Dynamic Tax Incidence and Intergenerationally Neutral Reform

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Forschungsbericht /
Research Memorandum No. 301
July 1992

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*Financial support by Deutsche Forschungsgemeinschaft, Sonderforschungsbereich 303 at the University of Bonn, is gratefully acknowledged. I am obliged to Dieter Bös, Bernhard Eckwert, Eckhard Janeba and Wolfgang Peters for helpful discussion. Constructive comments from Agnar Sandmo and two anonymous referees are also appreciated. All remaining shortcomings are my own responsibility.

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Abstract

The paper proposes a basic definition of intergenerational neutrality in the overlapping generations model when agents have a pure life cycle motive of savings. The derivation of intergenerationally neutral tax effects provides a redistribution free benchmark case that isolates the relative price effects of taxes and the deadweight losses associated with them. The paper clarifies the intergenerational incidence which has to be determined simultaneously with the substitution effects of taxes on savings and growth. Intergenerational neutrality of fiscal policy may be obtained by an endogenously determined transfer policy. A tax reform example demonstrates how taxes with diverging intergenerational incidence may be combined, first, to preserve equal revenues and, second, to keep the reform intergenerationally neutral by properly controlling for redistribution across generations. The second constraint ensures that the reform is Pareto improving.

Keywords: Intergenerational tax incidence, intergenerational redistribution, Pareto improving tax reform.
JEL–Classification: D91, E62, H22, H23.

Zusammenfassung

Das Papier führt eine grundlegende Definition intergenerativer Neutralität im Modell überlappender Generationen mit einem reinem Lebenszyklusmotiv des Sparens ein. Die Ableitung intergenerativ neutraler Steuerwirkungen beschreibt einen umverteilungsfreien Referenzfall, in welchem die relativen Preiseffekte von Steuern und die damit einhergehende Mehrbelastung isoliert werden. Das Papier klärt die intergenerative Inzidenz, welche simultan mit den Substitutionseffekten der Steuern auf Sparen und Wachstum bestimmt werden muß. Intergenerative Neutralität der Fiskalpolitik kann durch endogen bestimmte, generationenspezifische Transfers, aber auch durch geeignete Kombination von Steuern mit unterschiedlicher Inzidenz erreicht werden.

1 Introduction

The paper deals with intergenerational incidence of taxes in the overlapping generations model when agents have a pure life cycle motive for savings. The life cycle model is in some sense the extreme opposite case of the altruism model which links generations with an operative bequest motive of the Barro (1974) type. In the altruism model, the taxes' potential for intergenerational redistribution of incomes across agents does not affect utility and resource allocation because of the Ricardian neutrality proposition. Many authors analyze tax reforms using the altruism model, Judd (1987), Howitt and Sinn (1989) and Bovenberg (1986) among others, and thereby abstract from intergenerational income effects. Another branch of the literature uses the life cycle model to include intergenerational effects in the analysis of fiscal policy, for example Summers (1981a), Kotlikoff (1984) and Sibert (1990). In the life cycle model, however, the tax policy's redistributive content produces its own effects. Unfortunately, such redistribution of incomes from young to old and vice versa often occurs in rather implicit form, is not easily detected, and thereby complicates tax reform. This literature derives **net** effects of fiscal policy that combine relative price effects with intergenerational income effects. Boadway (1990) reviews the literature and discusses the implications of intergenerational redistribution for Pareto improving tax reform. Relying on simulation methods, some authors [e.g. Auerbach, Kotlikoff and Skinner (1983) and Auerbach and Kotlikoff (1987)] have been able to separate the redistributive component of fiscal policy by computing offsetting lump sum intergenerational transfers. The present paper addresses the same issues, but offers an analytical approach.

The non-neutrality of the redistributive content of fiscal policy is present whenever present and future generations are not linked via an operative altruistic bequest motive. If the value of bequests is included in the utility function rather than the utility of heirs as in Lindbeck and Weibull (1986), then present and future generations do not altruistically share resources with their descendants and intergenerational transfers are non-neutral as in the life cycle model without bequests. Weil (1987) showed that the chain of altruistically linked generations may be cut by bequest constraints if altruism is too weak. Abel (1989) argued that altruism may be selectively targeted to some, but not all the heirs. This is effectively the case in Blanchard's (1985) overlapping generations model with uncertain lifetimes or in Weil's (1989) model of overlapping infinitely lived agents. New families continuously enter the economy but are not linked to preexisting dynasties through operative intergenerational transfers. Bovenberg (1991), Nielsen and Sorensen (1991) and Engel and Kletzer (1990), for example, discuss tax and tariff policies within the framework of these models. Their analyses illustrate again that distributional and relative price effects operate simultaneously to give the overall effects of fiscal policy. Within this framework, Bovenberg (1991) gives the most detailed analysis of the redistributive component of fiscal policy and discusses combinations of tax instruments and government debt to yield Pareto improving transitions starting from an initially distorted equilibrium. However, his definition of intergenerational neutrality is different as will be evident from the discussion following proposition 4. Furthermore, the determination of the policies that are intergenerationally neutral according to his definition relies on the fact that the dynamics of the household and production sectors are independent and can be solved recursively in a small open economy model with an exogenous world net interest rate and fixed labor supply. Although this is quite a realistic case, the techniques cannot be extended to other interesting cases such as two country or closed economy models where capital accumulation and intergenerationally neutral transfers have to be determined simultaneously. This simultaneity is fully accounted for in the present approach. Furthermore, the information concerning the intergenerational incidence of policy instruments cannot be condensed in a single and easily interpreted parameter as in the two-period life cycle model.

The present paper elaborates on an idea first suggested by Auerbach (1989) and proposes a basic definition of intergenerational neutrality of fiscal policy in the life cycle model. The requirement of intergenerational neutrality imposes a restriction on the use of fiscal policy instruments that eliminates any systematic intergenerational welfare effects from redistribution and, thereby, isolates the relative price effects. The derivation of intergenerationally neutral tax effects provides a redistribution free bench mark case which reconciles in a sense the effects of fiscal policy as derived from the life cycle and the altruism model. In the present paper, the definition of intergenerational neutrality is used to endogenously determine a distribution of tax revenues in the form of transfers to young and old agents which exactly offsets the redistributive component of the fiscal experiment. In a model with two overlapping generations the share of these transfers in total tax revenues can be interpreted as the intergenerational incidence of the tax system.

Section 2 sets up a modified version of Diamond's (1965) life cycle growth model with fixed labor supply and including tax incentives for investment. Relying on the basic definition of intergenerational neutrality, section 3 scrutinizes the incidence of taxes which at the same time characterizes the taxes' potential for intergenerational redistribution. Using life cycle simulation models, Auerbach and Kotlikoff (1983, 1987 chapter 9) previously studied the effects of taxes with investment incentives on capital accumulation and intergenerational welfare. They could not, however, identify the precise intergenerational incidence. Section 4 shows how taxes with diverging intergenerational incidence may be combined to keep tax reforms intergenerationally neutral if the full set of generation specific lump sum transfers were not available. The reform is shown to be Pareto improving which requires to find not only a less distortive policy but also to pay due attention to the intergenerational incidence of the tax instruments involved. In a small open economy, the intergenerational incidence may be different due to the exogeneity of the internationally determined interest rate. Therefore, section 5 analyzes the incidence of a residence based tax on savings. Section 6 concludes.

