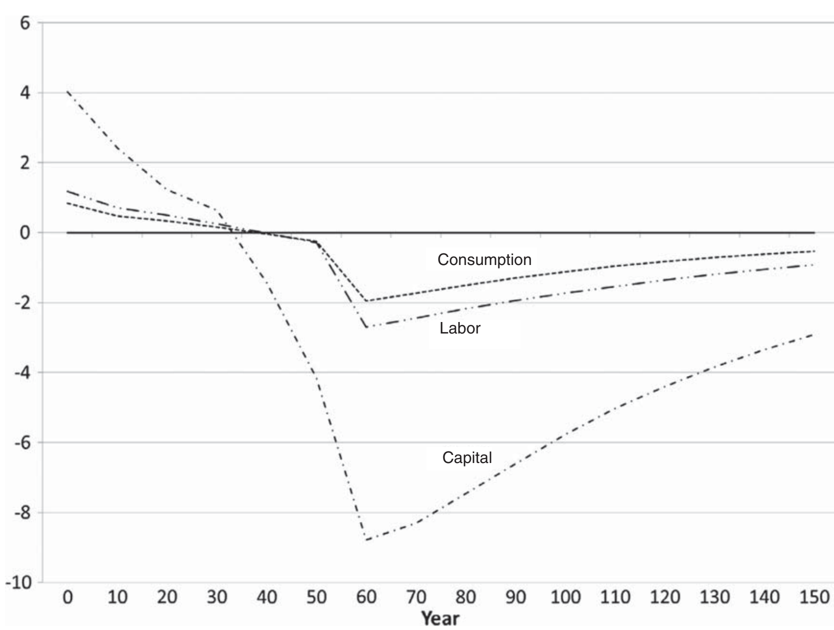

Fig. 4. Percentage-point difference in model tax rates for debt repayment vs. revenue-neutral carbon tax swap cases.

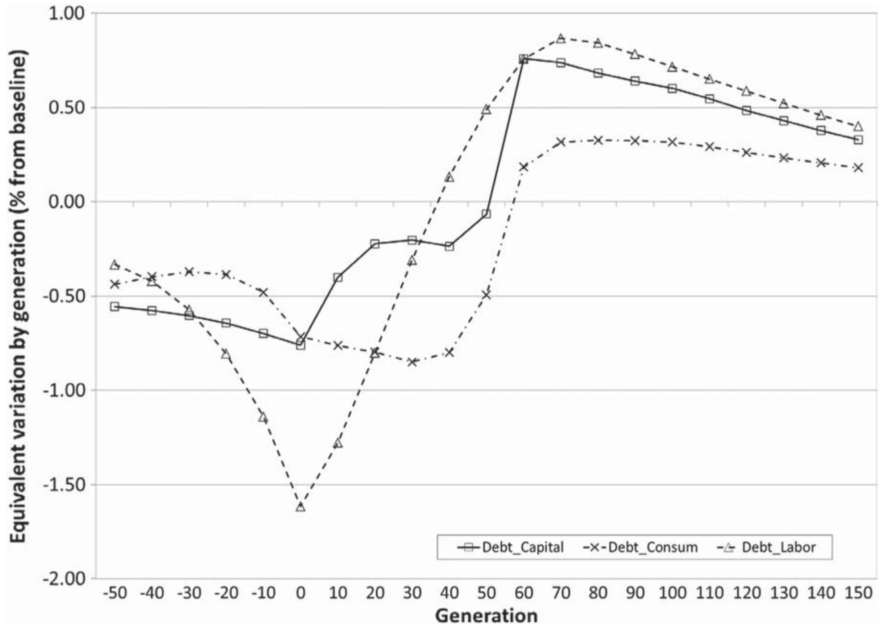

Fig. 5. Equivalent variation by generation for debt repayment (% change from baseline).

current and future consumption. Recycling future public budget surpluses through lower capital taxes produces long-run welfare gains falling in between the labor and consumption tax-recycling cases.[15] The consumption tax is the least distortionary of the three taxes, so cutting consumption taxes produces the smaller welfare gains than cutting the capital or labor taxes.

