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THE WELFARE COST OF CAPITAL INCOME TAXATION IN A GROWING ECONOMY

by

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It determines the level of consumption by the maximization of its intertemporal utility function. Future factor prices (wage and interest rates), depend on the accumulation of capital through a neoclassical technology, and are known with perfect foresight. The household behaves competitively: future (endogenous) prices are taken as given.

The welfare cost of the capital income tax is analyzed in the second section. Following common practice, we consider the welfare cost induced by a tax with lump-sum redistribution. Initially, the economy is assumed to be on the balanced growth path where capital income is taxed at a fixed rate (and tax revenues are refunded). At time zero the tax is abolished (together with the refunds). Thereafter. the economy moves on a dynamic path towards a new steady state. The welfare cost of the capital income tax is equal to the welfare gain obtained by the abolition of the tax, namely by the difference between the level of utility on the new dynamic path (after the tax reform), and the level of utility on the initial balanced growth path (with the tax in effect).[2] As usual, the welfare cost of the tax is measured by a wealth equivalent, and is of a second order with respect to the tax rate. A second approximation of this excess-burden is given,which depends on the parameters of the utility and production functions, and on the growth rate. An extension of the Levhari and Sheshinski result is obtained as a special case. Since the general excess-burden formula is exact only for infinitesimal values of the tax rate, the error of this second order approximation is analyzed in a numerical example.

The assumption of perfect foresight is relaxed in Section 3. Because the dynamic path after the abolition of the tax is no longer optimal, the welfare gain induced by the tax reform is smaller in this case. The case of myopic expectations is an important example of the more general class of expectations which are considered. In the next sections we revert to the assumption of perfect foresight.

The case where the tax rate of the capital income tax is not identical for all sectors of production (an example is found in the corporation tax), is considered in Section 4. The intertemporal welfare cost of the tax is compared to the inefficiency cost due to the misallocation of capital between the different sectors of production.

In Section 5, the assumption of a fixed labor supply is relaxed. Since the capital income tax lowers the long-run wage rate, its excess-burden depends on the (compensated) elasticity of the labor supply.

This analysis of the capital income tax relies on a stylized model.[3] However, numerous numerical examples show that some of the results obtained are fairly robust. These results are summarized and related to other studies using more disaggregated models[4] in the conclusion.

1. The Model

There is one good in the economy. This good can be consumed, or used as capital in the production process. Total output per efficiency unit of labor, net of capital depreciation, is given by the neoclassical production function:

$$y = f(k)$$

where k is the level of the capital stock per efficiency unit of labor.

The private sector is represented by a household, growing at the rate n, which takes prices as given, and maximizes under its budget constraint the utility function:

$$U = \int_0^{\infty} e^{-\rho t} e^{nt} u(c_t e^{\mu t}) dt \quad , \tag{1}$$

where the following notation is used:

ρ = pure rate of time preference;

μ = rate of growth of labor augmenting technological change;

c_t = consumption per unit of efficient labor.

The function u will be assumed to be of the form $u(c) = c^{1-\sigma}$.[5] The labor supply per capita is fixed, and normalized to one at time zero. The representative household is endowed with perfect foresight, and behaves competitively, taking the endogenous future prices (wage and interest rates), as given.

Because of the first order condition in the maximization of the utility function, the dynamic path of the economy satisfies the equation:[6]

$$\dot{c}_t = \frac{c_t}{\sigma}(r_t - \rho^*) \tag{2}$$

where r_t is the net rate of return available to the household, and $\rho^* = \rho + \sigma \cdot \mu$.

The capital accumulation is defined by

$$\dot{k}_t = f(k_t) - (n+\mu)k_t - c_t \ , \tag{3}$$

where k_0 represents the initial capital stock.

The dynamic behavior of the economy is defined by the equations (2) and (3), and by the initial values k_0 and c_0 , at time zero. The initial value of the capital stock k_0 , is given. There is a unique value of c_0 , such that its associated dynamic path satisfies the budget constraint of the household (which is equivalent here to the transversality conditions). For this value of c_0 , the dynamic path converges to the steady state defined by:[7]

$$\rho^* = r^* = f'(k^*) \tag{4}$$

$$c^* = f(k^*) - (n+\mu)k^* \tag{5}$$

(an asterisk will denote a steady state value).

The optimal path defines also a consumption function, giving the level of consumption per unit of labor as a function of the capital labor ratio at each instant (see Figure 1),

$$c = c(k) \ . \tag{6}$$

In the same way, at a given instant, the level of utility is determined by the integral (1) on the optimal path Γ for an initial value of the capital stock which is equal to k :

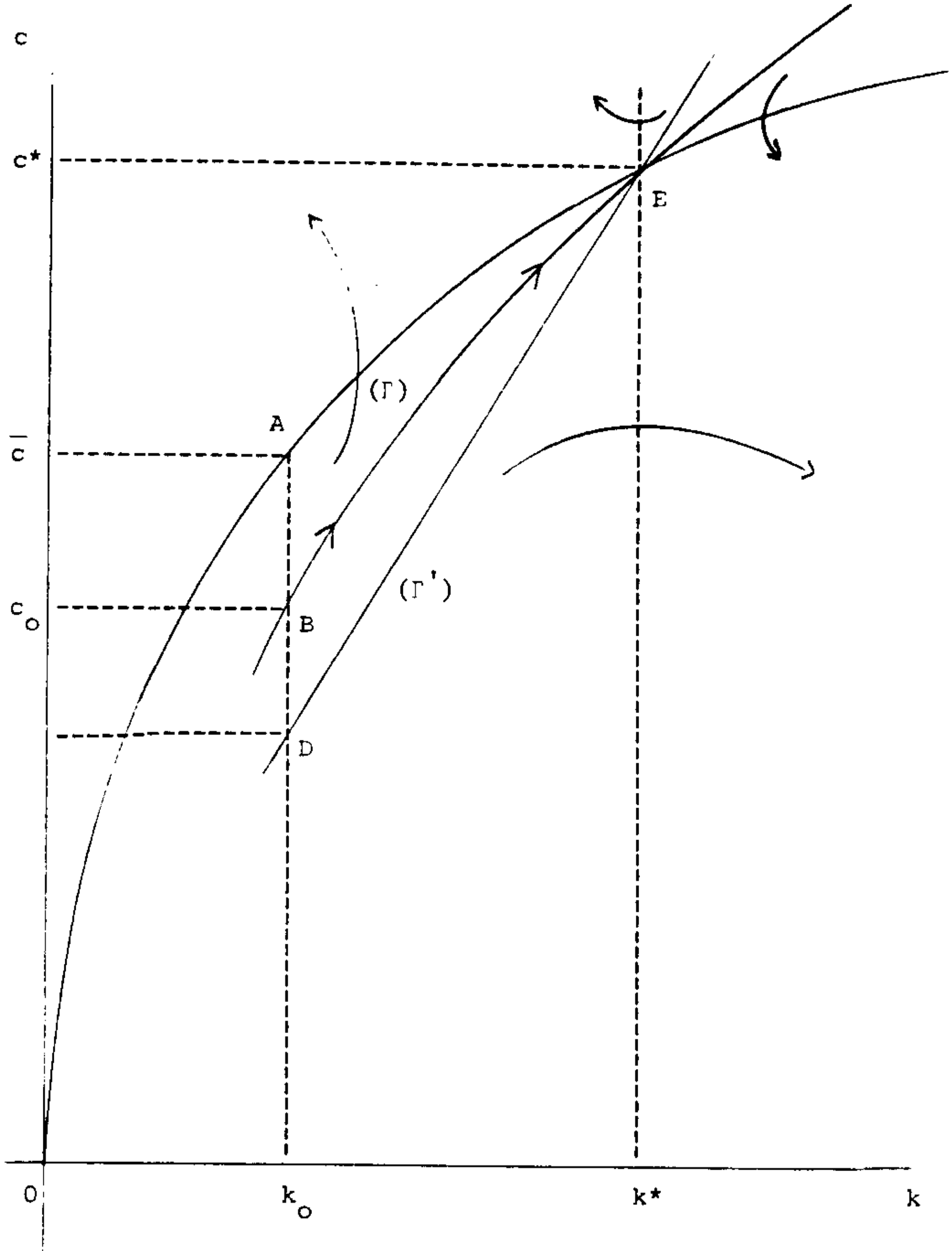

Figure 1

The consumption function and the dynamic path

$$U = J(k) .$$

We now review a few properties of the optimal path which will be useful in the subsequent sections:

The slope of the consumption function $c'(k^*)$, at the stationary point k^* is obtained by taking the limit of the ratio between the relations (2) and (3) when k tends to k^*; $c'(k^*)$ is equal to the positive root of the equation

$$x^2 - \lambda x - \gamma = 0 \tag{7}$$

where $\lambda = \rho^* - n - \mu$ and $\gamma = -[c(k^*)f''(k^*)]/\sigma = (1/\sigma\varepsilon)[c(k^*)(r^* + \delta)w^*/k^*f(k^*)]$.