2 The Life Cycle Growth Model

Consumption: In the basic two-period life cycle model, households supply labor inelastically, earn a wage income in the first period of life, and are retired when old. The labor force L_t which is identical to the size of the young generation in any period, grows exogenously at a constant rate n, $L_t = (1+n)L_{t-1}$. To eliminate the population growth trend all other quantities are expressed in labor units. Since we do not want to consider any heterogeneity of consumers other than age, it suffices to describe life cycle decisions of a representative young individual. Agents choose consumption in different periods to derive maximum lifetime utility $U(C^1, C^2)$ subject to their intertemporal budget constraint. More precisely, a generation born in period t solves the following problem:

$$\begin{aligned} V(r^n_{t+1}, M_t) &= \max_{\{c^1,c^2\}} \left\{ U(C^1_t, C^2_{t+1}) \;\; s.t. \;\; C^1_t + \frac{C^2_{t+1}}{1+r^n_{t+1}} \leq M_t \right\}, \\ M_t &\equiv w_t + T^1_t + T^2_{t+1}/(1+r^n_{t+1}). \end{aligned} \tag{1}$$

A single good is produced which can be used both for consumption and production, and its price is normalized to one. The upper index denotes life cycle periods $i = 1, 2$ and the lower index date of action t. If T^i is positive, it is a transfer, otherwise it is a tax. Agents apply a net of tax discount rate equal to r^n. Net wages w and lump sum taxes and transfers add up to total lifetime resources M. With individual labor supply equal to unity, all variables are per capita of the young. The utility function is assumed to be twice continuously differentiable and strictly quasiconcave. Its form is supposed to guarantee normality in both consumption goods. It additionally satisfies conditions which ensure solutions interior to the consumption set[1], $U_{C^1}/U_{C^2} \to 0(\infty)$ as $C^1/C^2 \to \infty(0)$. The utility maximizing choice of first and second period consumption, $C^i(r^n_{t+1}, M_t)$, determines by definition optimal life cycle savings to provide for old age consumption.

[1]Lower indices may either denote time or first derivatives such as $U_{C^i} \equiv \partial U(C^1, C^2)/\partial C^i$.

$$\begin{aligned}(1+n)A_{t+1} &= w_t + T_t^1 - C_t^1(r_{t+1}^n, M_t), \\ C_{t+1}^2 &= (1+r_{t+1}^n)(1+n)A_{t+1} + T_{t+1}^2.\end{aligned} \qquad (2)$$

The first period budget identity defines a savings function A_{t+1}. Eliminating savings from the two separate budget identities gives the lifetime wealth constraint. We assume that consumption in both periods is normal in income, $C_M^i > 0$. Hence, savings must increase with wage income, but less than one to one, $0 < A_w < 1$. The effect of a change in the interest rate cannot be determined a priori since substitution and income effects tend to offset each other. An increase in the interest rate increases savings only if the substitution effect dominates the income effect.

Production: The production technology is assumed to be of the linear homogeneous neoclassical type. The intensive form of the production function, $f(k)$, depends on the capital labor ratio k only and satisfies $f' > 0$ and $f'' < 0$ on its first and second derivatives as well as the Inada conditions $f'(k) \to 0\,(\infty)$ for $k \to \infty\,(0)$. Maximizing short-run profits for a given capital stock requires to employ labor in an amount that equates its marginal product to the competitive gross wage rate $\tilde{w} = f(k) - kf'(k)$.

Firm value in labor units being W_t, the total income from firm ownership includes capital gains $[(1+n)W_{t+1} - W_t]$ plus dividend payments χ_t net of corporate taxes. In a world with perfect capital markets and without uncertainty, all assets must earn a return identical to the market rate of interest r_t. Since an alternative investment would earn $r_t W_t$, arbitrage behavior dictates $r_t W_t = \chi_t + (1+n)W_{t+1} - W_t$. By forward solution, the value of the firm is seen to be equal to the present value of future dividends paid out to the owners[2] [see Auerbach (1979)],

$$\begin{aligned}(1+n)W_t &= \max_{\{i_s\}} \left\{ \sum_{s=t}^{\infty} \chi_s \prod_{u=t}^{s} \left(\tfrac{1+n}{1+r_u}\right) \qquad s.t. \right. \\ &\qquad \left. (1+n)k_{s+1} = k_s + \phi\left(\tfrac{i_s}{k_s}\right)k_s, \quad k_s > 0, \quad k_t = k^0. \right\}\end{aligned} \qquad (3)$$

A second technology constraint describes how investment i and existing capital combine to accumulate capital stocks. The technology is embodied in a linear homogeneous

[2]For the maximization problem to be well defined, the present value must be finite which requires the interest rate to exceed the growth rate in the long-run. Hence, the following analysis considers only dynamically efficient equilibria because many economic laws are suspended in case of inefficiency [see also Buiter and Kletzer (1990)]. Furthermore, the empirical evidence suggests the efficient case [see Abel et al. (1989)].

installation function.[3] The intensive form satisfies $\phi'(x) > 0$ and $\phi''(x) \leq 0$ where $x \equiv i/k$. More investment contributes to a higher capital stock but at a declining rate so. Additional investment becomes less productive in augmenting the capital stock the higher the rate of accumulation already is. A convenient normalization is $\phi(n) = n$ and $\phi'(n) = 1$ which means that a marginal unit of investment transforms into one unit of capital on a balanced growth path.

Dividend payments are net of a corporate tax at rate τ^k. Producers are allowed to subtract a fraction e of net investment expenditures i from the tax base. To keep the model as simple as possible, no further interaction of corporate and personal taxes is modelled. Section 5, however, considers a uniform tax on all forms of income from savings at the personal level. Investment spending is financed via retained earnings. Capital does not depreciate. While these assumptions are restrictive they suffice to capture the wealth effects of tax rate changes which turn out to be so important for the intergenerational incidence of capital income taxes.

$$\chi_s \equiv (1 - \tau_s^k)(f(k_s) - \tilde{w}_s) - (1 - \tau_s^k e_s) i_s. \tag{4}$$

Among the necessary conditions for a maximum are

$$\begin{aligned} &(a) \quad q_t \phi'(x_t) = 1 - \tau_t^k e_t, \\ &(b) \quad (1 + r_t) q_{t-1} = (1 - \tau_t^k) f'(k_t) + q_t[1 + \phi(x_t) - x_t \phi'(x_t)]. \end{aligned} \tag{5}$$

Forward solution of condition (5b) shows that the shadow value of new capital q is the present value of marginal future dividends. An incremental unit of capital not only generates a stream of marginal revenues but also saves on future investment spending. Since a higher capital stock today makes future investments more productive, less investment spending is required to achieve the desired capital stocks. According to condition (5a), value maximization leads to acceptance of all investment projects with a present value of incremental future income not less than the initial acquisition cost of new capital. The effective acquisition cost is the commodity price less the tax savings from investment expensing. By the arguments of Hayashi (1982), it follows from the transversality condition of firm optimization that $W_t = k_t q_{t-1}$ must hold in the optimum. Hence, one can interpret k as the number of equities issued and q as the asset price. From the necessary conditions it is seen that the tax is neutral with respect to investment decisions if the expensing rate

[3]The present approach follows Uzawa (1969) and Bovenberg (1986). Lucas (1967) and Summers (1981b) model adjustment costs as output losses associated with investment. This alternative formulation leads to similar results for the optimal investment rule.

is $e = 1$ and if tax rates are constant. In the absence of taxes and adjustment costs, (5a) gives $q = 1$ and (5b) reduces to the familiar condition $r = f'(k)$.