Table 3 shows the effects on generational welfare, as measured by the equivalent variation for generations born in year 0, 50, and 150, of changing key model parameter from the central case values presented in Section 2.7. While the overall qualitative conclusions of the analysis are robust, some parameters are found to have significant quantitative impacts. In particular, a higher value for the steady-state growth rate, γ, results in larger welfare losses for current young ($g = 0$) and smaller welfare gains for future generations ($g = 50$ and $g = 150$). A lower value for α, the weight on material consumption in intra-period utility, means that full consumption relies less heavily on goods that are sensitive to the increasing price of energy, which decreases welfare costs. A smaller value of the intra-temporal elasticity of substitution, σ_{cl}, makes labor supply less elastic. As a result, households born in year 0 that face higher labor taxes initially reduce labor supply by less implying much smaller welfare losses. In contrast, generations living beyond the period of the carbon policy are worse off as they are less able to increase their supply in response to the sustained increase in the after-tax wage rate. The intertemporal elasticity of substitution, σ, the benchmark interest rate, $\bar{r}$, and the capital depreciation rate, δ, are not found to have any major bearing on the results.

4.3. Can a fiscal reform package with carbon pricing be socially desirable?

Figs. 6 and 7 take a first stab at considering whether climate policy as part of a fiscal consolidation package is desirable from a social standpoint. Fig. 6 suggests that for all revenue-neutral carbon tax swaps produce negative societal equivalent variation when assuming a utilitarian SWF, i.e. $\rho = 1$.[16] As social discount rates increase welfare losses become initially larger before decreasing again for relatively high rates. This pattern thus reflects the U-shaped profile for households' equivalent variations from Fig. 3. The picture is changed dramatically if debt reduction is considered as an option to recycle the revenue from a carbon pricing policy. For social discount rates of less than 2%, Fig. 7 shows that such a combined policy can indeed be desirable from a social standpoint. If a lower weight is placed on the contribution of future generations, the social welfare assessment is less favorable and eventually turns negative.

It is worthwhile pointing out that of the three revenue recycling options we consider, only the capital and labor tax cuts support a positive societal welfare assessment (for $\rho = 1$). If future government budget surpluses are recycled through a consumption tax, the societal equivalent variation index is negative for virtually any assumed social discount rate. This reflects the fact that the capital and labor tax are more distortionary than the consumption tax, revenue-recycling efficiency gains are larger when cutting the capital or labor tax and smaller when cutting the consumption tax. This also implies that understanding fiscal consolidation merely as an intergenerational redistribution mechanism neglects important efficiency considerations.

Fig. 8 explores the questions how the desirability to implement a combined climate and fiscal consolidation policy depends on the stringency of the climate policy. We consider three climate policies starting with an initial carbon price of \$5, \$20, and \$40 per ton of metric CO_2 and each rising at 4% per year. For this graph we assume that revenues from deficit reduction are recycled via labor taxes and that $\rho = 1$. The insight borne out by Fig. 8 price is that less stringent climate policies are desirable for a larger range of social discount rates than those that aggressively reduce CO_2 emissions. There are two counteracting effects that explain this result. On the one hand, a higher carbon price path generates more revenue that can be used to reduce public debt and therefore relax future public budgets. Ceteris paribus implies a lower level of the endogenous tax instrument with ensuing positive effects on welfare. On the other hand, a more stringent carbon policy has adverse impacts on economic growth lowering the revenue from non-CO_2 taxes and therefore increases the need to raise additional tax revenue to close the government budget. This means that a higher level of the endogenous tax instrument is required to balance the public budget as compared to a case with a less stringent carbon policy. Consequently, welfare for all generations is lower. Fig. 8 therefore suggests that the beneficial link between

[15] Lifetime welfare gains for generations born after year 150, i.e. $g > 150$, are more or less similar to those for households $g = 150$. Fig. 5 therefore only shows impacts for up to $g = 150$.

[16] The results are not much changed if the social welfare metric places greater weight on equity as long as $0 \leq \rho < 1$.

Table 3
Welfare impacts by generation for alternative parameter assumptions (equivalent variation in % relative to baseline).

Generation	Debt_Capital			Debt_Labor		
	$g=0$	$g=50$	$g=150$	$g=0$	$g=50$	$g=150$
Central case[a]	−0.82	−0.04	0.32	−1.67	0.42	0.37
Steady-state growth rate ($\gamma=0.03$)	−0.96	−0.11	0.09	−2.37	0.32	0.16
Weight on consumption ($\alpha=0.5$)	−0.52	−0.08	0.20	−1.01	0.21	0.24
Intertemporal EOS ($\sigma=0.6$)	−0.81	−0.03	0.32	−1.62	0.39	0.37
Benchmark interest rate ($\bar{r}=0.05$)	−0.87	−0.09	0.28	−1.81	0.37	0.26
Intraperiod EOS ($\sigma_{cl}=0.4$)	−0.33	−0.12	0.12	−0.64	0.13	0.14
Capital depreciation rate ($\delta=0.1$)	−0.86	0.02	0.33	−1.67	0.42	0.37

Note: EOS = elasticity of substitution.
[a] Assumes parameter values as described in Section 2.7; in particular, $\gamma=0.02$, $\alpha=0.75$, $\sigma=0.35$, $\bar{r}=0.04$, $\sigma_{cl}=0.8$, and $\delta=0.07$.