ε is the elasticity of substitution between capital and labor in the production function when the capital labor ratio is equal to k^*.[8] Using a first order approximation of the capital accumulation (3) around k^*, the difference between k and its steady state value k^*, decreases asymptotically at a constant rate a:[9]

$$(k_t \dot{-} k^*) = -a(k_t - k^*) \tag{8}$$

a is the coefficient of adjustment of the economy towards the steady state, and is equal to the difference $c'(k^*) - \lambda$; $-a$ is also equal to the negative root of the equation (7).

The same asymptotic rule applies to every endogenous variable z_t, in the economy which depends only on the capital labor ratio (as for example, the gross factor prices):[10]

$$(z_t \dot{-} z^*) = -a(z_t - z^*) , \tag{8a}$$

where the coefficient a is the same as in equation (8).

2. The Excess-Burden of the Capital Income Tax

Consider now a tax on capital income at the constant rate θ, with lump-sum redistribution of its revenues. The analysis of the model described in the previous section applies with a net interest rate r now given by

$$r = (1-\theta)f'(k) .$$

In particular, in the long run, the net rate of return is constant and still equal to ρ^*. In the long run, the capital income tax increases the gross rate of return, lowers the capital stock and aggregate consumption. The levels of consumption and capital per unit of labor in the steady state with taxation, respectively $\bar{c}$ and $\bar{k}$, are given by:

$$\rho^* = (1-\theta)f(\bar{k}) \tag{4a}$$

$$\bar{c} = f(\bar{k}) - (n+\mu)\bar{k} . \tag{5a}$$

This steady state is represented by the point A in Figure 1.

We assume that initially, the economy is in the long-run equilibrium with taxation (point A). The deadweight loss of the tax is measured by the welfare gain induced by the suppression of the tax.[11]

At time zero, the capital income tax is abolished[12] (together with the lump-sum refund). The net rate of return suddenly increases, and consumption decreases immediately from $\bar{c}$ to c_0 (the optimal value which depends only on the initial capital stock $k_0 = \bar{k}$, as described in Section 1). After time zero, because of the increased savings,[13] the capital stock increases. The economy moves towards the new steady state E on the segment BE of the path Γ defined by the dynamic equations (2) and (3).

The welfare gain of the tax reform ΔU, is given by the difference between the utility on the path BE, and the utility in the steady state A :[14]

$$\Delta U = J(\bar{k}) - \frac{u(\bar{c})}{\rho^* - n - \mu} . \tag{9}$$

A Taylor expansion of (9) around k^* gives:

$$\Delta U \sim J(k^*) + J'(k^*)(\bar{k} - k^*) + \frac{J''(k^*)}{2}(\bar{k} - k^*)^2$$

$$- \frac{u(c^*)}{\rho^* - n - \mu} - \frac{u'(c^*)}{\rho^* - n - \mu} \frac{d\bar{c}}{d\bar{k}}(\bar{k} - k^*)$$

$$- \frac{u''(c^*)}{2(\rho^* - n - \mu)} \frac{d^2\bar{c}}{d\bar{k}^2}(\bar{k} - k^*)^2 .$$

From (5a) $d\bar{c}/d\bar{k} = f'(k^*) - n - \mu = \rho^* - n - \mu$. Furthermore, the marginal value of capital $J'(k^*)$, is equal to the marginal utility of consumption $u'(c^*)$. Therefore,

$$\Delta U \sim \frac{1}{2}\left(J''(k^*) - \frac{u''(c^*)}{\rho^* - n - \mu} \frac{d^2\bar{c}}{d\bar{k}^2}\right)\left(\frac{d\bar{k}}{d\theta}\right)^2 \theta^2 . \tag{10}$$

This welfare cost is of a second order with respect to the tax rate. It is convenient to divide it by the marginal utility of consumption at the stationary point E, $u'(c^*)$, in order to obtain its wealth equivalent ΔM :[15]

$$\Delta M = L\theta^2 \frac{c^*}{r^* - n - \mu} , \tag{11}$$

with

$$L = \frac{1}{2\sigma}\left(\frac{r^* a}{\gamma}\right)^2 \; ; \tag{12}$$

the parameters a and γ have been defined in the previous section.

The relation (11) is to be interpreted as follows: the welfare cost of a capital income tax at the (small) rate θ, is equivalent to a permanent reduction of consumption on the balanced growth path by a fraction $L\theta^2$. The variable L depends on the technology, the utility function and the growth rate. We now consider some of its properties.

The relation (12) can be rewritten:

$$L = L_P\left(\frac{(r^* - n - \mu)a}{\gamma}\right)^2 , \tag{13}$$

where

$$L_P = \frac{1}{2\sigma}\left(\frac{r^*}{r^* - n - \mu}\right)^2 . \tag{14}$$

From (14), and the definition of a and γ (equation (7)), it is straightforward to derive the following properties:

$$L < L_P \; ; \quad \frac{\partial L}{\partial \varepsilon} > 0 \; ; \quad \frac{\partial L}{\partial \sigma} < 0 \; ;$$

$$\lim_{\varepsilon \to \infty} L = L_P \; ; \quad \lim_{\varepsilon \to 0} L = 0 .$$

The excess burden of the tax is an increasing function of the elasticity of substitution ε, between capital and labor in the production function. When ε is equal to zero, the capital labor ratio is fixed, and since the labor supply is fixed, there is no welfare cost. When ε is infinite, the gross factor prices are fixed, $L = L_P$. This case is analogous to the partial equilibrium situation[16] with exogenous factor prices, and provides an upper bound for the general formula.

Since $1/\sigma$ is an index of the intertemporal substitutability of consumption in the utility function, it is not surprising that the excess burden is a decreasing function of σ .

Tables 1 and 2 present estimates of the variable L , and of the annual rate of convergence of the economy towards the steady state, a , for different values of ε and σ .[17] The other parameters of the model are chosen to characterize the U.S. economy:[18] $\mu = .02$; $n = .0$; the gross capital income share is equal to .33, and the rate of capital depreciation is equal to 5 percent. ρ^* is equal to the long-run value of the net rate of return, and is taken to be equal to 4 percent. There remain only two unknown parameters, ρ and σ . Since there is no general agreement about their values,[19] we present estimates for different values of σ . Once a value is chosen for σ , the pure rate of time preference is implicitly determined by the relation:

$$\rho = \rho^* - \sigma\mu \ .$$

As can be seen from Table 1, for realistic values of ε the excess-burden is not very sensitive to the elasticity of the marginal utility σ .[20]

The last column of Table 1 corresponds to the partial equilibrium case. It is clear that for realistic values of ε , the excess-burden is much smaller. The variable L is represented as a function of ε for a fixed value of σ , equal to one, on Figure 2 (curve (β=0)). For the relevant range of ε , the excess-burden of the interest rate increases almost linearly with ε .

