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LIFE-CYCLE WELFARE COSTS OF SOCIAL SECURITY

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Life-Cycle Welfare Costs of Social Security

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ABSTRACT

One-period models predict that a substantial welfare gain would result from removing the social security earnings test. In this paper we show that such models overestimate the size of potential gains.

If one uses instead a two-period model, which captures intertemporal effects, the net result of removing the earnings test is ambiguous. In the presence of a personal income tax, workers who reduce their labor supply in the first period create a welfare loss which must also be considered. We use a present value model to estimate the change in lifetime welfare. We find that the net potential gain from removing the earnings test is probably small, especially when compared to the alternative of an increased personal income tax.

Life-Cycle Welfare Costs of Social Security

Old Age and Survivors Insurance (OASI) is the largest single federal government program. It differs from other programs in that all of its funds are raised by a specific tax, which is now second only to the personal income tax as a source of federal government revenues; in 1977 the OASI tax collected over $68 billion.

The manner in which OASI taxes are collected--through a payroll tax--and the manner in which benefits are distributed--subject to a tax on earnings--have each been the subject of economic analysis, primarily through one-period models. Single-period, income-compensated models of labor supply indicate that a payroll tax will decrease the hours an individual works. Single-period analysis of the earnings test likewise predicts that such a tax on wages will decrease labor supply.[1] Thus one-period models predict, in unambiguous fashion, that the OASI system causes a loss in welfare.

We believe that this approach is misleading. If one uses instead a life-cycle model to examine OASI, the absolute welfare loss disappears; the effects of the taxes become ambiguous. What brings about this result?

We have argued elsewhere (Burkhauser and Turner, 1978) that although OASI has significantly decreased the labor supply of older men, it has had the opposite effect for younger men. We contend that responsibility for these effects lies with the method used to distribute benefits: application of an age-specific earnings test. By using a simple two-period model, this paper will attempt to provide a more accurate estimate of the change in welfare which would result from abolishing the earnings test.

In Section 1 we capture the welfare loss at older ages that is associated with the earnings test, using a traditional, one-period Harberger (1964) model. In Section 2 we develop a two-period model for welfare measurement that allows us to incorporate the effects of the OASI earnings test on relative wages across a worker's life and to estimate the subsequent changes on labor supply and welfare. Working with this new model, we then, in Section 3, explore two alternatives to the earnings test. First, we estimate the total welfare gain that would result from replacing the earnings test with a lump sum tax. Second, we consider replacing it with an increase in the personal income tax. This last, of course, presents in simplified form an alternative that an administration might well choose to implement.

1. THE EFFECT OF OASI ON WORK DURING THE CONSTRAINED PERIOD

The earnings test constraint on work, it is now clear, has significantly reduced the labor supply of older men (Boskin, 1977; Burkhauser, 1979; Quinn, 1977). Since 1948 the labor force participation rate of men 65 and over has fallen by over 50%; fewer than one-quarter of men in this age bracket now work. More decisive, perhaps, is the 25% drop for men aged 62 to 65 after they became eligible for OASI in 1961. Fewer than 55% now work.

In developing our argument, we use the rules for the OASI earnings test that applied in 1974: a 50% marginal tax rate on all wages and salary over a yearly exempt amount ($2400 for those aged 62 to 72). Workers over age 72 are no longer subject to the test.

Figure 1 estimates the welfare cost for an individual whose market wage is w and whose income-compensated labor supply curve is S_L.[2] In the presence of a proportional personal income tax, earnings are lower by a rate t, so that the net wage rate is equal to (1 - t)w, labor supplied is OG, and the welfare cost of the tax is equal to the area ABC.