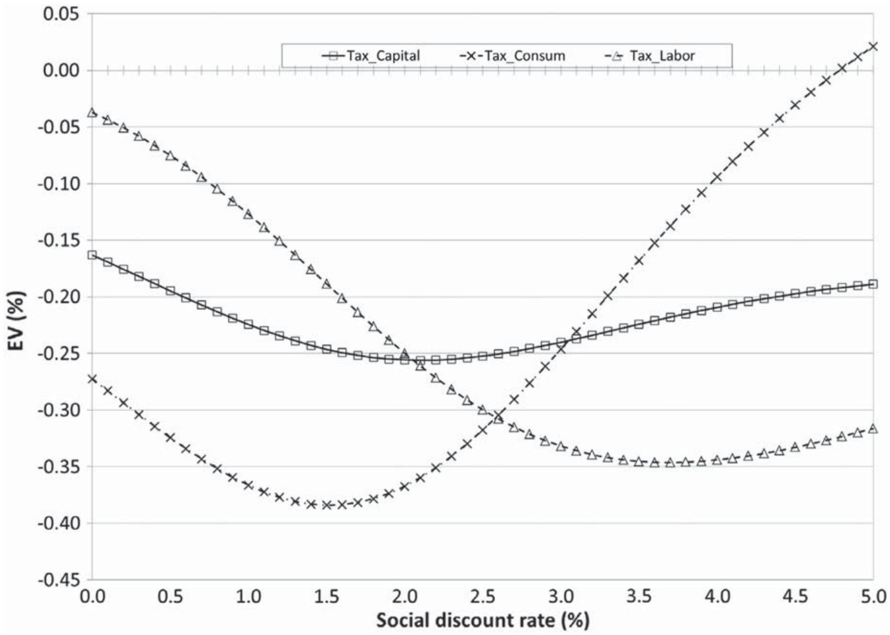

Fig. 6. Social welfare assessment of revenue-neutral tax swap cases (for $\rho=1$).

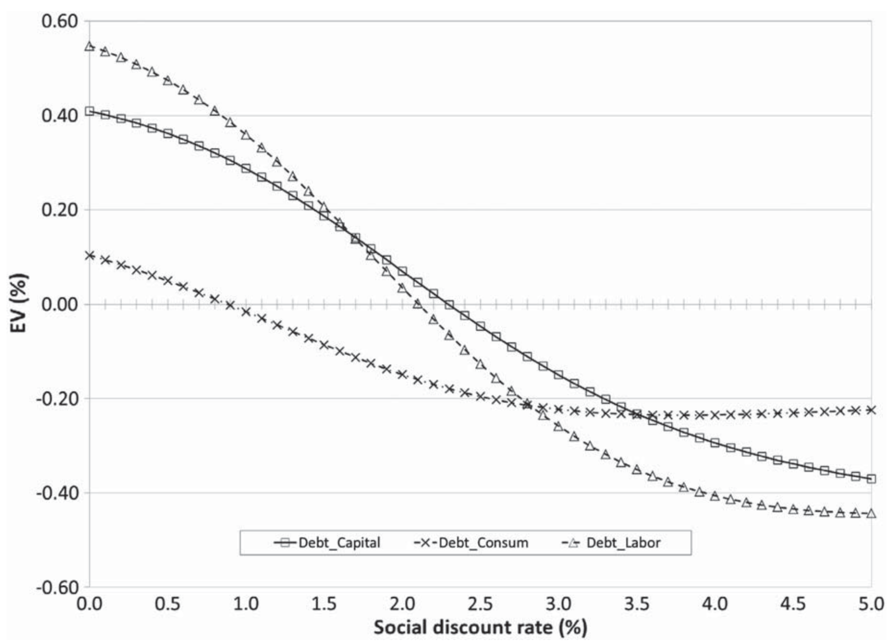

Fig. 7. Social welfare assessment of debt repayment cases (for $\rho=1$).