Government: The government collects taxes on income from wages and savings at rates τ^w and τ^r. The tax base on corporate profits is sales less wage costs less a fraction e of investment, and a rate τ^k is applied. Ignoring public debt[4], the government is constrained in its spending activities by

$$R_t \equiv \tau_t^w \tilde{w}_t + \tau_t^k [f(k_t) - \tilde{w}_t - e_t i_t] + \tau_t^r r_t A_t = g + T_t^1 + T_t^2/(1+n). \tag{6}$$

The government is assumed to spend its tax revenues per capita of the young, R_t, for the provision of a public good at a constant level g and possibly on lump sum transfers. Since we never change the per capita level of the public good, we need not include it in the utility function of the private agents. In fact, with fixed labor supply, lump sum transfers T^1 and the wage tax rate τ^w amount to the same instrument. We need both, however, to characterize the incidence of wage taxes. The net of tax wage rate available to consumers is $w_t = (1 - \tau_t^w)\tilde{w}_t$

Equilibrium: General equilibrium with perfect foresight is a sequence of prices and an intertemporal resource allocation that clear all markets and are consistent with optimality of production and consumption decisions of private agents. To describe the equilibrium of the economy it suffices to consider the capital market condition

$$k_{t+1} q_t + b_{t+1} = A_{t+1}. \tag{7}$$

Gross savings of the young are equal to the value of the domestic capital stock plus the net claims on the world economy. Foreign bonds b_t accumulate according to

$$(1+n) b_{t+1} = (1 + r_t) b_t + tb_t. \tag{8}$$

The trade balance surplus tb_t plus interest income from abroad add to net foreign wealth. In case of a closed economy, both foreign bonds and the trade imbalance are identically zero.[5]

3 Intergenerational Incidence of Taxes

We disturb the initial equilibrium by marginally increasing either the wage or the capital income tax rate and let marginal tax revenues be refunded in the form of lump sum

[4]Atkinson and Sandmo (1980) show public debt to be equivalent to lump sum transfers T^1 and T^2.

[5]Equilibrium in the commodity market follows by Walras' Law, $f(k) = C^1 + C^2/(1+n) + i + g + tb$.

intergenerational transfers. How does the policy shift incomes and affect utility across generations? Apart from the distribution of tax liabilities, the ultimate intergenerational burden of the tax increase depends indirectly on the general equilibrium changes in prices. To compensate these intergenerational income effects one may distribute tax revenues among agents in a way that eliminates any systematic welfare effects across generations resulting from new tax liabilities and price changes. Such an offsetting transfer scheme is called 'intergenerationally neutral'. If the tax increase changes relative prices, there will be further changes in income and utility due to intertemporal substitution in consumption. These substitution effects produce deadweight losses. Combining the increase of a distortive tax with an intergenerationally neutral rebatement policy therefore isolates the pure efficiency effects. At the same time, the neutral rebatement policy gives the correct measure for the intergenerational incidence of the tax. If we have to refund most of the additional tax revenues to old agents to compensate them for their burden due to the increased tax liability and the general equilibrium effects on prices, then the incidence of the tax increase lies mainly with the elder population. On the other hand, the choice of the rebatement policy influences the general equilibrium response of the economy as intergenerational transfers are non-neutral in the life cycle model without bequests. An important simultaneity is involved.

It is assumed throughout this section that the economy is closed and the initial situation is a steady state equilibrium (ISS). Furthermore, let tax revenues in the ISS be collected from wage income and corporate profits with equal rates $\tau^w = \tau^k = \tau$. Taxes on capital gains and any more complicated interaction of personal and corporate taxes are ignored for simplicity. The section on the open economy, however, will consider uniform taxation of all income from savings including capital gains. Revenues just suffice to finance the provision of a public good ($R = g$), and intergenerational transfers are zero initially ($T^1 = T^2 = 0$). To investigate the deadweight loss and the intergenerational incidence of taxes more closely, consider how utility of agents is affected by the tax increase. Using Roy's identity, $V_r = \frac{(1+n)A}{1+r} V_M$, and the closed economy version of (7), the change in indirect utility of a representative young agent is $dV_t = V_M[dM_t + \frac{1+n}{1+r} kqdr_{t+1}]$. The change in lifetime income, dM_t, is seen from (1). The arbitrage condition (5b) reveals the influences of tax rates and marginal productivities of capital and investment on the rate of return. Defining $\tilde{r} = (1 - \tau^k) f'(k)$, differentiation yields

$$qdr_{t+1} = d\tilde{r}_{t+1} + nd(\tau^k_{t+1} e_{t+1}) + (1 + n)dq_{t+1} - (1 + r)dq_t. \tag{9}$$

With this information, the change in utility turns out to be

$$\begin{aligned} dV_t &= V_M[dI_t^1 + \tfrac{1}{1+r}dI_{t+1}^2], \\ dI_t^1 &= dT_t^1 + dw_t - (1+n)kdq_t, \\ dI_{t+1}^2 &= dT_{t+1}^2 + (1+n)k\{d\tilde{r}_{t+1} + nd(\tau_{t+1}^k e_{t+1}) + (1+n)dq_{t+1}\}. \end{aligned} \tag{10}$$

Equation (10) shows how the change in utility of an arbitrary generation t depends on the policy induced income effects over life cycle periods, dI_t^1 and dI_{t+1}^2. **Intra**generational income effects over the life cycle, however, have a counterpart in **inter**generational income effects across age cohorts living simultaneously in the same period. To detect the fiscal policy's content of intergenerational redistribution one needs to relate explicitly the income effects on the young in their first period of life, dI_t^1, to the income effects on the old in their second period of life, dI_t^2. With details given in appendix A,

$$dI_t^1 = DWL_t - \frac{dI_t^2}{1+n}, \qquad DWL_t \equiv \tau(f'dk_t - edi_t). \tag{11}$$

This equation relates the income effects which the young and old agents coexisting in period t perceive as a consequence of the tax perturbation. Except for deadweight losses, these intergenerational income effects tend to be opposite in sign expressing intraperiod redistribution among agents of different age. If the tax change reduces the asset price, the young may acquire a given level of assets at a lower price which increases their effective income for consumption. At the same time, the old must sell at a lower price, too, and are effectively expropriated of part of their resources for consumption. Gross factor returns change in opposite directions as is seen from the factor price frontier, and thereby affect the two age cohorts in opposing ways. Finally, the particular distribution of the additional tax liabilities and transfer entitlements across agents produces direct intergenerational income effects. Upon substituting (11) into (10), the change in indirect utility of a representative agent born in period t emerges in a recursive form,

$$\begin{array}{ccccccccc} & & & & \Updownarrow & & & & \\ \frac{dV_t}{V_M} & = & DWL_t & - & \frac{1}{1+n}dI_t^2 & + & \frac{1}{1+r}dI_{t+1}^2, & & \\ & & & & & & \Updownarrow & & \\ & & \frac{dV_{t+1}}{V_M} & = & DWL_{t+1} & - & \frac{1}{1+n}dI_{t+1}^2 & + & \frac{1}{1+r}dI_{t+2}^2. \\ & & & & & & & & \Updownarrow \end{array} \tag{12}$$

The deadweight losses DWL_t which are associated with the tax increase, reflect the utility losses from adjustment in asset demands to bring about the desired intertemporal substitution in consumption. The terms dI_t^i contain the income effects across life cycle periods or, equivalently, across generations living in the same period. They are responsible for systematic intergenerational welfare effects. For example, the current generation's utility gain may come at the expense of the next generation while the next generation gains at the expense of its succeeding generation and so on. These intergenerational welfare effects may be offset, however, by an appropriate choice of generational transfers. By defining neutrality with respect to old age income the definition avoids any windfall gains or losses of the initially living old agents who are locked into their previously acquired assets.