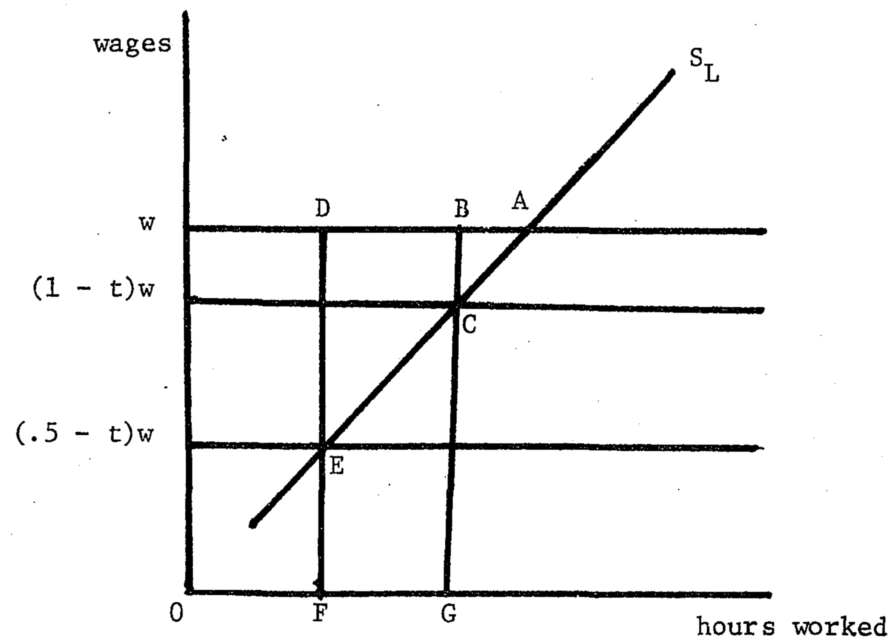

Figure 1. Single-period welfare cost model.

To find the incremental welfare cost of the OASI earnings test, we add the effect of this 50% marginal tax in Figure 1. The net wage rate now becomes (.5 - t)w and the new equilibrium labor supply is OF. The total welfare loss becomes ADE and the incremental cost of OASI is BCED.

Of course, by choosing to analyze OASI in the presence of an income tax we magnify the welfare loss from the additional tax (Browning, 1975), because total welfare cost varies with the square of the effective marginal tax rate.

2. THE EFFECT OF OASI ON LIFETIME WELFARE

Paralleling the large fall in the labor supply of older men after World War II is a curious consistency in the labor supply of younger men. Between 1900 and 1940 hours of work per week for prime-age males had fallen from 58 to 42. But even adjusting for sick leave and vacations, men still worked 41 hours per week in 1970 (Owen, 1971). We argue that the OASI earnings test is also behind this change in labor supply.

If a worker's wages are subject to an earnings test at only one period in his life, he will be induced to change his lifetime work pattern--he will substitute work in the unconstrained period for work in the constrained period (Lewis, 1957; Smith, 1975). We have estimated that the effect of OASI has been to induce males under age 62 to work at least 2 hours more than they otherwise would have done (Burkhauser and Turner, 1978). Previous measures of welfare effects of OASI have ignored this change in across-life labor supply effort.

The welfare effect of the substitution of work to younger ages can be estimated using a variation of the Harberger method. Rather than a one-period, two-good model, consider a one-good (labor/leisure), two-period model.