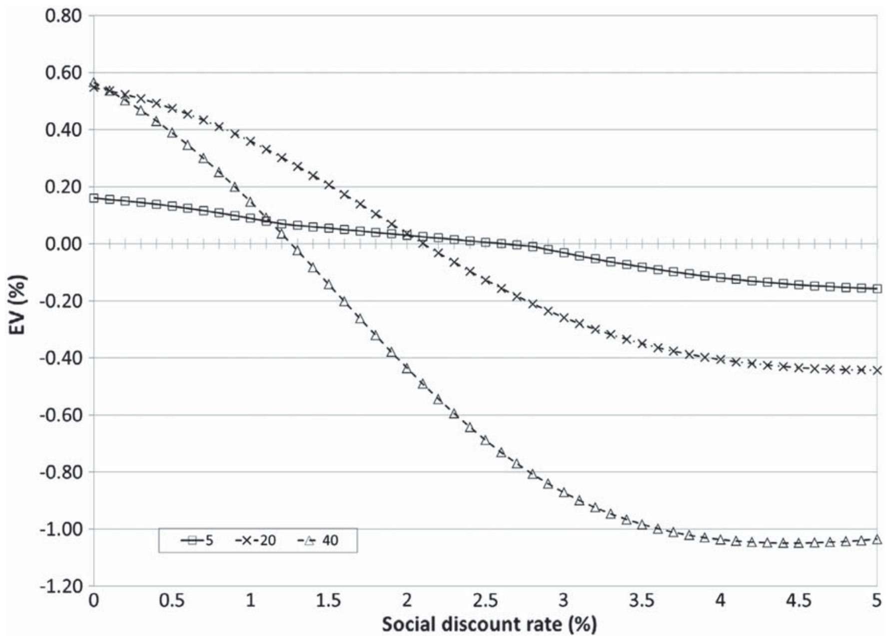

Fig. 8. Social welfare assessment of debt repayment cases for different stringency of carbon policy (wage-tax recycling and for $\rho = 1$).

a jointly implemented climate and fiscal consolidation policy breaks down for sufficiently aggressive climate policies.

Fig. 9 concludes with a simple comparison of SWF results for alternative cardinalizations of welfare. This figure reminds us that the SWF by itself does not automatically judge the desirability of a joint climate and debt consolidation policy. As such a combined policy measure involves both winners and losers, we first have to decide how gains by some households and generations should be traded off with losses by others. Fig. 9 shows that if the societal assessment is more concerned with intergenerational equity, i.e. has a higher inequality aversion reflected by increasingly negative values for ρ, a combined climate and fiscal consolidation policy is desirable for sufficiently high social discount rates.

5. Concluding remarks

In view of the current stance of public finances in the United States (and many other European nations), a revenue-raising climate policy can potentially help to relax future public budgets. An extensive literature—coined the "double-dividend literature" (see, for example, Bovenberg and Goulder, 1996)—has examined the interactions of environmental taxation and the broader fiscal system typically focusing on the efficiency effects from using the carbon revenue to fund rate cuts in distortionary taxes. The interactions between a revenue-raising climate policy and a debt consolidation program have, however, not been investigated widely. The appeal of such a combined fiscal consolidation and climate policy package is that it can potentially address