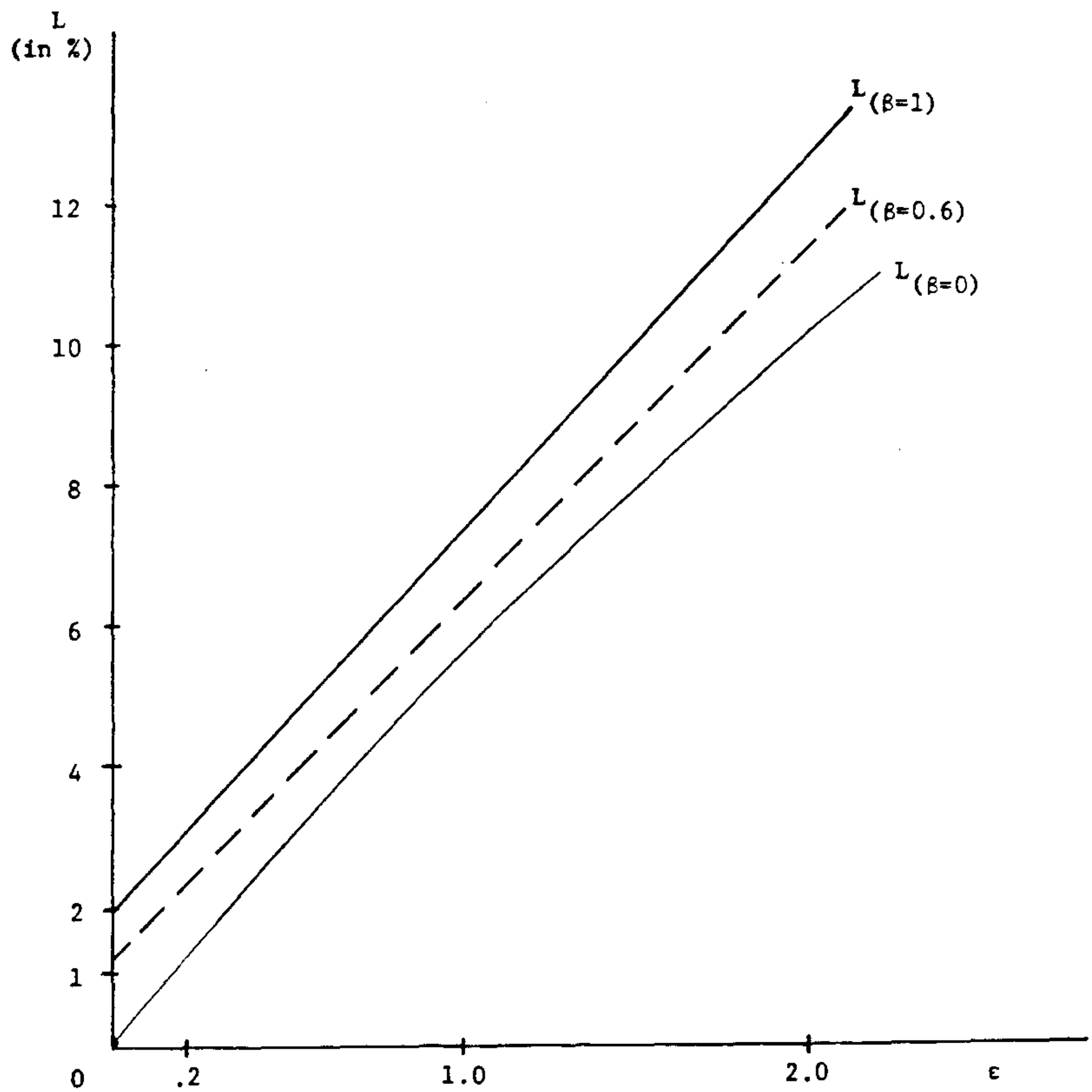

Figure 2

The Normalized Excess Burden

(ε : elasticity of substitution between capital and labor

β : compensated elasticity of substitution between leisure and consumption)

TABLE 1

The Normalized Excess-Burden
of the Capital Income Tax
(given by equation (12), in percentage
of annual consumption)

σ \ ε	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0	∞
.5	1.24	2.41	3.56	4.67	5.76	6.83	7.88	8.91	9.92	10.93	400.0
1.0	1.21	2.33	3.41	4.45	5.46	6.44	7.40	8.33	9.25	10.14	200.0
1.5	1.19	2.28	3.31	4.30	5.25	6.16	7.05	7.92	8.76	9.58	133.33
2.0	1.17	2.23	3.22	4.17	5.07	5.94	6.78	7.59	8.37	9.13	100.0

TABLE 2

Annual Rate of Convergence Towards
the Balanced Growth Path
(a is measured in percentage)

σ \ ε	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0
.5	33.98	23.74	19.21	16.51	14.67	13.31	12.25	11.40	10.70	10.10
1.0	23.74	16.51	13.31	11.40	10.10	9.14	8.40	7.80	7.30	6.88
1.5	19.21	13.31	10.70	9.14	8.08	7.30	6.69	6.21	5.80	5.46
2.0	16.51	11.40	9.14	7.80	6.88	6.21	5.68	5.26	4.91	4.62

The value of the normalized excess burden L, depends also on the discount rate r^*, and on the growth rate $n+\mu$. No general rule can be derived about the effects of these parameters. When the elasticity ε is large, L increases with $n+\mu$ and decreases with r^* (as it is clear from the limit case $\varepsilon = \infty$, described by equation (14)). However, when the elasticity of substitution is smaller than 2, and the other parameters of the model have the same values as above, it is found that L is an increasing function of both the discount rate and the growth rate.

Following some numerical experimentations, a good rule of thumb is that L is almost proportional to r^*, when r^* is between 2% and 6%.[21]

<u>The excess-burden for large tax rates</u>

The measure of the excess-burden given by expressions (11) and (12) is exact only for infinitesimal values of the tax rates. In order to estimate the bias involved for large values of θ, we have to use a different method.

At time zero, the economy is on its balanced growth path under taxation (point A on Figure 1), and the initial values of the capital stock and the consumption level are given by (4a), (5a). The dynamic path after the tax cut, characterized by (2) and (3) is transformed into a discrete formulation, and simulated numerically using a gradient algorithm of optimal control. The consumption equivalent of the utility after the tax cut c_1, is defined by the stationary level providing the same utility as the dynamic path after the tax cut:

$$\frac{u(c_1)}{\rho^* - n - \mu} = J(\bar{k}) .$$

Table 3 reports the ratio $[(c_1 - \bar{c})/\bar{c}](1/\theta^2)$ as a function of θ, for $\sigma = \varepsilon = 1$; the other parameters of the model have the same values as in the first two tables.

TABLE 3

The Normalized Excess-Burden for Large Tax Rates
(in percentage; $\sigma = \varepsilon = 1$)

θ	.0	.05	.1	.2	.3	.4	.5
$\frac{c_1 - \bar{c}}{\bar{c}} \cdot \frac{1}{\theta^2}$	5.46	5.82	6.25	7.27	8.58	10.33	12.77

The first number in the table (for $\theta = 0$), is obtained by formula (12). When θ is small, it gives a good approximation of the normalized excess-burden. However, we can see that for large values of the tax rate θ, the approximation formula (12) underestimates the welfare gain of the tax cut (for $\theta = 50\%$, by a factor slightly smaller than 1/2).[22]

In order to illustrate the previous discussion, let us consider two numerical examples of a shift from capital income taxation to lump sum taxation:

Assume that the aggregate consumption in the steady state under taxation is normalized to one. When the tax rate θ is equal to 50%, total revenues are equal to 12.34%. A shift to a lump-sum tax increases the level of welfare by a consumption equivalent of 3.19% and the level of consumption in the long run by 8.38%. The welfare cost of the capital income tax is equal to 26% of the amount of tax revenues. The marginal welfare cost is obtained by multiplying the average cost by a factor of two (this factor should be somewhat greater than two for large rates, since the normalized excess burden increases with the tax rate).

When θ is equal to 30%, tax revenues are equal to 6.73%. A shift to lump-sum taxation would increase consumption in the long-run by 3.3%. The welfare cost of the tax is equal to .77% of consumption level, or 11% of the revenues.

The method followed in this section takes into account both the short-run and the long-run incidence of the suppression of the capital income tax. We can observe that the welfare gain of tax reform (measured in consumption equivalent) is much smaller than the percentage increase of consumption in the long-run. Also, the excess-burden of the capital income tax, although small in terms of aggregate consumption, is not negligible in terms of the revenues generated.

3. The Case of the Non-Perfect Foresight

In the previous section, the welfare gain of a reform from capital income taxation to lump-sum taxation was determined under the assumption that the economy follows an optimal path towards the new steady state. However, when there is no complete set of future markets to convey information on future prices, individuals may not have perfect foresight. In this case, the dynamic path after the tax reform is no longer optimal, and the welfare gain obtained is smaller.

The assumption of perfect foresight is relaxed in this section. For its saving decision, the competitive household relies now on point expectations about the future wage and interest rates. By assumption, these expectations satisfy the following property: at each time t, anticipated future prices depend only on the value of the capital stock at time t (for example through the factor prices at time t), and on some constant parameters (as the long-run values of the factor prices).[24] It follows that the consumption level can be expressed as a function of k, $c_I(k)$.

We also assume that expectations are consistent with the steady state, and do not affect its stability. The rate of convergence of the economy a_I, depends on the type of expectations considered. For example, in the case of myopic expectations (where the factor prices observed at a given time are expected to be the same in the future), the rate of convergence is greater than in the case of perfect foresight.

As in the previous section the initial situation of the economy is in the steady state with taxation. After the suppression of the tax at time zero, the economy converges to the steady state E on the path Γ' $(B'E)$, which in general is different from the path Γ. The welfare gain is measured by the difference:

$$\Delta U = \tilde{J}(\bar{k}) - \frac{u(\bar{c})}{r^* - n - \mu} , \tag{15}$$

where $\tilde{J}(\bar{k})$ represents the integral (1) on the path B'E .