Definition (Intergenerational Neutrality) *The choice of generational transfers dT^{i*} is intergenerationally neutral if it offsets the induced income effects due to tax and price changes. In each period t, neutral rebatement must satisfy $dI_t^2 = 0$.*

In Barro's (1974) model of perfect altruism, any generation would fully internalize the succeeding generation's welfare change and offset any policy induced income effects via compensating bequests. Hence, Ricardian neutrality obtains and fiscal policy operates via relative price effects only. In the life cycle model without bequests an appropriate transfer policy can be designed to achieve the same objective. The results on the non-distortive cash flow tax [see the discussion following proposition 1] suggests that Ricardian neutrality in the altruism model corresponds with intergenerationally neutral policies in the life cycle model. In both cases, fiscal policy operates via relative price effects only since any redistributive content is exactly offset either via bequests in the altruism model or the endogenously determined transfer policy in the life cycle model. The requirement of intergenerational neutrality makes the comparative statics depend on substitution effects only as is shown in proposition 1. Hence, it isolates the deadweight losses that are imposed on agents because of distortive taxation. As usual, these are zero in a first order approximation if the economy starts out from an undistorted equilibrium. The concept of intergenerational neutrality defines a benchmark case. By comparing any arbitrary fiscal policy to its intergenerationally neutral counterpart, one can disentangle the effects on efficiency from those on intergenerational redistribution.

Of course, the neutral rebatement policy directly depends on the change in tax rates, but also on the induced changes in asset prices and in the capital labor ratio which determines the changes in gross factor rewards. On the other hand, the induced changes in asset prices and capital labor ratios depend on the rebatement policy in operation. To resolve this simultaneity, one must evaluate the comparative dynamic effect of the tax under the neutral rebatement scheme. Appendix A separates the total price effects on consumption into substitution and income effects. Appropriately collecting the income terms reveals how taxes combined with an arbitrary rebatement policy operate via intergenerational redistribution. After some calculations explained in appendix A, one obtains the general equilibrium effects of tax changes on the capital labor ratios with transfers chosen to satisfy intergenerational neutrality. The local deviations of the capital labor ratios from the initial steady state values are described by a saddle-point stable difference equation system in capital and investment. In case of zero adjustment costs, the dynamics reduces to a first order equation. As argued in appendix A, the same qualitative results obtain for capital accumulation even in the absence of adjustment costs although the economy will adjust more rapidly in this case. The effect of the corporate tax depends on the sign of $f' - er$. Note from (5) that $f' - er \lesseqgtr 0$ as $e \gtreqless 1$ in the ISS. The choice of the expensing rate determines the corporate tax wedge $\frac{f'-r}{r} = \frac{\tau^k}{1-\tau^k}(1-e)$.

Proposition 1 (Intergenerationally Neutral Tax Effects) *Given that the ISS equilibrium is stable ($\psi(1) < 0$), the long-run effects of intergenerationally neutral increases in the corporate tax and investment expensing rates are*

$$\begin{aligned}(a)\quad \tfrac{dk_\infty}{d\tau^k} &= \frac{(f' - er)}{[-\psi(1)\theta_1(1+n)]q} C_r^1|_u \lesseqgtr 0 \iff e \lesseqgtr 1,\\ (b)\quad \tfrac{dk_\infty}{de} &= \frac{-\tau r}{[-\psi(1)\theta_1(1+n)]q} C_r^1|_u > 0.\end{aligned}$$

Convergence to the long-run effect is monotonic, $dk_t = dk_\infty(1-\lambda^t)$, with the stable root $0 < \lambda < 1$ determining the speed of adjustment. An intergenerationally neutral increase in the wage tax involves no effects on the capital labor ratio.

Since the tax changes are kept intergenerationally neutral by an offsetting rebatement policy, the changes in utility are identical to the deadweight losses as indicated in (12). If $e \leq 1$ initially, utility is reduced in the long-run since the capital tax rate sharpens the intertemporal distortion and reduces efficiency. With neutral rebatement satisfying $dI_t^2 = 0$ in each period, the long-run deadweight loss is, using $di_\infty = ndk_\infty$ in (11),

$$DWL_\infty = \tau[f' - en]dk_\infty \lesseqgtr 0 \iff e \lesseqgtr 1. \tag{13}$$

The term $[f' - en]$ is the corporate tax base per unit of capital in the ISS. Note that the capital tax increase with neutral rebatement involves zero effects on capital accumulation and utility if $e = 1$ initially[6]. This is the case of a cash flow tax with full investment expensing from the tax base. It is well known that a cash flow tax is intertemporally neutral since it eliminates any tax wedge between the marginal product of capital and

[6]To characterize the investment incentives in actual tax systems, e close to zero seems to be empirically relevant.

the consumer discount rate. If the tax is made also intergenerationally neutral by the endogenous choice of transfers, then the effects on capital accumulation and utility are zero. An increase in the tax rate produces only wealth effects that are offset by transfers to keep it intergenerationally neutral. An intergenerationally neutral increase in the wage tax involves no effects on the capital labor ratio, of course, since no substitution effects are involved with fixed labor supply. The wage tax is imposed on the young. The intergenerationally neutral rebatement policy refunds all of the marginal tax revenues to the young only and thereby neutralizes any potential effects from redistribution.

What is the intergenerational incidence of taxes? The burden of taxes is not only the reduction of existing income due to higher tax rates but is additionally aggravated or alleviated by the induced general equilibrium effects on wages, dividends and asset prices. The incidence may be characterized more precisely by the transfers which are required to offset these income effects. Particularly important is the tax capitalization effect on asset prices [differentiate (5a)]

$$\begin{array}{lrcl} (a) & kdq_t & = & -q\phi''(di_t - ndk_t) - kd(\tau_t^k e_t), \\ (b) & di_t - ndk_t & = & dk_\infty(1+n)(1-\lambda)\lambda^t. \end{array} \tag{14}$$

An increase in the tax rate raises tax savings from investment expensing and, thereby, reduces the purchase costs of new capital goods. Furthermore, in the spirit of Tobin's q-theory of investment, the asset price changes proportionally with the rate of change in capital stocks. If the tax increase reduces long-run capital stocks, the asset price has to decline initially by more than in the long-run to initiate the desired capital decumulation. The initial overshooting effect is transitory, however, since the first term in (14a) vanishes over time as capital stocks approach their long-run equilibrium values. If the initial expensing rate were higher than unity in the initial equilibrium, a rise in the corporate tax rate is expansionary according to proposition 1. Therefore, the initial decline in asset price is certainly less than the long-run, and it could actually increase with a very concave installation function. Empirically, however, such generous investment expensing is rather unlikely.

From the definition of intergenerational neutrality [set $dI_t^2 = 0$ in (10)],

$$\frac{dT_t^2}{1+n} = k(f' - en)d\tau^k - (1-\tau)kf''dk_t - \tau nkde - (1+n)kdq_t. \tag{15}$$

The old experience several sorts of income effects that must be offset by transfers. A higher tax rate puts a heavier tax liability on the corporation and reduces dividends by the first term in (15). On the other hand, an increase of the tax rate depresses capital accumulation in case of insufficient investment incentives ($e < 1$) whereby the remaining capital becomes more productive and raises the dividend rate. The third term shows the tax savings from more generous investment expensing allowing for higher dividends. Finally, the tax induced changes in asset prices [see the discussion following (14)] imposes windfall gains or losses on old agents who sell their assets to the young generation. Tax incidence may be characterized more sharply by computing the fraction β of the additional tax revenues which must be allocated to the old so as to offset intergenerational income effects, $dT_t^2/(1+n) = \beta_t dR_t$. The rest of tax revenues is rebated to the young, $dT_t^1 = (1-\beta_t)dR_t$, of course. The magnitude of this fraction is revealed when deviding (15) by the change in tax revenues [see (A.1)]. The intergenerationally neutral rebatement policy β need not lie necessarily between zero and unity. If it exceeds unity, for example, the old receive lump sum transfers higher than the additional tax revenues which are financed by lump sum taxes on the young in addition to other taxes. By proposition 1 an intergenerationally neutral increase in the wage tax leaves capital formation unchanged since the wage tax involves no substitution effects in a model of fixed labor supply. It is immediately derived from the definition of the rebatement policy that the incidence of the wage tax is $\beta = 0$. Young agents bear the full burden of the tax since they supply labor inelastically and, therefore, cannot evade it through behavioral adjustments. Hence, all of the additional tax revenues must be refunded to the young to avoid redistribution.