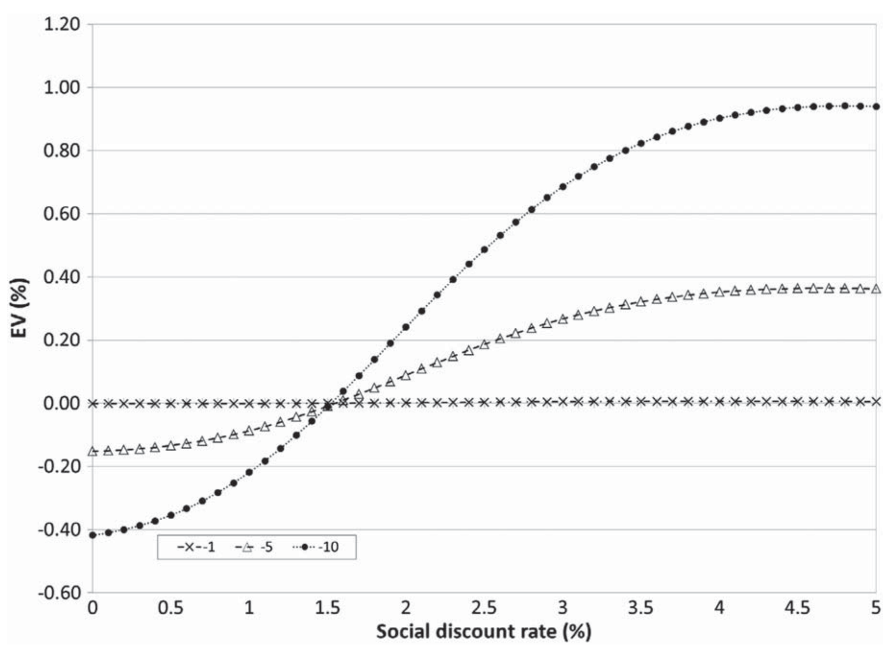

Fig. 9. Social welfare assessment for debt repayment with capital-tax recycling for alternative degrees of inequality aversion ($\rho = \{1;\ -1;\ -5;\ -10\}$).

the two long-term problems of growing public debt and the build-up of greenhouse gas emissions.

This paper has examined the efficiency and intergenerational distributional impacts of a jointly implemented fiscal and climate policy package that uses the revenue from putting a price on carbon to repay the principal government debt. Using carbon revenues for deficit reduction implies a relaxation of future public budgets as debt repayment results in lower future interest obligations. While any debt reduction program raises concerns of intergenerational equity between generations living through the fiscal consolidation period and those future generations who can reap the benefits of future public budget surpluses, our analysis suggests that a carbon policy combined with a fiscal consolidation program is likely to receive a more favorable societal assessment than just a carbon policy alone. In particular, we found that if social discount rates are sufficiently low or if social preferences exhibit a large aversion with respect to intergenerational inequality, combining fiscal consolidation and climate policy may offer the chance for positive societal gains even without considering potential benefits from averted climate change. We thus argue that framing revenue-raising climate policies as part of a broader fiscal deal are likely to enhance the political support for measures aimed at mitigating greenhouse gas emissions.

This analysis represents a modest first step towards a more complete assessment of the interactions of climate policy and public debt reduction alternatives in an economy with large-scale government intervention. There are a number of caveats to our analysis. First, our stylized analysis fails to incorporate any notion of (aggregate, household-specific or climate-related) risk, does not incorporate real-world demographic projections, nor do we introduce features of the system of direct taxation or consider energy-saving technological progress. Second, our analysis does not consider any potential benefits from averted climate change due to a greenhouse gas control policy. While including this aspect is clearly beyond the scope of what this model can deliver, it does not seem unreasonable to hypothesize that it would be mostly future generations benefitting from curbing greenhouse gas emissions. A combined policy aimed at reducing government debt and averting climate change is therefore likely to raise serious concerns with respect to intergenerational equity. Despite all of these deficiencies, we find the results to be quite thought-provoking, as it is clear that the design of fiscal consolidation programs requires a careful balance between intergenerational fairness and efficiency considerations. Further work is clearly needed to provide an assessment of the conclusions based on the simple model analyzed in this paper.

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Appendix A. Structure of production and consumption technologies