The second order approximation of the utility level after the tax cut, $\tilde{J}(\bar{k})$, depends only on the slope of the dynamic path at the steady state,[25] $c_I'(k^*)$, or on the rate of adjustment towards the steady state, a_I (since $a_I = c_I'(k^*) - (r^* - n - \mu))$:

$$\tilde{J}(\bar{k}) = F(a_I, \bar{k}) , \tag{16}$$

this utility is smaller than the utility on the optimal path:

$$F(a_I, \bar{k}) \le F(a, \bar{k}) = J(\bar{k}) . \tag{17}$$

The welfare gain induced by the tax cut is equivalent to a permanent increase of the consumption level by a fraction $L_I\theta^2$, where L_I is defined by:

$$L_I = (Q(a_I)/Q(a)) \cdot L , \tag{18}$$

with

$$Q(a_I) = \frac{a_I}{\lambda + 2a_I}\left(- \frac{2}{\lambda} + \frac{a_I}{a \cdot c'(k^*)}\right) , \tag{19}$$

L is equal to the perfect foresight value defined by (12) in the previous section.

Using the relations (18) and (19), and the properties of a and $c'(k^*)$ (described in Section 1), it is straightforward to show that the ratio L_I/L is always smaller than one. When the private sector does not anticipate future prices with perfect foresight, the welfare gain induced by the suppression of the capital income tax is reduced.

The ratio between the values of the excess-burden with non-optimal and optimal adjustments L_I/L, is represented in Figure 3 as a function of the ratio between the rates of convergence (a_I/a). The different curves correspond to different values of the discount rate r^*. The growth rate $n + \mu$ is equal to 2%, and the product $\sigma\epsilon$ is equal to 1.

Also the cases $(r^*=3\%)$ and $(r^*=6\%)$ provide respectively a very good approximation (less than 1% error) of the cases $(r^*=4\%, \sigma\epsilon = 1/3)$ and $(r^*=4\%, \sigma\epsilon = 2.5)$.

It is interesting to observe that, in general, a shift from capital income taxation to lump-sum taxation always induces a welfare gain (L_I is positive unless a_I has an irrealistically large value, greater than $(12.1)\cdot a$). This gain is close to its maximum for a wide range of values of the ratio (a_I/a). When this ratio is between 1/3 and 3, L_I is equal to at least 86 percent of L for the case $(r^*=4\%, \sigma\epsilon=1)$.

As an example, let us consider the case of myopic expectations. The consumption takes then the following form:

$$c_S(k) = \left(1 + \frac{1}{\sigma}\,\frac{\rho^* - r}{r - n - \mu}\right)(f(k) - (n+\mu)k)) .$$

Using (18) and (19), after elementary manipulations, the ratio between the normalized excess-burden under myopic expectations and its value under perfect foresight, L_S/L is given by:

$$L_S/L = \frac{1}{2}\left(1 + \frac{\lambda\sqrt{\lambda^2 + 4\gamma}}{\lambda^2 + 2\gamma}\right) \tag{20}$$

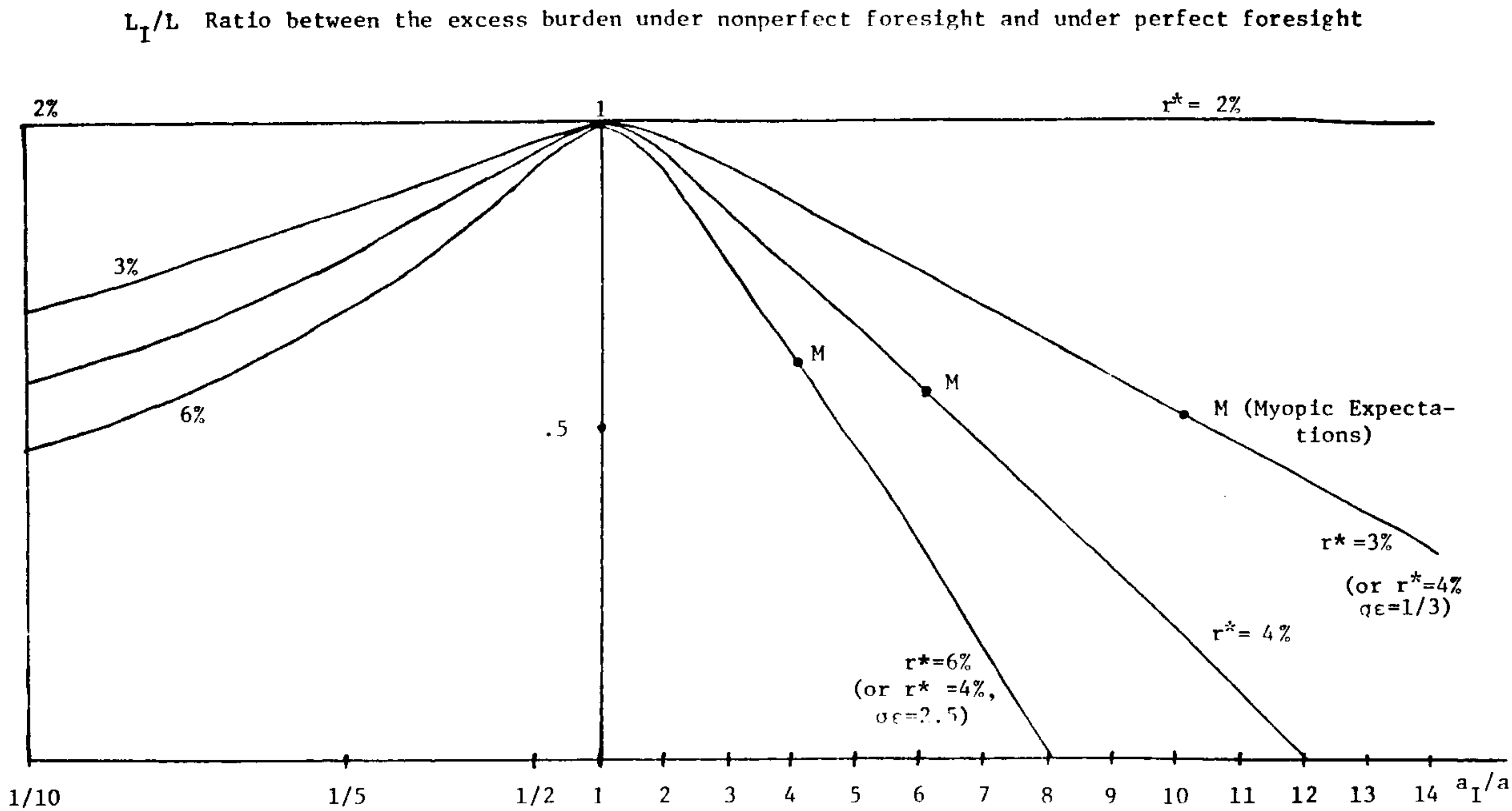

Figure 3

The excess burden under non-perfect foresight with $\lambda = r^* - n - \mu$, and γ is the parameter described in equation (7). A good approximation of (21) is given by:

$$L_S/L = \frac{1}{2}\left(1 + \frac{\lambda}{\lambda + a}\right) , \tag{21}$$

where a is the optimal rate of convergence reported in Table 2.

Under myopic expectations, the welfare gain of the tax reform is always equal to at least 50% of the perfect foresight value. This case is represented by the point M on the Figure 3 (for $\varepsilon = \sigma = 1$, the rate of convergence towards the steady state under myopic expectations a_S , is about six times larger than the value under perfect foresight a). The ratio L_S/L depends on the long run value of the rate of return r^* , the growth rate $n+\mu$, and the parameters ε and σ . When $r^*=.04$ and $n+\mu = .02$, it can be determined for different values of ε and σ , using Table 2, and the relation (21).

We see in Figure 3 that, for the relevant range of values of the various parameters, the ratio between the welfare gains of tax reform under myopic expectations and under perfect foresight is between .55 and .65, and is not very sensitive to the parameters of the model.[26]

Figure 3 allows us to consider a more general class of expectations which lead to different values of the rate of convergence a_I . For example, when the private sector underestimates the future rate of convergence of economy, the rate of convergence a_I is in the interval $[a, a_S]$. For this special class of expectations, the welfare gain of a tax cut is bounded below by the value found in the myopic case.