The intergenerational incidence is easiest to characterize if the initial equilibrium is untaxed. With asset revaluation given in (14a), the incidence formula for a change in the corporate tax rate reads

$$\beta_t = \frac{dT_t^2}{(1+n)dR_t} = 1 - \frac{f''}{(f'-en)}\frac{dk_t}{d\tau^k} - \frac{1+n}{(f'-en)}\frac{dq_t}{d\tau^k}. \tag{16}$$

Proposition 2 (Incidence of Corporate Tax) *If capital is adjusted without installation costs, if the initial equilibrium is laissez-faire, and if $(f' - en) > 0$ initially, the short-run intergenerational incidence of the corporate tax is $\beta_0 = 1$ for $e = 0$, but strictly exceeds unity for $e > 0$ initially. The intergenerational incidence declines over time for $0 \le e < 1$, stays constant for $e = 1$ and increases for $e > 1$.*

The condition $(f' - en) > 0$ means that the corporate tax base is positive in the initial equilibrium. Hence, revenues increase proportionally with this factor if the tax rate is increased. The assumption of zero initial tax rates eliminates any effects of a changing tax base on revenues. Absent any installation costs ($\phi'' = 0$), the incidence formula reduces to

$$\beta_t = \frac{f'+e}{f'-en} - \frac{f''}{(f'-en)}\frac{dk_t}{d\tau^k}. \tag{17}$$

Since capital is in fixed supply in period zero, the implications for short-run intergenerational incidence follow immediately. Proposition 1 holds for zero adjustment costs as well and states that an increase in the corporate tax rate under neutral rebatement leaves capital unchanged for $e = 1$, depresses capital formation for $0 \leq e < 1$, but accelerates it for $e > 1$. Capital formation changes the long-run intergenerational incidence according to (17). For zero initial taxes the long-run change in the capital labor ratio as well as the intergenerational incidence is brought about within one period [see appendix A].

What does it mean that the intergenerational incidence β may be larger than one? Take for example the cash flow tax with $e = 1$ which avoids any intertemporal distortions. To keep it intergenerationally neutral one must choose β strictly greater than unity. The tax increase not only reduces the net dividend return, but also devalues the effective price of capital at which old agents can sell their previously acquired assets and young agents can buy them.[7] Because of tax capitalization, the full burden on old agents is higher than marginal tax revenues. We must combine the tax increase with lump sum redistribution from young to old agents ($\beta > 1$) to keep it intergenerationally neutral. If the tax is intergenerationally and intertemporally neutral, it does not affect capital accumulation and utility neither in the present nor in the future. Hence, short and long-run incidence coincide according to (17).

In case of costly installation of new capital, the incidence formula becomes more complicated. Evaluate (16) for the short-run and use (14) to obtain

$$\beta_0 = \frac{f' + e}{f' - en} + \frac{(1+n)q\phi''}{(f' - en)k}\frac{di_0}{d\tau^k}. \tag{18}$$

The first term is larger than unity again. Suppose that the expensing rate is less than unity. Hence, an intergenerationally neutral increase in the corporate tax rate lowers the capital labor ratio, and the initial impact on investment is of the same sign according to (14b). The initial devaluation of old capital must exceed in magnitude the lower acquisition costs of new capital to initiate the decumulation. This is reflected in the second term of (18), and rebatement to the old must be raised in addition to the first effect. Intuitively, installation costs increase the burden of the corporate tax on the old because they increase the fixity of capital and the burden of taxes lies mainly with inflexible factors. The overshooting effect of asset price devaluation is transitory only since the term $(di_t - ndk_t)$ in (14) vanishes over time. Hence, it contributes to the short-run incidence but lowers it over time. The capital deepening effect of capital decumulation is

[7] Similar tax capitalization effects are associated with the taxation of land. See, for example, Chamley and Wright (1987).

zero initially but increases the productivity of capital over time. It also contributes to a decline in the burden of the tax. Long-run incidence is lower due to the last two effects. However, if the expensing rate exceeded unity in the ISS then the economy would build up a higher capital stock in response to an increase in the corporate tax rate. The decline in the asset price would be less pronounced in the early transition phase to provide the incentive for capital accumulation. As a theoretical possibility, the value of old capital may rise even though acquisition costs of new capital goods decline if the installation function is very concave. In this case, the corporate tax increase would be less of a burden to the old generation in the short-run.

Proposition 3 (Incidence with Initial Taxes) *(a) Short-run incidence: Precluding any Laffer type reaction of tax revenues and with $f' - en > 0$ initially, the short-run intergenerational incidence of the corporate income tax is $\beta_0 > 1$ for $e = 0$ and $e = 1$.*
(b) Long-run incidence: If $e = 1$, short and long-run intergenerational incidence is identical and exceeds unity.

The conclusions are obtained by evaluating appropriately (15) and (A.1) and substituting into the incidence formula given by the first equality of (16). Part (b) simply stems from the fact that for $e = 1$ the tax does not contain intertemporal distortions. If the tax increase is also made intergenerationally neutral, capital accumulation is unaffected. The short and long-run wealth effects are identical. If $e \neq 1$, proposition 2 does not easily generalize to the case of an equilibrium with positive taxes. If taxes are present initially, the change in tax revenues additionally depends on capital formation which augments or erodes the tax base. Tax revenues as well as the intergenerationally neutral transfers to old agents increase in the short-run and both tend to decline over time. Nothing strong is deduced about the relative magnitudes precluding any clear cut results on incidence except in the special cases of proposition 3. However, one may develop some intuition by comparing to the case of proposition 2.

Equations (14) and (15) also characterize the incidence of more generous investment expensing. The effect on the asset price is twofold. First, the asset price declines because more generous expensing reduces the effective purchase price of new capital goods. Second, to bring about the desired capital accumulation, the asset price would have to be transitorily higher than its long-run value. Therefore, the short-run effect on asset prices is indeterminate[8] while the long-run effect is unambiguously negative due to the

[8]The empirical evidence presented by Lyon (1989) suggests that firm values increase upon the introduction of an investment tax credit. Note, however, that a tax credit is a direct grant while investment expensing from the tax base generates savings depending on the size of the tax rate.

first channel. The wealth effects would, therefore, put a burden on old agents in the long-run. According to (15), the old experience an additional burden over time since capital accumulation erodes dividend rates per unit of capital. Since the young gain from the associated wage increases, the burden lies mainly with the old.

4 Intergenerationally Neutral Tax Reform

Apart from characterizing generational incidence of taxes which is interesting in its own right, one can fruitfully exploit this approach in the design of intergenerationally neutral tax reforms. Such a reform is Pareto improving in the example given below. Only if the initial equilibrium is distorted, policy makers may reap efficiency gains by employing 'less distorting' tax alternatives. In the life cycle model different tax instruments may have vastly different intergenerational incidence. While it may be possible to increase efficiency by introducing less distorting taxes, such a reform may entail adverse intergenerational redistribution. Redistribution inevitably hits some agents to the benefit of others and may thereby preclude potential Pareto improvements by exploiting efficiency gains.

In our model with fixed labor supply one could eliminate the intertemporal distortion associated with the capital income tax by moving to a cash flow tax that allows for a deduction of investment spending from the tax base. The rationale of such a policy is that it eliminates the tax wedge between the marginal product of capital and the consumers' discount rate. It promises efficiency gains and possible Pareto improvements. However, the reform may devalue old capital and, therefore, expropriate old agents of their consumption possibilities. If there are no corrective measures the proposed reform cannot be Pareto improving in the life cycle model. However, the rates of the capital and labor income taxes with different intergenerational incidence may be combined in a way, first, to preserve revenue neutrality and, second, to guarantee intergenerational neutrality by appropriately correcting for the adverse intergenerational incidence of a change in the expensing rate e. No transfers to old agents are needed in this section since taxes with diverging generational incidence are used to control for redistribution.