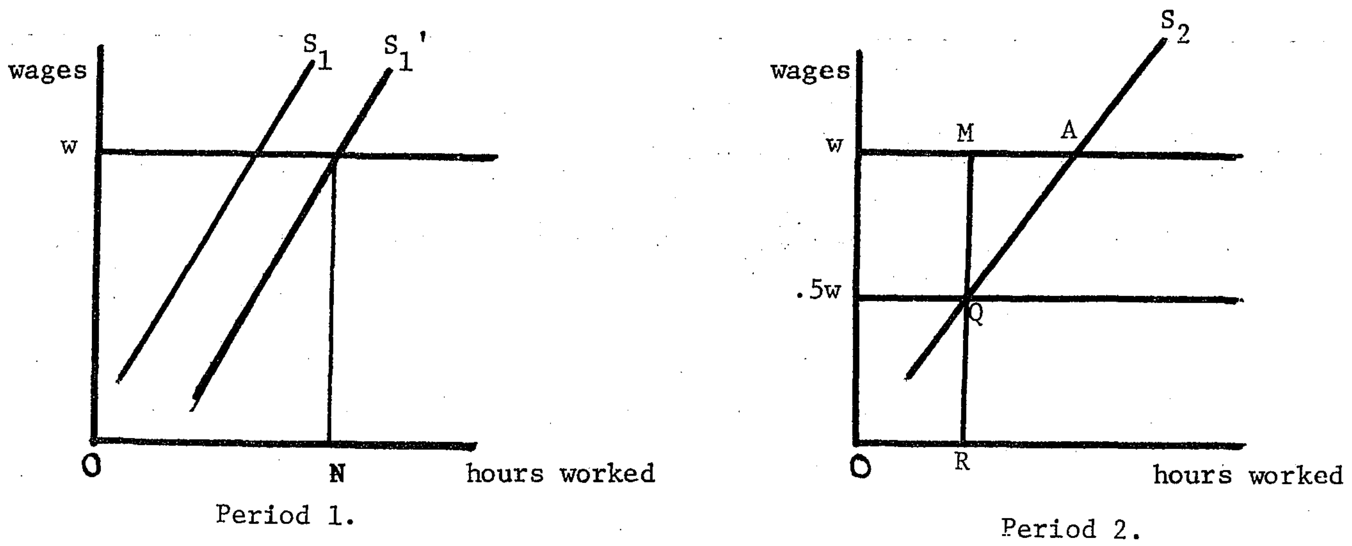

Figure 2. Life-cycle welfare cost model (without other taxes).

Let period 1 and period 2 of Figure 2 represent, respectively, the unconstrained and constrained periods of a worker's life. The earnings test reduces net wages in period 2 to .5w and labor supplied to OR. The fall in the relative price of leisure in period 2 induces substitution of labor across periods. Thus the supply schedule shifts outward in period 1 to S_1' and work increases to ON. In this special case, where no other taxes exist, the total welfare cost AMQ occurs in period 2. But if there is an income tax, looking only at welfare changes in the constrained period and ignoring the across-period substitution effect will overestimate the full life-cycle welfare loss.

Let us, then, impose a proportional income tax of rate t in both periods (Figure 3). During the constrained period (period 2 in Figure 3) equilibrium results at OF, as net wages fall to (.5 - t)w, just as it did in Figure 1. But now welfare costs are not fully measured by

ADE, for they are influenced by the outward shift of S_1 in the unconstrained period owing to the change in the relative price of leisure. The new supply curve S_1' now intersects with (1 - t)w at K. The increase in labor to V' offsets the reduction in labor induced by the income tax in this period. The welfare gain in this period (tw · VV') reduces the net effect of the earnings test on life-cycle welfare.