Finally, it may be interesting to observe that when the private sector applies a modest amount of rationality, the dynamic path of the economy is close to the optimal path. Around the steady state, the variation through time of the factor prices is given by the expression:

$$(z_t \dot{-} z^*) = -a_I(z_t - z^*) \ .$$

Assume now that the long run values of the factor prices are known, and that the only uncertainty left is about their rate of convergence to the new steady state. Furthermore, individual expectations are of the regressive form; the expected values of a parameter x, at some future date t, x_t^e, are determined by the following rule:

$$(x_t^e \dot{-} x^*) = -\alpha(x_t^e - x^*) \tag{22}$$

$$x_t^e = x_0 \ .$$

Individuals revise at each instant the estimated value α of the future rate of convergence, using the observed value $\hat{a}$ (given by $\hat{a} = \dot{z}/(z^* - z)$, where z is an arbitrarily chosen endogenous variable), and an adaptive rule, for example

$$\dot{\alpha} = \nu(\hat{a}-\alpha) \quad \text{where} \quad \nu > 0 \ .$$

Under these assumptions, and for an initial value of the capital stock not too different from the steady state value, both the estimated value α and the actual value $\hat{a}$ of the rate of convergence tend to the optimal value a.[27] The dynamic path is <u>tangent</u> to the perfect foresight path in the steady state. The value of the welfare gain of tax reform is close to its (maximum) perfect foresight value.

4. The Welfare Cost of the Corporation Tax

Most studies on the corporation tax assume that the corporate and the noncorporate sector produce two different goods, and that the ratio between their respective output depends on their relative prices.[28] For the sake of simplicity we assume here that both sectors produce the same good, and that the aggregate production function can be written in the form:[29]

$$y = g(k_1, k_2)$$

where all quantities are divided by the total effective labor supply, and k_1 and k_2 represent respectively the corporate and the noncorporate capital stock. The function $g(k_1, k_2)$ is assumed to be homogeneous in its arguments.

Initially the economy is in the steady state where only the corporate capital income is taxed at the rate θ. In each sector, the net rate of return is equal to the optimal stationary value ρ^*, and the values of the capital stocks, $\bar{k}_1$ and $\bar{k}_2$, are determined by

$$\rho^* = (1-\theta)\frac{\partial g}{\partial k_1}(\bar{k}_1, \bar{k}_2) = \frac{\partial g}{\partial k_2}(\bar{k}_1, \bar{k}_2) \ . \tag{23}$$

The elimination of the corporate tax at time zero, has two effects: First, capital is reallocated between the two sectors to equalize their rates of return. The aggregate production function takes now the form:

$$y = f(k) \tag{24}$$

where $f(k) = \underset{k_1+k_2=k}{\mathrm{Max}} \ g(k_1, k_2)$.

After time zero, the private sector is endowed with perfect foresight, and the economy moves on the dynamic path studied in Section 1, which is characterized by the equations:

$$\dot{c} = \frac{c}{\sigma}(f'(k) - \rho^*)$$

$$\dot{k} = f(k) - (n+\mu)k - c$$

$$k_0 = \bar{k} = \bar{k}_1 + \bar{k}_2 .$$

As in the relation (9), the welfare gain of the tax cut is equal to

$$\Delta U = J(\bar{k}) - \frac{u(\bar{c})}{(r^* - n - \mu)} .$$

This difference can be decomposed into:

$$\Delta U = \left[J(\bar{k}) - \frac{u(\hat{c})}{r^* - n - \mu} \right] + \left[\frac{u(\hat{c}) - u(\bar{c})}{r^* - n - \mu} \right] \tag{25}$$

where $\hat{c} = f(\bar{k}) - (n+\mu)\bar{k}$ is the stationary consumption available when the level of capital $\bar{k}$ is allocated efficiently between the corporate and the non corporate sector.

The first term of the RHS of (25) has been analyzed in Section 2, and measures the intertemporal welfare cost of the corporate tax, originating in the reduction of capital accumulation. It is equivalent to a permanent reduction of the consumption level by a fraction $L_{C1}\theta^2$ where L_{C1} is defined by:[30]

$$L_{C1} = \left(\frac{\bar{k}_1}{\bar{k}} \right)^2 \cdot L . \tag{26}$$

Since the tax revenues are equal to $\theta r^* k_1$, this relation implies that for small values of the tax rates, the intertemporal welfare cost of capital income taxation depends only on the total amount of tax revenues; (for example, a 10% uniform tax on the whole capital stock, and a 20% tax on half the capital stock have up to the second order, the same intertemporal welfare cost).[31]

Although the distribution of the tax burden across the different sectors does not affect the intertemporal welfare cost, it creates a distortion in the allocation of the capital stock between sectors. This production cost is measured by the second term in the RHS of (25), and is equal to:[32]

$$\frac{u(\hat{c}) - u(\bar{c})}{(r^* - n - \mu)} = \frac{u'(\bar{c})}{(r^* - n - \mu)}(f(\bar{k}) - g(\bar{k}_1, \bar{k}_2)) \quad . \tag{27}$$

The welfare cost induced by the production inefficiency is equivalent to a permanent reduction of the consumption level by a fraction $L_{C2}\theta^2$, where

$$L_{C2}\theta^2 = (f(\bar{k}) - g(\bar{k}_1, \bar{k}_2))/\bar{c} \quad . \tag{28}$$

This is precisely the excess burden studied by Harberger and others.

The total welfare cost of the corporate tax is equal to the sum of the intertemporal cost, and of the cost due to production inefficiency. It is equivalent to a permanent reduction of the consumption level by a fraction $L_C\theta^2$, where:

$$L_C = L_{C1} + L_{C2} = L\left(\frac{\bar{k}_1}{\bar{k}}\right)^2 + \frac{(f(\bar{k}) - g(\bar{k}_1, \bar{k}_2))}{\bar{c}} \quad ; \tag{29}$$

$\bar{k}_1$, $\bar{k}_2$ and $\bar{k}$ are given by (21), and

$$\bar{c} = f(\bar{k}) - (n+\mu)\bar{k} \quad . \tag{30}$$

In order to have an order of magnitude of the respective quantities assume that the ratio k_1/k is equal to 1/3, which is close to the value observed in the U.S. economy, and that only the capital income originating in the corporate sector is taxed at the rate of 50%. Using the results of Section 2, the intertemporal welfare cost is about .25% of the level of aggregate consumption (or around 7.8% of the tax revenues).[33] The value is somewhat lower than the cost of inter-sectoral misallocation, which in the same model is equal to 1.1% of consumption (this value is well within the range of current estimates of .5%-1.5%, see Shoven (1976)). The interindustry misallocation caused by the corporate tax seems to be much greater than the intertemporal distortion.

5. The Case of an Elastic Labor Supply

The capital income tax increases the gross rate of return and, by the factor price frontier, lowers the wage rate. When the labor supply is not fixed, this tax creates, in addition to the intertemporal distortion, a distortion in the choice between consumption and leisure at a given instant of time.

For example, assume that the elasticity of substitution between capital and labor in the production function is equal to zero; the capital labor ratio is constant. When the labor supply is fixed, the tax has no incidence on the capital stock, and is equivalent to a lump-sum tax with no excess-burden. However, it increases the gross rate of return, and by the price possibility frontier, lowers the wage rate. When the labor supply depends on the net factor prices, the incidence of the tax is to decrease the long run labor supply, the capital stock and the consumption level.[34]

In general, it can be expected that the excess burden of the capital income tax is increased when the labor supply is variable. In this section, the framework developed in Section 2 is extended in order to measure this additional effect.

The utility function of the private sector depends on the amounts of consumption and leisure:

$$U = \int_0^\infty e^{-\rho t} e^{nt} u(c_t e^{\mu t},\ \ell_t)\,dt \qquad (31)$$

where $c_t e^{\mu t}$ is the consumption per capita, and ℓ_t the labor supply per capita (measured in natural units, and not in effective units).

For the sake of simplicity we consider the following form for the utility function u :[35]

$$u(c,\ell) = (1-\beta)\log c + \beta \log(T-\ell) ,$$

where β and T are exogenous parameters. The dynamic path of the economy is now characterized by the relations:

$$\dot{c}_t = c_t(r_t(1-\theta) - \rho^*) \tag{32}$$

$$\dot{k}_t = f(k_t, \ell_t) - (n+\mu)k_t - c_t \tag{33}$$

$$\frac{\beta c_t}{(1-\beta)(T-\ell_t)} = w_t , \tag{34}$$

where r_t and w_t are respectively, the gross interest and wage rates, and k_t represents now the aggregate capital stock divided by the efficiency index $e^{\mu t}$.

The equations (32) and (33) are the same as in the fixed labor supply case, and, at each time t , the marginal rate of substitution between the consumption of leisure and of produced goods is equal to the wage rate (equation (34)).

At a given instant, the labor supply depends not only on the wage rate at the same moment, but also on the future factor prices (wage and interest rates).

The initial state of the economy (where the tax has been in effect for an infinite amount of time), is defined by the stationary equivalents of (32)-(34):

$$\bar{r} = \frac{\rho^*}{1-\theta} \tag{35}$$

$$\bar{c} = A(\bar{r})\bar{\ell} \tag{36}$$

$$\frac{\beta\bar{c}}{(1-\beta)(T-\bar{\ell})} = w(\bar{r}) \tag{37}$$

where $A(r)$ is defined using the production function

$$A(r) = r\left(\frac{k}{\ell}(r)\right) + w(r) \ ,$$

and the capital labor ratio k/ℓ is expressed as a function of the gross rate of return r .