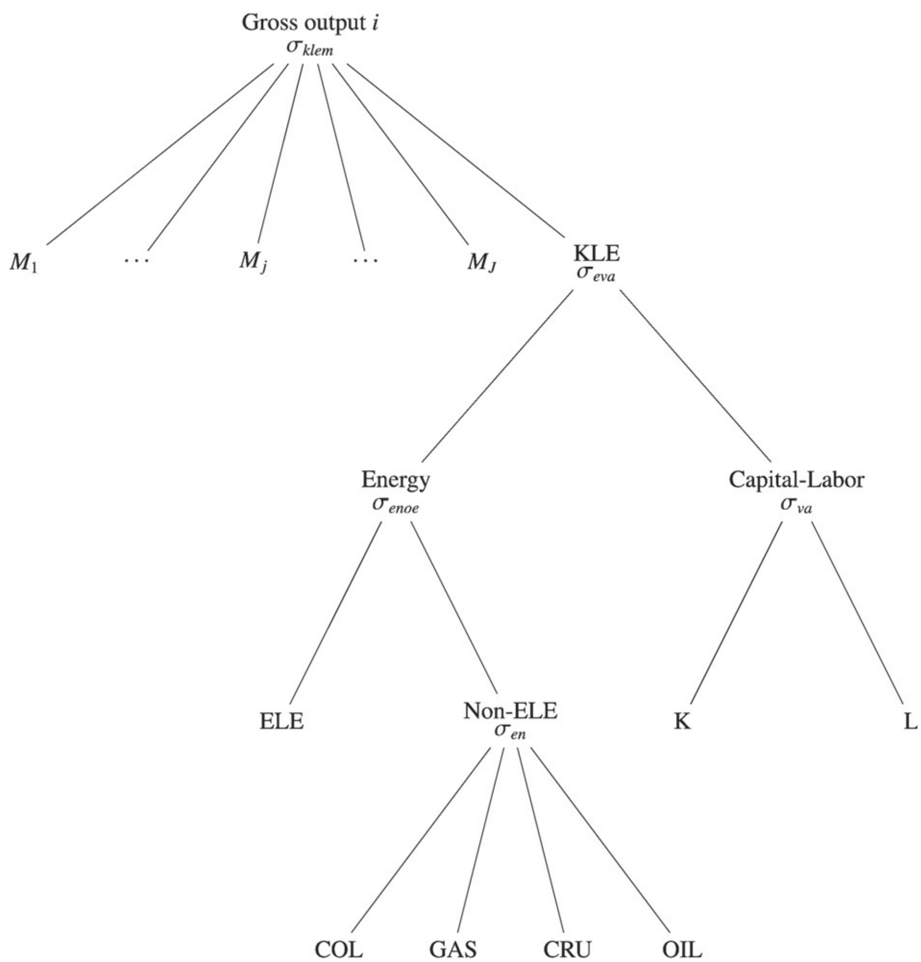

Fig. A.10. Structure of production for $i \in$ {TRN, EIS, SRV, CRP, I _ S, NFM, NMM, PPP, MAN}.

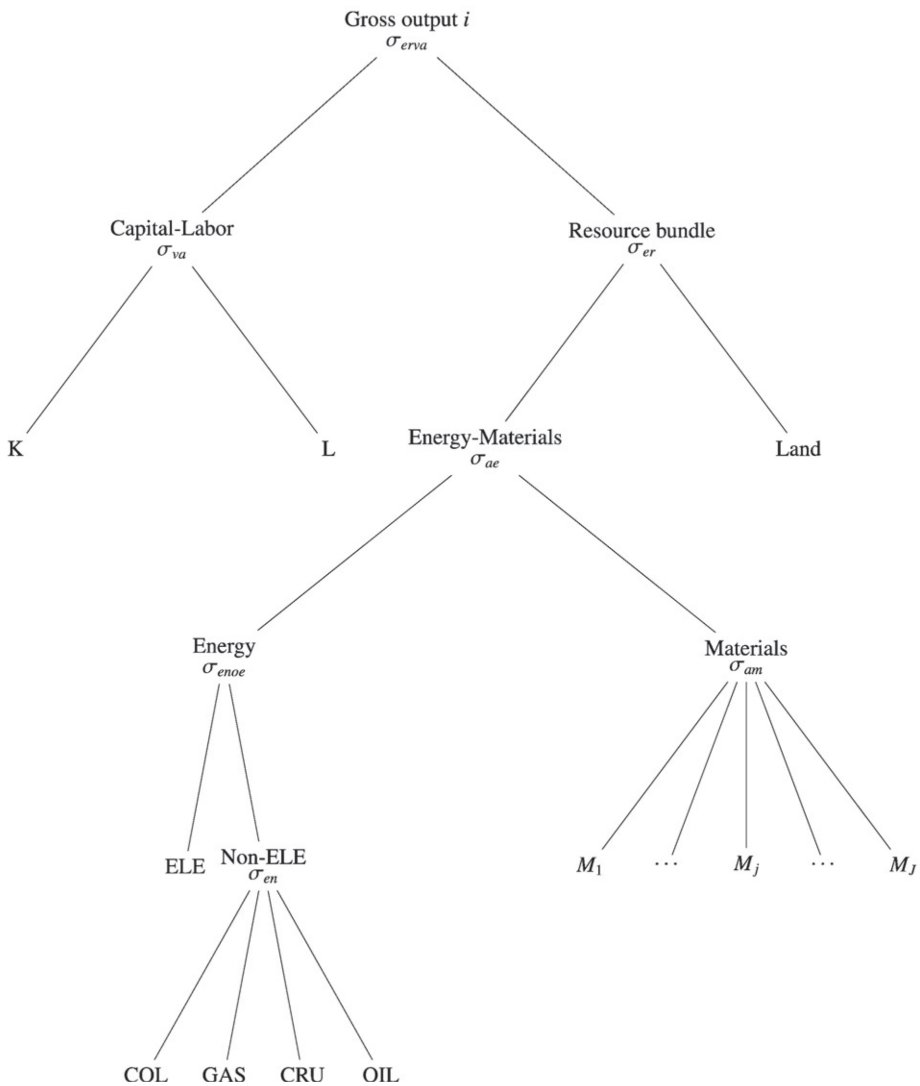

Fig. A.11. Structure of production for $i \in$ {AGR}.