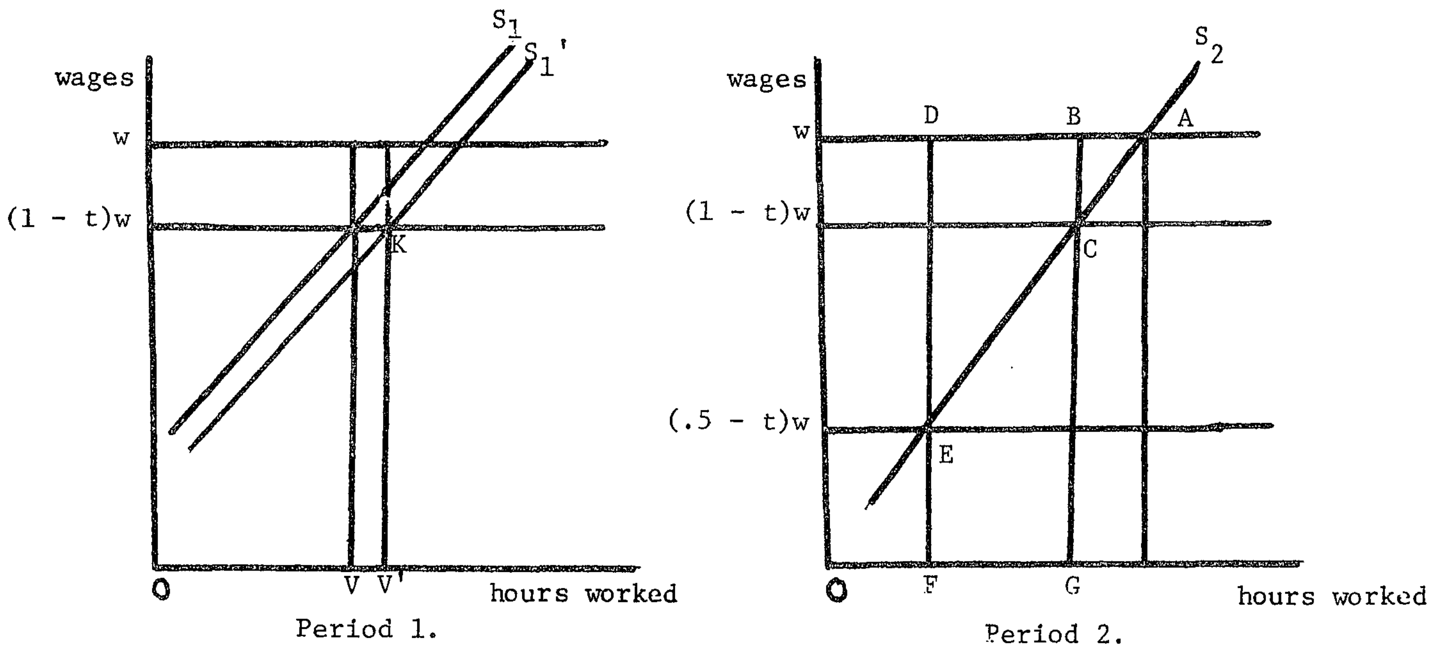

Figure 3. Life-cycle welfare cost model (with an income tax).

The information necessary to estimate the full life-cycle impact of the earnings test on welfare is expressed more formally by using the general Harberger equation of a set of taxes on welfare

$$\ell = \frac{1}{2} \sum_i \sum_j S_{ij} T_i T_j \tag{1}$$

where $S_{ij} = \partial x_i | \partial p_j$, is the compensated cross-derivative of supply with respect to price, T_i is the tax per unit of good i, and ℓ (when positive) is a welfare loss.[3]

Let t be the marginal income tax rate and e be the earnings test tax rate, and L_1 and L_2 labor supplied in the two periods. The wage rate in the first period is w_1, and w_2 is the discounted wage rate in the second period. The net wage rate in the unconstrained period is then $(1 - t)w_1$, and the discounted net wage rate in the constrained period is $(1 - t - e)w_2$. Equation (1) can thus be written

$$\ell = \frac{1}{2}\left(\frac{\partial L_1}{\partial w_1}\right)_u t^2 w_1^2 + \frac{1}{2}\left(\frac{\partial L_2}{\partial w_2}\right)_u (t+e)^2 w_2^2 + \left(\frac{\partial L_1}{\partial w_2}\right)_u t(t+e)w_1 w_2 \qquad (2)$$

where the subscript u indicates that the derivative is a compensated substitution effect.

Equation (3) then shows the welfare gain (positive $\Delta\ell$) due to replacing the earnings test by a lump sum tax.

$$\Delta\ell = \frac{1}{2}\left(\frac{\partial L_2}{\partial w_2}\right)_u w_2^2 (e^2 + 2te) + \left(\frac{\partial L_1}{\partial w_2}\right)_u w_1 w_2 et \tag{3}$$

or in terms of elasticities

$$\Delta\ell = \frac{1}{2} \varepsilon_{L_2 w_2} [(e + t)^2 - t^2] w_2 L_2 + \varepsilon_{L_1 w_2} etw_1 L_1.^4 \tag{4}$$