At time 0, the tax is suppressed. Thereafter, the dynamic behavior of the economy is described by (32), (33), and (34), where θ is replaced by 0; the new steady state characterized by:

$$r^* = \rho^* \tag{38}$$

$$c^* = A(r^*)\ell^* \tag{39}$$

$$\frac{\beta c^*}{(1-\beta)(T-\ell^*)} = w(r^*) \ . \tag{40}$$

The increase of welfare induced by the tax cut can be approximated to the second order by the same method as in Section 2; and its income equivalent is of the form

$$\Delta M = L_\beta \frac{c^*}{r^* - n - \mu}\theta^2$$

which depends on the parameter β . The formula for L_β is rather complicated,[36] so we present in Tables 4 and 5 some numerical estimates analogous to those in Section 2.

L_β is also represented as a function of ε in Figure 2 for the values $\beta = 0, .6, 1$; β measures the long-run compensated elasticity of the labor supply with respect to the wage rate. When it is equal to zero, the labor supply is fixed; this is the case studied in Section 2.

In Table 4 and Figure 2, we can see that the excess burden $L_\beta\theta^2$, for a given value of θ , is increasing with β , and is bounded by

TABLE 4

The Normalized Welfare Cost of the Capital Income Tax
with a variable labor supply
(in percentage)

β \ ε	.0	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0
.0	.0	1.21	2.33	3.41	4.45	5.46	6.44	7.40	8.33	9.25	10.14
.2	.45	1.60	2.71	3.77	4.81	5.82	6.80	7.76	8.71	9.63	10.54
.4	.86	1.98	3.07	4.13	5.16	6.17	7.16	8.13	9.09	10.03	10.96
.6	1.25	2.34	3.42	4.47	5.51	6.53	7.53	8.52	9.50	10.47	11.42
.8	1.61	2.68	3.75	4.81	5.85	6.89	7.92	8.93	9.94	10.95	11.94
1.0	1.95	3.01	4.07	5.13	6.20	7.26	8.32	9.39	10.45	11.51	12.58

TABLE 5

The Annual Rate of Convergence Near the Balanced Growth Path
(in percentage)

β \ ε	.0	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0
.0	∞	23.74	16.51	13.31	11.40	10.10	9.14	8.40	7.80	7.30	6.88
.2	40.09	22.17	16.85	14.06	12.27	11.00	10.04	9.28	8.66	8.14	7.70
.4	28.47	20.91	17.20	14.90	13.31	12.11	11.18	10.42	9.79	9.25	8.79
.6	23.35	19.87	17.55	15.86	14.57	13.53	12.68	11.96	11.35	10.82	10.35
.8	20.32	19.01	17.91	16.97	16.16	15.45	14.83	14.27	13.76	13.30	12.89
1.0	18.28	18.28	18.27	18.27	18.26	18.26	18.25	18.24	18.24	18.23	18.23

the value $L_1\theta^2$, obtained for $\beta = 1$.[37] It is remarkable that the difference $L_\beta - L_0$ does not appear to be significantly affected by the value of ε [38] (for ε smaller than 2), and that this difference is relatively small with respect to L_0 when the production function is of the Cobb-Douglas type $(\varepsilon = 1)$.

When ε is infinite, we have the partial equilibrium case again. It is straightforward to show that the relation (14) is still valid:

The welfare cost of the capital income tax at the rate θ is measured by a fraction of the full consumption of produced goods and of leisure (valued at the wage rate), which is equal to $L_P\theta^2$, where

$$L_P = \frac{1}{2}\left(\frac{r^*}{r^* - n - \mu}\right)^2 .$$

6. Conclusion

The general equilibrium models used in this study are highly stylized. However, the numerical examples considered indicate that the character of its results is fairly general.

The value of the excess-burden of the capital income tax depends mainly on the elasticity of substitution between capital and labor ε . When ε is smaller than two, the excess-burden is almost proportional to ε . No general rule could be derived about the effects of the discount rate and the growth rate. When the other parameters of the model are chosen to characterize the U.S. economy, the excess-burden of the capital income tax increases with the discount rate and the growth rate.

Interestingly enough, when ε is smaller than 2, an increase of the intertemporal substitutability of consumption (measured here by the inverse of the marginal utility of consumption), increases the value of the excess-burden only by a negligible amount. In this case, although the deadweight loss of the tax is relatively small with respect to the level of aggregate consumption, or to its value in the case of fixed factor prices $(\varepsilon = \infty)$, it is not negligible with respect of the amount of tax revenues: a capital income tax of 50% implies a welfare loss equivalent to 26% of the tax revenues; when the tax rate is equal to 30%, the deadweight loss is equal to 11% of the tax revenues. These values should be multiplied by a number between 1 and 4/3 if the labor supply is elastic.

These numbers are indicative of the welfare gain induced by a shift from the capital income taxation to lump-sum taxation, when individuals have perfect foresight about the behavior of the economy after the tax is suppressed. Since the determination of the perfect foresight path is not a easy task for most economists, even in a simple model, this assumption may not be realistic. When the tax reform does not lead to an optimal path, its benefits are reduced. For example under myopic expectations, the welfare gain induced by the abolition of the capital income tax is only equal to about 60% of its value under perfect foresight. However, myopic expectations grossly underestimate the future behavior of the economy. When individuals anticipate somewhat this future behavior, the welfare gain of tax reform is close to its maximum value, even if the degree of foresight is not very accurate. (A method to approximate the perfect foresight path has also been suggested in Section 3.1; also, the results of this section can be applied to any tax reform in a dynamic framework).

Finally, under the present U.S. tax system, the rates of the capital income tax vary by a large amount from one sector of production to another. When the overall elasticity of substitution between capital and labor is not too large (less than 2), the welfare gains obtained by an equalization of these rates dwarf the gains obtained by a reduction of the global tax on capital income.

APPENDIX

1. The Excess-Burden in Partial Equilibrium

An income equivalent of the excess-burden is given by the well-known Harberger-Hicks-Hotelling formula.[1] In a continuous time formulation, this becomes:

$$\Delta M = \frac{1}{2} \int_0^\infty \int_0^\infty \Delta p_t \Delta p_{t'} \left(\frac{\partial c_t}{\partial p_{t'}}\right)^U e^{mt} dt dt' \qquad \text{(A-1)}$$

with the following notations:

$$\begin{cases} m = n + \mu \\ p_t = e^{-r^*(1-\theta)t} \quad \text{(price of } c_t \text{ at time } 0\text{)} \\ \Delta p_t = r^*\theta t e^{-r^* t} \end{cases}$$

$\left(\frac{\partial c_t}{\partial p_{t'}}\right)^U$, compensated derivative of c_t with respect to $p_{t'}$.

By application of Slutsky's equation,

$$\Delta M = \frac{1}{2} \int_0^\infty e^{mt} \Delta p_t \left[\int_0^\infty \frac{\partial c_t}{\partial p_{t'}} \Delta p_{t'} dt'\right] dt$$

$$+ \frac{1}{2} \int_0^\infty e^{mt} \Delta p_t \frac{c_t}{M} \left(\frac{M}{c_t} \frac{\partial c_t}{\partial M}\right) [\int_0^\infty e^{mt'} c_{t'} \Delta p_{t'} dt'] dt .$$

The expression in brackets in the first term is simply equal to the variation of the consumption at time t, Δc_t, after an uncompensated interest tax has been applied.

Since the utility function is homogeneous, the income elasticity of consumption is equal to one, and the excess-burden is given by

$$\Delta M = \frac{1}{2}\int_0^\infty e^{mt}\Delta p_t \Delta c_t dt + \frac{1}{2M}\left(\int_0^\infty e^{mt} c_t \Delta p_t dt\right)^2 .$$

From (2) and the budget constraint, the uncompensated demand function, c_t , is expressed as follows:

$$c_t = \nu M e^{\alpha t} \text{, with } \nu = r^* - n - \mu - \theta r^*\left(1 - \frac{1}{\sigma}\right),$$

$$\text{and } \alpha = -\frac{r^*}{\sigma}\theta .$$

Therefore, when θ is small,

$$\Delta c_t = -Mr^* \left\{\left(1 - \frac{1}{\sigma}\right) + \frac{(r^* - n - \mu)t}{\sigma}\right\}$$

We replace Δc_t in the above expression of ΔM , and since the wealth M is equal to the present value of the consumption stream on the balanced growth path, we have:

$$\Delta M = -L_P \frac{c^*}{r^* - n - \mu}\theta^2 \qquad \text{(A-2)}$$

with

$$L_P = \frac{1}{2\sigma}\left(\frac{r^*}{r^* - n - \mu}\right)^2 .$$

For a given value of the interest tax rate, the welfare cost in partial equilibrium is an increasing function of the intertemporal substitutability of consumption in the utility function, which is measured by $1/\sigma$.