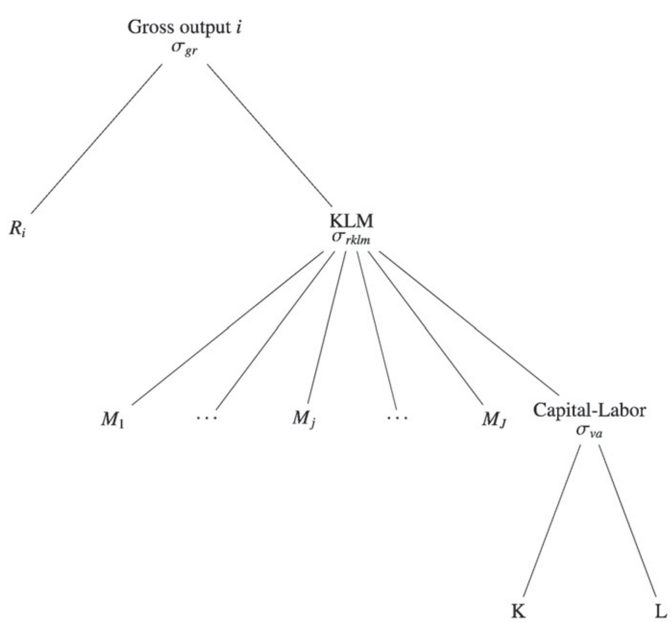

Fig. A.12. Structure of primary energy sectors $i \in$ {COL,CRU,GAS}.

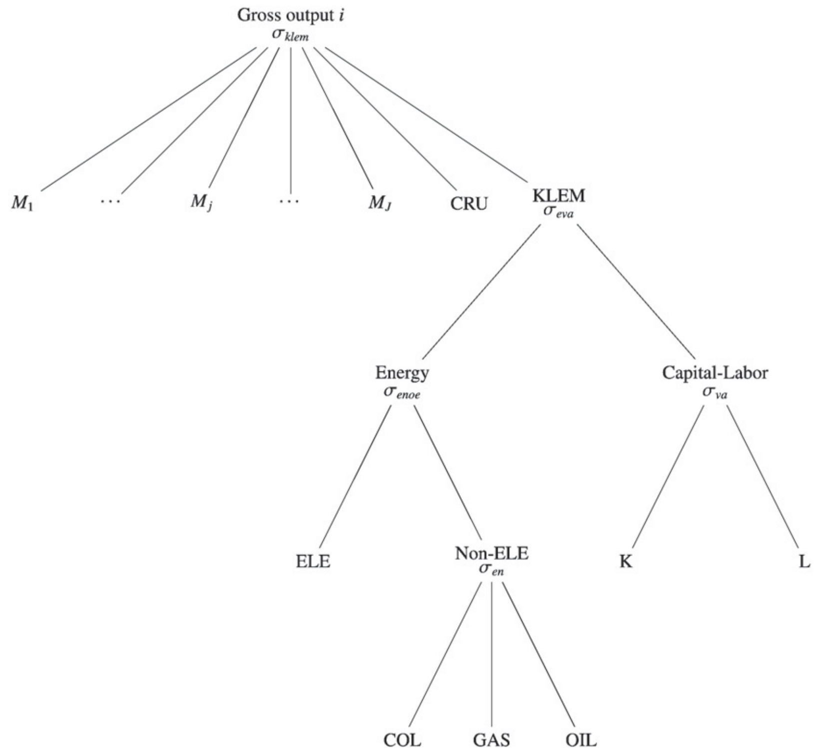

Fig. A.13. Structure of production for $i \in$ {OIL}.