3. ESTIMATING THE LIFE-CYCLE WELFARE GAIN FROM REMOVING THE OASI EARNINGS TEST

We will use equation (4) to estimate the incremental welfare gain from replacing the earnings test in the constrained period, given the presence of other taxes. We assume a compensated labor supply elasticity of .3 for older workers and .2 for prime age workers.[5] We use a marginal personal income tax rate of 30% that combines the rate for the median federal taxpayer (which has varied around 20% since World War II--Turner 1977) with Browning's (1975) estimate that state and local income and general sales taxes add another 10%. We compare this tax with one that also includes the 50% earnings test. Browning (1976) used $742 billion as the total factor share of labor in GNP in 1974. We estimate that the share of GNP which would have been produced by those people aged 62 to 72 in the absence of the earnings test is $67 billion, or 9% of total labor share.[6]

Substituting these values into the first term of equation (4), we find that replacing the earnings test with a lump sum tax causes an undiscounted welfare gain of $5.5 billion. This single-period measure is only the first step in measuring the full impact of OASI. The effect of the earnings test on work in the unconstrained period must also be calculated.

One-period models measuring the effect of the OASI payroll tax indicate that labor supply should fall for those age groups paying the taxes. Browning (1975) argued that to the degree benefits are positively related to payroll taxes, this fall in labor supply is reversed, but he ignored his own point in estimating a $2.7 billion welfare loss arising from a fall in labor during this period. But we have shown that the increase in labor supplied at younger ages--induced by the earnings test--(Burkhauser and Turner, 1978) overwhelms this relatively small payroll tax effect on wages for that group.[7]

Next, we assume that the value of the compensated cross-elasticity of labor supply in the unconstrained period with respect to wages in the constrained period is (-.06).[8] If we substitute this value into the second term of equation (4) together with the labor factor share of younger workers (91% of $742 billion), we arrive at an undiscounted welfare loss of $6.1 billion. This more than equals the $5.5 billion gain in welfare associated with removing the earnings test in the constrained period.

Such a result, of course, must be considered with care. The total welfare effect of such a change in OASI is not the simple, undiscounted sum of the welfare gain in the constrained period and the welfare loss in the unconstrained period. A proper measure of the change in welfare from removing the tax is a lifetime one summed over individuals. The fact that at a moment in time the welfare loss of one age cohort is greater than the welfare gain of another age cohort does not mean the effect of removing the tax over individuals' lives is negative, although it could be.

A lifetime analysis measures the effect of the earnings test on the lifetime utility of individuals. The cross-sectional measure above indicates a negative effect in part because of the age structure of the population. A true life-cycle measure would look at one cohort across time, discounting the future welfare gains in the constrained periods of the lifetime as well as the losses during the unconstrained period.

Table 1 presents examples of such a measure. Here we make use of a present value calculation to estimate the life-cycle change in welfare for a worker whose yearly gains and losses in welfare are equivalent to the per capita values of the gains and losses estimated above.[9]

Table 1

Life-Cycle Welfare Gain from Removing the Earnings Test in the Presence of a Personal Income Tax

			Unconstrained Period		Constrained Period				
Row	Discount Rate	Compensated Cross-Elasticity	Annual Welfare Loss	Total Welfare Loss	Compensated Supply Elasticity	Annual Welfare Gain	Total Welfare Gain Constrained Period	Net Life-Cycle Change in Welfare	Asset Value of OASI[a]
A	3%	–.06	$75	$1,734	.3	$615	$1,865	$131	$11,910
B	2	–.03	37.5	1,026	.2	410	1,668	642	17,632
C	0	–.06	75	3,000	.3	615	6,150	3,150	38,850
D	0	–.03	39.4	1,575	.3	289	2,890	1,315	38,850
E	0	–.03	37.5	1,500	.3	615	6,150	4,650	38,850

[a]Present discounted value at the beginning of work life of all future benefits for the median OASI-covered worker aged 62 in 1974 (Burkhauser, 1979).

Under such an assumption each worker would have an annual \$615 per capita gain in the constrained period (assumed to last 10 years) and an annual \$75 per capita loss in the unconstrained period (assumed to last 40 years). If we assume a zero discount rate, the gain in the constrained period from removing the earnings test would be \$6150--row C, Table 1. But when the across-period substitution effect is included, the net per capita life-cycle welfare gain decreases by almost one-half to \$3150.