It is a decreasing function of the discount rate and an increasing function of the growth rate.

2. The Excess-Burden in General Equilibrium

We determine here a second order equivalent of the welfare gain ΔU, obtained by the suppression of the interest tax:

$$\Delta U = J(\bar{k}) - \frac{u(\bar{c})}{\lambda}, \quad (\lambda = \rho^* - n - \mu) .$$

The terms $J(\bar{k})$ and $u(\bar{c})$ are considered separately.

$J(\bar{k})$ is equal to

$$J(\bar{k}) = \int_0^\infty e^{-\lambda t} u(c_t) dt$$

where c_t is taken on the dynamic path BE (Figure 1 in the text).

This integral can be decomposed in two terms:

$$J = u(c_t)\Delta t + \int_{\Delta t}^\infty e^{-\lambda t} u(c_t) dt ,$$

where Δt is a small interval of time. By taking an infinitesimal value for Δt, we verify that the function J satisfies the relation:

$$0 = u(c) - \lambda J + J'(k)\dot{k} ,$$

or, using the capital accumulation equation (equation (3) in the text):

$$0 = u(c(k)) - \lambda J(k) + J'(k)(f(k) - nk - c(k)) .$$

Differentiating this expression twice at the point k^*, we obtain

$$J'(k^*) = u'(c^*) \quad , \quad J''(k^*) = \frac{u''c'^2 + f''u'}{2(\lambda+a)}$$

where $u = u(c^*)$, $u' = \frac{du}{dc}(c^*)$, $c' = \frac{dc}{dk}(k^*)$, $c'' = \frac{d^2c(k^*)}{dk^2}$, $a = c'(k^*) - \lambda$.

Therefore, a second order approximation of J at $\overline{k}$ is given by:

$$J(\overline{k}) = \frac{u}{\lambda} + u'(\overline{k} - k^*) + \frac{1}{2(\lambda + 2a)}(u''c'^2 + f''u')(\overline{k} - k^*)^2 \ . \qquad \text{(A-3)}$$

Using the properties of the optimal consumption function described in Section 1 of the text, we can rearrange the term of the second order:

$$\frac{u''c'^2 + f''u'}{2(\lambda+2a)} = \frac{u''}{2(\lambda+2a)}\left(c'^2 - \frac{cf''}{\sigma}\right) = \frac{u''(c'^2 + c'a)}{2(\lambda + 2a)} = \frac{u''c'(c' + a)}{2(\lambda+2a)} = \frac{u''c'}{2}$$

Hence,

$$J(\overline{k}) = \frac{u}{\lambda} + u'(\overline{k} - k^*) + \frac{u''c'}{2}(\overline{k} - k^*)^2 \ . \qquad \text{(A-4)}$$

The value of consumption in the steady state under taxation, $\overline{c}$ is determined by:

$$\overline{c} = f(\overline{k}) - (n+\mu)\overline{k} \ .$$

The second order equivalent of $u(\overline{c})/\lambda$ can be written as follows:

$$\frac{u(\overline{c})}{\lambda} = \frac{u}{\lambda} + u'(\overline{k} - k^*) + \frac{1}{2\lambda}(u'f'' + u''\lambda^2)(\overline{k} - k^*)^2 \qquad \text{(A-5)}$$

$$= \frac{u}{\lambda} + u'(\overline{k} - k^*) + \frac{u''}{2}\left(\lambda + \frac{c'a}{\lambda}\right)(\overline{k} - k^*)^2 \ . \qquad \text{(A-6)}$$

Taking the difference between $J(\overline{k})$ and $u(\overline{c})/\lambda$ (in (A-4) and (A-6), we have

$$\Delta U = -\frac{u''}{2}\frac{a^2}{\lambda}(\bar{k} - k^*)^2$$

where a is the positive root of $x^2 + \lambda x - \gamma = 0$ (described in Section 1).

Since $f'(\bar{k}) = \rho^*/(1-\theta)$, and $(\bar{k} - k^*)f'' \sim \rho^*\theta$, the welfare change can be rewritten

$$\Delta U = \frac{u'}{2}\frac{c}{\lambda}\left(\frac{\rho^*}{\lambda}\right)^2\left(\frac{\sigma\lambda a}{cf''}\right)^2\theta^2 = u'\frac{c}{r^* - n - \mu}\theta^2 L \ ,$$

where

$$L = L_P\left(\frac{\lambda a}{\gamma}\right)^2 \ ,$$

$$L_P = \frac{1}{2\lambda}\left(\frac{\rho^*}{\lambda}\right)^2 \ ,$$ (the partial equilibrium value of L expressed by the relation (14) in the text

$$\gamma = \frac{-cf''(k^*)}{\sigma} \ .$$

The term $\lambda a/\gamma$ is equal to the positive root of the equation $(\gamma/\lambda^2)x^2 + x - 1 = 0$. This root is contained in the interval $(0,1)$. Its properties when ε varies follow immediately. The sign of $\partial L/\partial\sigma$ is obtained by the same method.

3. The Case of Non Perfect Foresight

When the private sector is not endowed with perfect foresight, $c'(k^*)$ is no longer the positive root of the equation $x^2 - \lambda x - \gamma = 0$. The welfare gain of the interest tax cut is obtained by the same method as before. However, taking the difference between (A-3) and (A-5), we find

$$\Delta U = u'\left(\frac{\bar{k} - k^*}{2}\right)^2 \left\{ f''\left(\frac{1}{\lambda + 2a_I} - \frac{1}{\lambda}\right) + \frac{\sigma}{c}\left(\lambda - \frac{c_I'^2}{\lambda + 2a_I}\right)\right\}$$

where c_I and a_I represent the consumption function, and the coefficient of adjustment of the economy towards the balanced growth path, under nonperfect foresight.

Use the relation $a_I = c_I' - \lambda$, and the definition of the optimal values for a_I and c_I', respectively a and c', to obtain

$$\Delta U = u'(c^*)f''(k^*)\left(\frac{\bar{k} - k^*}{2}\right)^2 Q(a_I)$$

where $$Q(a_I) = \frac{a_I}{\lambda + 2a_I}\left(-\frac{2}{\lambda} + \frac{a_I}{ac'}\right) .$$

The consumption equivalent of the welfare gain can then be expressed as follows:

$$L_I = L \cdot Q(a_I)/Q(a) \quad ,$$

where L is the value of L_I under perfect foresignt, and

$$Q(a_I) = \frac{a_I}{\lambda + 2a_I}\left(-\frac{2}{\lambda} + \frac{a_I}{ac'}\right) .$$

4. The Corporation Tax

We examine here the long run incidence of the corporation tax on the capital stock. The capital stocks in the corporate and in the noncorporate sector, respectively k_1 and k_2, are determined in the long run by the relations:

$$\rho^* = (1-\theta)g_1'(k_1, k_2) = g_2'(k_1, k_2) .$$

Differentiate this expression around $\theta = 0$ to obtain the variation of the aggregate capital stock, dk :

$$dk = dk_1 + dk_2 = \left(\frac{g_{22}'' - g_{12}''}{\Delta}\right)\rho^*\theta \tag{A-7}$$

with

$$\Delta = g_{11}''g_{22}'' - g_{12}''g_{21}'' .$$

Assume now that the tax is applied uniformly to both sectors, and call Dk the variation of the capital stock:

$$Dk = \left(\frac{g_{11}'' + g_{22}'' - 2g_{12}''}{\Delta}\right)\rho^*\theta . \tag{A-8}$$

Taking the ratio between (A-7) and (A-8)

$$\frac{dk}{Dk} = \frac{g_{22}'' - g_{12}''}{g_{11}'' + g_{22}'' - 2g_{12}''} .$$

Since the production function $g(k_1, k_2)$ is homogeneous, it can be rewritten under the form $g(k_1, k_2) = H(F(k_1, k_2))$, where F is homogeneous of degree one.

Use the properties of F, and the equality of F_1' and F_2' (at $\theta = 0$), to write:

$$g''_{22} - g''_{12} = H'(F''_{22} - F''_{12}) = H'F''_{22}\left(1 + \frac{k_2}{k_1}\right)$$

$$g''_{11} + g''_{22} - 2g''_{12} = H'F''_{22}\left(1 + 2\frac{k_2}{k_1} + \left(\frac{k_2}{k_1}\right)^2\right) .$$

Taking the ratio between these relations,

$$\frac{dk}{Dk} = \frac{k_1}{k} .$$

This result could be generalized easily. The long-run incidence on the total capital stock of a tax falling the capital in some sectors is proportional to the share of the taxed capital with respect to the total capital stock.