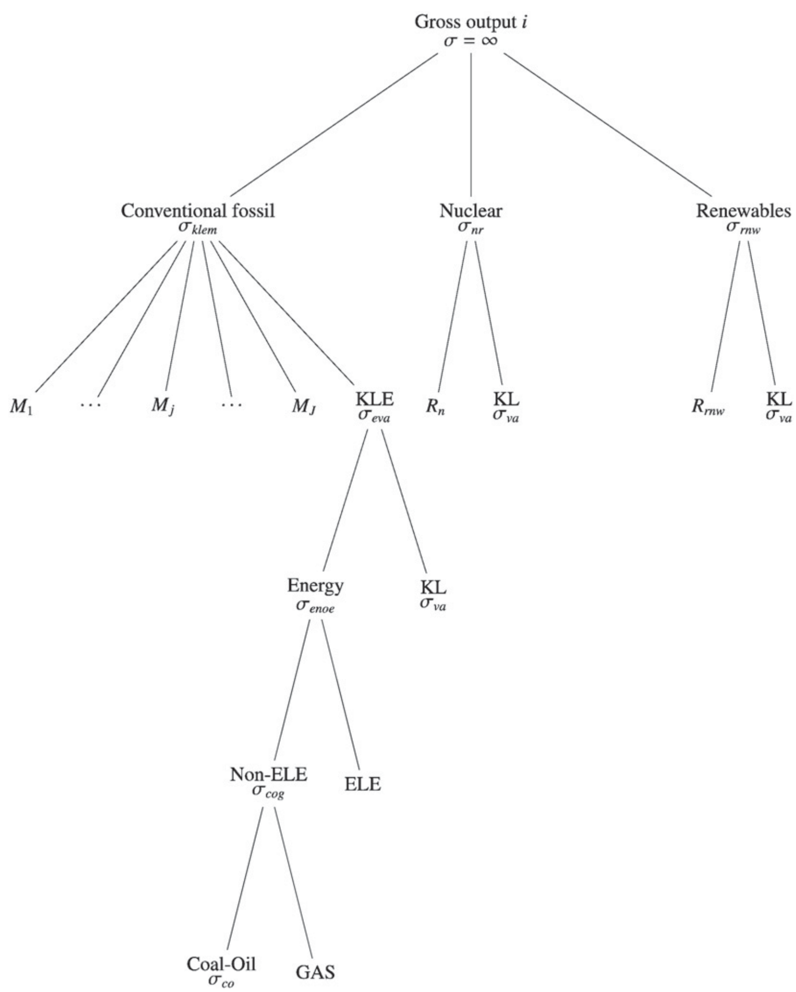

Fig. A.14. Structure of electricity production $i \in$ {ELE}.

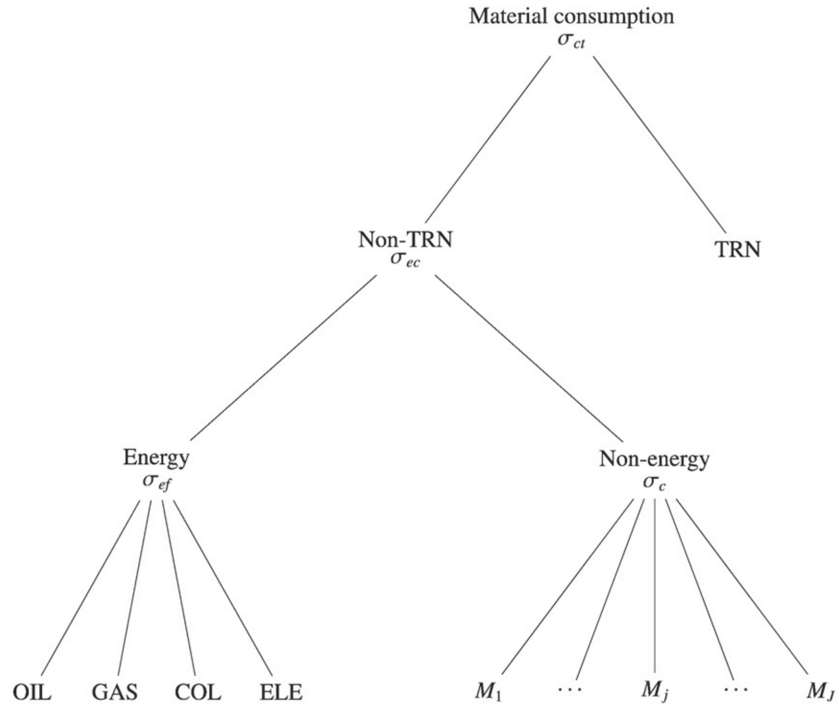

Fig. A.15. Structure of private material consumption.

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