Consider, for example, an initial equilibrium with equal tax rates on wage and corporate income and zero investment expensing. Tax revenues just cover the spending on public consumption.[9] The tax experiment is an exogenous and permanent increase in the expensing rate $de > 0$. Additionally, the labor and corporate income tax rates must be adjusted endogenously to guarantee equal revenues and intergenerational neutrality of

[9]Hence, $\tau^k = \tau^w = \tau$, $\tau^r = 0$, $e = 0$, $q = 1$, $T^1 = T^2 = 0$ and $R = g$ in the initial equilibrium.

the tax reform package. Two instruments, $d\tau_t^k$ and $d\tau_t^w$, are available to satisfy simultaneously two constraints. Revenue neutrality requires to adjust the tax rates to keep per capita tax revenues unchanged. Differentiating (6) we obtain under our assumptions concerning the ISS

$$dR_t = \tilde{w} d\tau_t^w + kf' d\tau_t^k + \tau f' dk_t - \tau nk de_t = 0. \tag{19}$$

To obtain the second constraint one needs to derive the utility differential in a recursive form. It will reveal any systematic utility effects across generations which must be offset by the change in tax rates if the tax reform package is to be intergenerationally neutral. By the same arguments as in the previous section, the income effects across life cycle periods, dI_t^1 and dI_{t+1}^2, are translated into within period income effects across generations, dI_t^1 and dI_t^2. Relying mainly on the government budget constraint and the factor price frontier, intergenerational income effects are related according to (11) with a deadweight loss equal to $DWL_t = \tau f' dk_t$. Except for an efficiency term, the policy induced income effects tend to affect the agents in opposing ways. Upon substitution, the utility differential emerges again in the recursive form of (12).

By tax capitalization, an investment incentive $de > 0$ affects the prices at which old agents may sell their previously acquired assets. To compensate them for these windfall gains or losses, the corporate tax rate may be adjusted to satisfy the fiscal policy rule for intergenerational neutrality,

$$dI_t^2 = 0 \qquad \Longleftrightarrow \qquad f' d\tau_t^k = (1-\tau) f'' dk_t + n\tau de + (1+n) dq_t. \tag{20}$$

When introducing a small investment incentive, equations (19) and (20) indicate how the two tax rates must adjust endogenously to preserve intergenerational neutrality and equal per capita revenues. To evaluate the implications for utility of present and future generations, the effect of this tax reform package on capital accumulation must be determined. Appendix B derives the intergenerationally neutral impact on growth which reflects the intertemporal substitution effects only.

$$\frac{dk_\infty}{de} = -\frac{\tau(1+r)}{\theta_1(1-\lambda)q} C_r^1|_u, \qquad dk_t = dk_\infty(1-\lambda^t). \tag{21}$$

What is implied for the wage and corporate income tax rates? If installation costs are absent, the fiscal policy rule for intergenerational neutrality in (20) implies together with the asset price effects in (14) that the corporate tax rate must be lowered to offset two sorts of income effects on the old. First, an increase in the expensing rate makes new capital effectively cheaper. Since old and new capital are perfect substitutes, the asset price is reduced by the same amount equal to $-\tau de$. More generous expensing reduces the corporate tax bill and raises dividends. The net effect is negative, however. Second, the induced capital accumulation erodes the dividend rate per unit of capital. The reduction in the corporate tax rate must exactly offset these income and wealth effects to keep the reform intergenerationally neutral, and it can do so since its burden falls mainly on old agents. Fortunately, the lower tax rate also reinforces the efficiency effect of a higher expensing rate since both instruments contribute to a reduction in the tax wedge. In case of costly installation of new capital, the implication for the intergenerationally neutral adjustment of the tax rate is less clear. In this case, the change in the asset price depends on the rate at which capital is accumulated. Since new capital is installed subject to adjustment costs, old capital becomes more valuable. Old and new capital are imperfect substitutes. The higher the adjustment speed and the more concave the installation function, the less the asset price will decline. As a transitory short-run phenomenon it may even increase to initiate the accumulation of capital but it unambiguously decreases over the long-run. Hence, the short-run reduction in the corporate tax rate is less in case of installation costs. Even if it increases in the short-run, the combined effects of the tax reform package unambiguously increase capital stocks.

The change in the wage tax must offset the revenue effects of the intergenerationally neutral adjustments in the corporate tax and expensing rates. It is implied by the revenue constraint in (19) with $f' d\tau_t^k$ determined by the requirement of intergenerational neutrality: $\tilde{w} d\tau_t^w = \tau n k de - k f' d\tau_t^k - \tau f' dk_t$. Without adjustment costs the wage tax must be increased initially to compensate for the revenue losses from more generous investment expensing and from the reduction in the corporate tax rate. Most probably, the wage tax rate will exceed its initial value during all of the transition, since the corporate tax rate is lowered. However, a base widening effect of the higher level of capital on the tax base might conceivably allow even for a lower wage tax rate than initially. Barring a Laffer type argument, this source of tax base widening will not dominate the effect on the revenue neutral wage tax rate. The same conclusions hold also with adjustment costs as long as intergenerational neutrality requires a reduction in the corporate tax rate.

What are the welfare consequences of the proposed reform? The fiscal policy rule in (20) keeps the reform intergenerationally neutral and, therefore, offsets any changes in utility due to intergenerational income effects. Changes in utility reflect the efficiency gains from lowering intertemporal distortions, and they are equal to $DWL_t = \tau f' dk_t$. The changes in capital labor ratios depend on intertemporal substitution effects only, and so does the deadweight loss. On impact, the equilibrium capital labor ratio remains fixed ($dk_0 = 0$) but grows monotonically in subsequent periods. Therefore, utility of the initial young and old agents remains unaffected ($dV_{-1} = dV_0 = 0$), but lifetime utility of succeeding generations increases by the amount of the efficiency gain.

Proposition 4 (Intergenerationally Neutral Tax Reform) *(a) A permanent introduction of a small investment incentive combined with intergenerationally neutral adjustments of the corporate and wage taxes makes the capital labor ratio monotonically converge to a higher steady state level. Given fixed labor supply, the policy is Pareto improving. (b) In the absence of installation costs, intergenerational neutrality requires a gradual reduction of the corporate tax rate. At least for some initial periods, an increase of the wage tax rate is required to achieve equal tax revenues. In case of non-zero installation costs, the corporate tax rate is reduced in the long-run while the intergenerationally neutral adjustment is ambiguous in the short-run.*

In the tax reform example the corporate tax rate is used to control for the intergenerational distributional effects of the investment expensing rate which requires a reduction of the tax rate except possibly for some initial periods. Fortunately, such a reduction also alleviates the intertemporal distortion in the initial equilibrium and, therefore, reinforces the beneficial efficiency effect of introducing investment expensing. The intergenerationally neutral reform isolates the substitution effects of the implied changes in net interest rates, and gives a Pareto improvement. However, this is not a general feature of intergenerationally neutral tax reforms. If labor supply were elastic, the increases in the wage tax rates which preserve equal revenues, would introduce new within period distortions that offset lower intertemporal distortions from capital taxation. If Pareto improvement or maximization of social welfare were the main objective, one would willingly deviate from the concept of intergenerationally neutral tax reform. By using debt policy, for example, one could change the pattern of welfare effects across generations. Atkinson and Sandmo (1980) showed that intergenerational transfers are in fact equivalent to debt policy. Appealing to Phelps and Riley's (1978) result that a maximin optimal growth path must equalize utilities of generations at the largest possible value, one could make all generations share equally in the welfare improvement, $dV_t = dV_{t+1} = dV_{t+2} \ldots > 0$, by installing appropriate lump sum transfers. Relying on these ideas, Auerbach and Kotlikoff (1987) designed a 'Lump Sum Redistribution Authority' that uses lump sum taxes and transfers as well as debt to keep cohorts before a specified date at their status quo level of utility and to raise the utility of all cohorts born after this date by a uniform amount. Similarly, Bovenberg's (1991) concept of intergenerational neutrality requires that utility of all generations changes by a uniform amount. Making the changes in utility equal across generations, however, would violate the definition of intergenerational neutrality proposed in the present paper. As a consequence, new intergenerational income effects would appear which mix with the substitution effects that were isolated in the computation of intergenerationally neutral tax effects.