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FOOTNOTES

[1]In fact, if would be sufficient to assume that individuals' utilities depend on their consumption in their own finite life-time, and on the welfare of their immediate descendants (for a development of this argument, see Barro (1974)). If individuals do not leave a bequest, the problem of intergenerational equity arises, and the concept of excess burden used here does not apply: Even in the case where no revenue has to be raised, the no-tax solution is not the first best; the level of capital has no optimal property (Diamond (1965)). In order to redistribute income between generations, a benevolent social planner would impose a tax or a subsidy on capital income (and possibly on other goods). For an analysis of taxation is a general equilibrium model where individuals maximize a life time utility function with no bequest, see Hall (1969), Diamond (1970), Summers (1979), Chamley (1980)).

[2]We could also consider the imposition of a tax on the initial balanced growth path with no taxation. However, the analysis of the abolition (instead of the imposition) of the tax, is technically more simple, and suits better the problems of tax reform. For small values of the tax rate, it has been verified that the two methods give the same results.

[3]The same method could have been used to analyze the excess-burden of the labor income tax, or the income tax (Chamley (1980a)).

[4]See for example, Hudson and Jorgenson (1976) and Fullerton, Shoven and Whalley (1979).

[5]This assumption is necessary for the existence of a competitive balanced growth path when the intertemporal welfare function is additive, and the rate of labor augmenting technological change μ , is different from zero. In a discrete time formulation one could also use a stationary utility function. The existence and stability of optimal balanced growth paths in this context is studied by Iwai (1972).

[6]The consumption levels at time t and $t+\Delta t$ satisfy the relation:

$$\frac{u'(e^{\mu(t+\Delta t)}c_{t+\Delta t})}{u'(e^{\mu t}c_t)} = \frac{1+\rho\Delta t}{1+r\Delta t} .$$

Up to the first order, this expression is equivalent to:

$$\frac{u'(e^{\mu t}c_t) + u''(e^{\mu t}c_t)(c_t\mu\Delta t + \Delta c_t)e^{\mu t}}{u'(e^{\mu t}c_t)} = 1 + (\rho - r)\Delta t .$$

A straightforward manipulation gives:

$$\frac{1}{c_t}\frac{\Delta c_t}{\Delta t} = \frac{1}{\sigma}(r - \rho - \sigma\mu) \ .$$

When Δt tends to 0, this relation corresponds to (2).

[7]The second order conditions are derived from the concavity of the utility and the production functions. For an exhaustive treatment, see Arrow and Kurz (1970).

[8]The parameter γ can also be expressed as a function of quantities which are easily measurable:

$$\gamma = \frac{(1-\alpha)(r^* + \delta)}{\sigma\varepsilon}\left(\frac{r^* + \delta}{\alpha} - (\delta + n + \mu)\right)$$

where α is the share of gross capital income in the gross production function, and δ is the depreciation rate of the capital stock.

[9]This regressive rule may be a very good approximation even if the difference $k - k^*$ is large (see Chamley (1979)).

[10]If $z_t = g(k_t)$, to the first order: $(\dot{z_t - z^*}) = g'(k^*)\dot{k}_t = -g'(k^*)a(k_t - k^*)$ $= -a(z_t - z^*)$.

[11]When the tax revenues are not equal to zero, this is equivalent to the gain obtained by a shift from an interest tax to lump-sum taxation.

[12]It is essential throughout this study that the tax changes are unanticipated; for an analysis of the effects of anticipated tax changes, see Hall (1971).

[13]The observed elasticity of gross savings η , with respect to the net rate of return at time zero (under the assumption of perfect foresight about future interest rates), can be determined from the parameters of the model: $\eta = a\varepsilon(r^*/((r^* + \delta)(n + \mu + \delta)(1-\alpha)))$ where α and δ are defined in footnote 8, and a is given in Table 2. For the values used below, in the Cobb-Douglas case $(\sigma = \varepsilon = 1)$, $\eta = .95$.

[14]When the tax rate θ is small, the following experiment is symmetrical, and gives the same result: Assume that the economy is in the steady state with no tax (point E). At time 0, the tax is instituted (with lump-sum refunds). The economy moves then on a path towards the point B . Call J_1 the utility level on this path, and J_0 the utility level at the steady state E . The excess burden of the interest tax is equal to $J_0 - J_1$.

[15]The relations (11) and (12) are derived in the appendix 2.

[16]This formula has been derived by Levhari and Sheshinski (1972) for a stationary economy. Another proof, using the well known Harberger-Hicks-Hotelling formula is given in the appendix 1.

[17]These values of the rate of convergence can be compared with those discussed by Sato (1966), and give additional information for a choice of ε and σ .

[18]See, for example, Jorgenson and Christensen (1973).

[19]Available estimates of σ seem to point to a value higher than one. Weber (1975) reports values between 1.3 and 1.8. Wright's (1969) estimates are somewhat higher--around 4; see also footnote 20.

[20]In the limit case where the discount rate r^* , and the growth rate are equal, the variable L becomes

$$L = -\frac{1}{2}\frac{{r^*}^2}{c^*f''(k^*)} = \frac{\alpha}{2(1-\alpha)^2}\cdot\left(\frac{n+\mu}{n+\mu+\delta}\right)^2\cdot\varepsilon$$

which is independent of the utility function and linear in the elasticity ε (<u>ceteris parib</u>

[21]When $\varepsilon = \sigma = 1$, the following values are obtained: Take $n+\mu = 2\%$; when r^* increases from 2% to 6%, L increases from 3.00% to 8.04% (from 2.73% to 8.19% with the rule of thumb). When r^* is equal to 4% and $n+\mu$ increases from 2% to 4%, L increases from 5.46% (Table 1) to 7.26%.

[22]On the other side, when θ is large, the model considered here implies a sudden increase of saving which could be too large to be borne by a real economy. Therefore, it is likely that the numbers in Table 3 may be overestimated.

[23]For the class of expectations considered below, the dynamic path Γ' converges to the steady state.

[24]This class includes perfect foresight, myopic, stationary, and regressive expectations. This section uses some intuitive results derived in Chamley (1979).

[25]A proof is given in appendix 3.

[26]When the difference λ between the rate of return r^* and the growth rate $n+\mu$ tends to zero, the ratio L_S/L tends to 1/2 . Also, at the same time, the error implied by myopic expectations, which is measured by the ratio a_s/a , tends to infinity.

[27]Numerical simulations have shown that for almost any initial value of the capital stock, the convergence to the perfect foresight path occurs after only a few periods. This procedure may be used as an algorithm to determine the perfect foresight solution.

[28]See Harberger (1962, 1976), Shoven (1972, 1976), and Boadway and Treddenick (1975) for a static analysis. Friedländer and Vandendorpe (1977) extend Harberger's study to a dynamic framework. However, they do not address the problem of the incidence on the intertemporal welfare, and do not consider a saving function derived from the optimization of an intertemporal utility function. Fullerton and associates (1979) are currently working on a more elaborate model.

[29]The usual assumption that the corporate and the noncorporate sector produce two separate goods may also be a crude description of reality; see, for example, Ebrill and Hartman (1977).

[30]A proof is given in the appendix 4.

[31]The extension to many sectors is straightforward. In particular, this analysis can be applied to a model with four types of capital: corporate and noncorporate capital, housing and human capital.

[32]To a second order, it is equivalent to evaluate this difference at $\bar{k}$ or k^*.

[33]These estimates are obtained with a simplified version of the model in Section 2: there is no depreciation, and the production function takes the form $y = k_1^{\beta} k_2^{\beta}$ (with a 50% corporate tax rate, $k_1/k_2 = .5$). The capital income share, net of depreciation, 2β, is the same as for the previous numerical results, and is equal to .18. We have also used Table 2 in the correction for large tax rates.

[34]A sufficient condition for these properties to be verified is the homotheticity of the utility function. This homotheticity is a necessary condition for the existence of an optimal balanced growth path.

[35]When μ is different from 0, and the elasticity of substitution in u between consumption and leisure is different from 1, there is no optimal balanced growth path.

[36]A computer program for its numerical evaluation is available.

[37]The compensated elasticity of the labor supply β, is bounded by 1.

[38]Numerical experiments have shown that the difference $L_1 - L_0$ is not sensitive to variations of δ, ρ or μ, for realistic values of ε. When ε is equal to zero, the excess-burden of the capital income tax arises because of its incidence on the wage rate. In this special case, the interest tax has the same excess-burden as the wage tax which generates an equal amount of revenues (Chamley (1980a)).