5 Intergenerational Incidence in the Open Economy

Taxes on capital income importantly determine savings and investment decisions, and the induced factor price changes feed back on the intergenerational incidence of taxes. In small open economies with free international movement of financial assets, savings and investment need not coincide as any difference is financed by current account imbalances. The implications of capital income taxes on growth and intergenerational incidence will be quite different. Consider, for example, a residence based tax on savings where the home country government taxes its citizens on their world wide income. Arbitrage activities tend to equalize the investors' net returns irrespective of whether assets are invested at home or abroad. Since the same tax rate applies, the market rate of interest at home is fixed to the rate prevailing in the rest of the world. If the tax rates on interest, dividends and capital gains were all different, a change in the interest tax would generally affect investment decisions [see Nielsen and Sørensen (1991), for example]. Assume, for simplicity only, that the residence based tax treats all forms of income from savings alike, be it interest, dividends or capital gains. Uniform taxation of savings just multiplies the tax factor $(1-\tau^r)$ on both sides of the no-arbitrage condition which was discussed in deriving (3). Hence, the gross return on equities is fixed to the exogenous world rate of interest r. In this case, the production sector is not affected leaving investment, gross wages, dividends and capital gains unchanged in response to a change in the uniform residence based tax on savings. To simplify further, set the source based tax τ^k which may possibly be levied in addition to the residence based tax, equal to zero.[10]

Keeping the wage tax rate at its initial level, net and gross wages remain fixed. The analysis of tax incidence needs to consider the household sector and the government budget only, and external wealth changes by the amount of additional gross savings. The residence based tax τ^r drives a wedge between the gross return of all assets equal to the exogenous world interest rate and the savers' net return. A perturbation in the interest tax affects utility as in (10) showing the dependence on intragenerational income effects $dI^1 = dT^1$ and $dI^2 = dT^2 + (1+n)Adr^n$. Using the government budget constraint

[10] A separate appendix which is available upon request analyzes additionally the source based tax.

$dT_t^2/(1+n) = dR_t - dT_t^1$ and the revenue equation (6) in differentiated form, income effects across generations are revealed in (11) with $DWL_t = \tau^r r dA_t$ and the income effects given above. Hence, the changes in utility of each generation depend on the changes in utility of preceeding and succeeding generations according to (12) implying $dI_t^2 = 0$ for intergenerational neutrality. Using the Slutzky decomposition, the definitions of the intergenerational income terms and (11), the differential of the savings equation in (2) gives $(1+n)dA_{t+1} = (1 - C_M^1)\tau^r r dA_t - C_r^1|_u dr_{t+1}^n$ if the intergenerationally neutral transfer policy is implemented. Hence, savings follows a first order difference equation with root $\lambda = \frac{(1-C_M^1)\tau^r r}{1+n}$ which is assumed stable. The root is zero in case of a laissez-faire equilibrium initially, indicating instantaneous adjustment.

Proposition 5 (Intergenerationally Neutral Tax on Savings) *(a) In a small open economy, the long-run effect of an intergenerationally neutral increase in the residence based tax on savings is* $\frac{dA_\infty}{d\tau^r} = \frac{rC_r^1|_u}{(1+n)(1-\lambda)} < 0$. *Convergence to the long-run effect is monotonic,* $dA_t = dA_\infty(1-\lambda^t)$. *The current account deteriorates and utility is reduced. (b) The short-run intergenerational incidence is* $\beta_0 = 1$ *and increases over time.*

The measure of intergenerational incidence is obtained from the neutrality constraint $dI_t^2 = 0$ and the rebatement rule for the additional tax revenues, $dT_t^2/(1+n) = \beta_t dR_t$, giving $\beta_t = [1 + \frac{r^r}{A}\frac{dA_t}{d\tau^r}]^{-1}$. The incidence of a residence based tax on savings is unity on impact but increases in the following periods. A constant amount of transfers must be refunded to the old to compensate them for the direct burden of the tax increase. As opposed to the closed economy they perceive no other income effects on their assets such as a reduction of dividend rates or capital losses. On the other hand, tax revenues decline over time as intertemporal substitution makes households save less. Hence, the burden of the tax on old agents exceeds revenues in the long-run. In case that the initial equilibrium is laissez-faire the decline in savings is immediate and permanent. Furthermore, the erosion of the tax base has no revenue effects. Consequently, short and long-run incidence coincide with zero initial taxes.

6 Conclusions

The paper proposed a basic definition of intergenerational neutrality in the life cycle growth model. The derivation of intergenerationally neutral tax effects provides a redistribution free benchmark case that isolates the relative price effects of taxes and the deadweight losses associated with them. The paper clarified generational incidence in the pure life cycle model which has to be determined simultaneously with the substitution effects of taxes on capital accumulation. One of the interesting results is that the presence of investment incentives places more of the burden of capital income taxes on old agents than in the case without such incentives. This is due to tax capitalization effects of an increase in the tax rate which partly expropriate old agents who are the owners of capital. The overall burden of capital income taxes on old agents may easily exceed tax revenues. Apparently, governments place great weight on transitional windfall gains or losses which contribute importantly to the overall incidence of taxes. The paper emphasized that any tax reform should recognize the dual role of taxes in the life cycle model. They alter relative prices, and they redistribute across generations depending on their specific intergenerational incidence.

The intergenerational incidence of taxes depends importantly on wealth effects from tax capitalization. The presence of adjustment costs reinforces or alleviates them. In concentrating on these issues, the paper kept the model simple in other respects to ensure tractability. Future research may investigate the substitution effects of taxes and their intergenerational incidence when labor supply is elastic. As discussed at the end of section 4, endogenous labor supply certainly changes the welfare implications of intergenerationally neutral tax reforms if only distortive taxes with diverging incidence are available to control for redistribution. Furthermore, it is worthwhile to investigate whether a similar concept of intergenerational neutrality can be applied to other models with more flexible generational overlap to isolate the substitution effects of taxes on growth and the associated deadweight losses. Such a rule must offset the policy induced intergenerational income effects and must fully take account of the feedback of the redistribution policy on growth.

Appendix A derives the tax effects given in proposition 1 for the closed economy. $\tau^w = \tau^k = \tau$ while $\tau^r = 0$ initially. From (6), the change in revenues is

$$dR_t = \tilde{w} d\tau_t^w + \tau(f' dk_t - edi_t - ide_t) + (f' - en)kd\tau_t^k. \tag{A.1}$$

With government consumption fixed, $dT_t^2/(1+n) = dR_t - dT_t^1$ from (6). Substitute this into dI_t^2 defined in (10) and use (A.1). The changes in net interest rates and net wages are $d\tilde{r}_t = -f' d\tau_t^k + (1-\tau^k) df_t'$ and $dw = -\tilde{w} d\tau^w + (1-\tau) d\tilde{w}$. By linear-homogeneity of the production function, $d\tilde{w} + kdf' = 0$. Therefore, (11) holds.

Using (2) and (7), $(1+n)q_t k_{t+1} = w_t + T_t^1 - C_t^1(r_{t+1}, M_t)$ is the closed economy capital market condition. Differentiate it given that ISS transfers are zero. Substitute the Slutzky decomposition $C_r^1 = C_r^1|_u + \frac{(1+n)A}{1+r} C_M^1$, use the ISS relation $A = qk$ and the definition of

dI_t^1 given in (10) to obtain

$$(1+n)qdk_{t+1} = (1-C_M^1)dI_t^1 - C_M^1(1+n)kdq_t - \tfrac{C_M^1}{1+r}dT_{t+1}^2 - C_M^1\tfrac{1+n}{1+r}kqdr_{t+1} - C_r^1|_u dr_{t+1}. \quad (A.2)$$

For the fourth term on the r.h.s. substitute the change in the net return qdr_{t+1} from (9) which may also be written as $qdr_{t+1} = \frac{dI_{t+1}^2 - dT_{t+1}^2}{(1+n)k} - (1+r)dq_t$. Hence,

$$(1+n)qdk_{t+1} = (1-C_M^1)dI_t^1 - \frac{C_M^1}{1+r}dI_{t+1}^2 - C_r^1|_u dr_{t+1}. \quad (A.3)$$

Eliminate dI_t^1 using (11). Set $dI_t^2 = 0$ all t for intergenerational neutrality and obtain

$$(1+n)qdk_{t+1} = (1-C_M^1)\tau(f'dk_t - edi_t) - C_r^1|_u dr_{t+1}. \quad (A.4)$$

Assuming a constant change in the tax parameters and using (14a), (9) yields

$$\begin{aligned} qdr_{t+1} &= [(1-\tau)f'' + \frac{(1+n)nq\phi''}{k}]dk_{t+1} - [\frac{(1+n)q\phi''}{k}]di_{t+1} - \\ &\quad [\frac{(1+r)nq\phi''}{k}]dk_t + [\frac{(1+r)q\phi''}{k}]di_t - f'd\tau^k + rd(\tau^k e). \end{aligned}$$

Substitute this into (A.4) and collect terms to obtain

$$\begin{array}{lllllll} & & \theta_1 di_{t+1} = \theta_2(1+n)dk_{t+1} + \theta_3 di_t - \theta_4 dk_t + \theta_5 d\tau^k - \theta_6 de, & & & & \\ \theta_1 &=& C_r^1|_u\frac{(1+n)\phi''}{k} > 0, & \theta_4 &=& (1-C_M^1)\tau f' + C_r^1|_u\frac{(1+r)n\phi''}{k} > 0, & \\ \theta_2 &=& q + C_r^1|_u[\frac{(1-\tau)f''}{(1+n)q} + \frac{n\phi''}{k}] > 0, & \theta_5 &=& -C_r^1|_u\frac{1}{q}[f' - er] \gtrless 0, & (A.5)\\ \theta_3 &=& (1-C_M^1)\tau e + C_r^1|_u\frac{(1+r)\phi''}{k} > 0, & \theta_6 &=& -C_r^1|_u\frac{\tau r}{q} > 0. & \end{array}$$

Substituting out $(1+n)dk_{t+1}$ by the differentiated equation of motion in (3) and adding it as a second dynamic equation gives the dynamic system which describes the local deviations from the ISS equilibrium,

$$\begin{bmatrix} di_{t+1} \\ dk_{t+1} \end{bmatrix} = \begin{bmatrix} \frac{\theta_2+\theta_3}{\theta_1} & \frac{\theta_2-\theta_4}{\theta_1} \\ \frac{1}{1+n} & \frac{1}{1+n} \end{bmatrix} \begin{bmatrix} di_t \\ dk_t \end{bmatrix} + \begin{bmatrix} \frac{\theta_5}{\theta_1} \\ 0 \end{bmatrix} d\tau^k - \begin{bmatrix} \frac{\theta_6}{\theta_1} \\ 0 \end{bmatrix} de. \quad (A.6)$$

Denote this by $X_{t+1} = ZX_t + U$. The characteristic polynomial is $\psi(s) = \det(sI - Z)$. Since $\psi(0) = \det(Z) = \frac{\theta_3+\theta_4}{(1+n)\theta_1} = \lambda\mu > 0$, both eigenvalues are of the same sign. The system is saddle-point stable with roots $0 < \lambda < 1 < \mu$ if $\psi(1) < 0$. Upon evaluation

$$\begin{aligned} -\psi(1)\theta_1(1+n) &= [n(\theta_3 - \theta_1) + (1+n)\theta_2 - \theta_4] \\ &= \left\{(1+n)q + \tfrac{1-\tau}{q}C_r^1|_u f'' - \tau(f' - en)(1-C_M^1)\right\} > 0. \end{aligned} \quad (A.7)$$

If the ISS is untaxed, then $\psi(1) < 0$, and it is assumed to remain so for small tax rates.

The steady state solution of (A.6) is easily computed as $X_\infty = (I-Z)^{-1}U$, see proposition 1. Transition paths follow $X_t = X_\infty + \omega[^v_1]\lambda^t$ where $[v,1]'$ is the eigenvector corresponding to the stable root. Evaluating the second line of $(\lambda I - Z)[^v_1] = 0$ gives $v = (1+n)\lambda - 1$. The weight $\omega = -dk_\infty$ is determined from the initial condition for the state variable, $dk_0 = 0$. Hence, $dk_t = dk_\infty(1-\lambda^t)$ giving rise to monotonic transition paths.

Absent any installation costs ($\phi'' = 0$), the results remain the same qualitatively. $\theta_1 = 0$ and (A.6) reduces to a first order equation in capital labor ratios. We obtain $(1+n)(\theta_2+\theta_3)dk_{t+1} = (\theta_3+\theta_4)dk_t - \theta_5 d\tau^k + \theta_6 de$ after eliminating di_t in (A.5) by the differentiated accumulation equation. The root $\lambda = \frac{\theta_3+\theta_4}{(1+n)(\theta_2+\theta_3)}$ is positive and must be smaller than unity for stability. The long-run solution in proposition 1 still holds except that the square bracket in the denominator is replaced by the curly bracket on the r.h.s. of (A.7) which must be positive for stability. If $\phi'' = 0$ and $\tau = 0$ in the ISS, the coefficient of dk_t is zero implying instantaneous and complete adjustment.

Appendix B derives (21). Differentiate the capital market condition and perform the same steps following (A.2) in appendix A. Especially, use (9) and (10) to write the change in the net rate of return as $q dr_{t+1} = \frac{dI^2_{t+1}}{(1+n)k} - (1+r)dq_t$ and obtain (A.3) in exactly the same form. The implementation of intergenerational neutrality, $dI^2_t = 0$ in all periods, implies $dI^1_t = DWL_t$ and $q dr_{t+1} = -(1+r)dq_t$. From (14) and the accumulation equation, $dq_t = -\tau de - \frac{q\phi''}{k}(1+n)(dk_{t+1} - dk_t)$. With this information, the intergenerationally neutral tax effects are $\theta_1 dk_{t+1} = \theta_2 dk_t - C^1_r|_u \tau \frac{(1+r)}{q} de$, with coefficients $\theta_1 = (1+n)q + C^1_r|_u \phi'' \frac{(1+r)(1+n)}{k}$ and $\theta_2 = (1-C^1_M)\tau f' + C^1_r|_u \phi'' \frac{(1+r)(1+n)}{k}$. Both are positive. Stability requires that the root $\lambda = \theta_2/\theta_1$ be smaller than unity or, equivalently, $\theta_1 - \theta_2 = (1+n)q - \tau f'(1-C^1_M) > 0$ which is guaranteed if the tax rate is not too large. Under these conditions, the solution in (21) gives a monotonic transition.

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