The specific estimates developed here should be taken with a healthy dose of skepticism. They depend heavily on the supply elasticity and cross-elasticity, as well as the discount rate and labor shares used in each period.[10] Since the welfare gain occurs in the second-period, while the welfare loss occurs in the first period, increases in the discount rate will decrease the net gain from removing the earnings test. Row A uses the same assumptions as row C, except that the discount rate is 3%. In this case the bias from not considering first-period effects is even more important. If we look only at the second period impact, the welfare gain appears to be \$1865 per person; but the net life-cycle gain is only \$131 per person.

In the unconstrained period, decreases in the assumed value of the compensated cross-elasticity decrease the across-period substitution, lessening the bias (row C vs. row E). In the constrained period, decreases in the compensated supply elasticity will have the opposite effect. Finally, the larger the part of labor's share of GNP that is attributed to younger workers (see note 6), the greater is the bias from excluding the cross-substitution effect (row E vs. row D).

Given these caveats, two results of Table 1 stand out. First, ignoring the cross-substitution effects that arise when the earnings test is removed clearly leads us to overestimate the welfare gains from such a move. Even in row E, the most extreme case, the welfare gain of $6150 per person is reduced nearly 25% by including the cross-substitution effect.

Second, over most of the range of values in Table 1, the net life-cycle welfare effects of the OASI system are small when compared to the size of the transfers distributed through OASI. Burkhauser (1979) estimated that the present value of all future OASI benefits at the beginning of work life for the median worker aged 62 in 1974 was $38,850. Under the assumptions used in the most extreme case (row E), the welfare loss of the earnings test is 12% of total transfers. But this falls to 1% under the assumptions of row A.

We will now consider our second alternative--replacing the revenue that is lost when the earnings test is removed through increases in the personal income tax. (As we have noted, this is a policy that might well at some point be considered by the federal government.) We will show that were such to happen the gains in welfare would fall over the entire range of values used in Table 1.

We will estimate additional welfare cost associated with the necessary increase in the income tax using equation (5) where t_b is the new marginal income tax rate.

$$\Delta\ell' = \frac{1}{2}\left(\frac{\partial L_1}{\partial w_1}\right)_u (t^2 - t_b^2) w_1^2$$

$$+ \frac{1}{2}\left(\frac{\partial L_2}{\partial w_2}\right)_u (t^2 - t_b^2)\, w_2^2 \qquad (5)$$

$$+ \left(\frac{\partial L_1}{\partial w_2}\right)_u (t^2 - t_b^2)\, w_1 w_2$$

or, in terms of elasticities

$$\Delta\ell' = \frac{1}{2}\, \varepsilon_{L_1 w_1} (t^2 - t_b^2)\, w_1 L_1$$

$$+ \frac{1}{2}\, \varepsilon_{L_2 w_2} (t^2 - t_b^2)\, w_2 L_2 \qquad (6)$$

$$+ \varepsilon_{L_1 w_2} (t^2 - t_b^2)\, w_1 L_1.$$

The net change in welfare from removing the earnings test and substituting a higher proportional income tax, the sum of equation (4) and equation (6), is now contained in equation (7).

$$\Delta\ell + \Delta\ell' = \frac{1}{2}\, \varepsilon_{L_2 w_2} [(e + t)^2 - t^2]\, w_2 L_2$$

$$+ \varepsilon_{L_1 w_2}\, e t w_1 L_1 \qquad (7)$$

$$+ \frac{1}{2}\, \varepsilon_{L_1 w_1} (t^2 - t_b^2)\, w_1 L_1$$

$$+ \frac{1}{2}\, \varepsilon_{L_2 w_2} (t^2 - t_b^2)\, w_2 L_2$$

$$+ \varepsilon_{L_1 w_2} (t^2 - t_b^2)\, w_1 L_1.$$

Table 2

Life Cycle Welfare Gain from Removing the Earnings Test When Lost Revenues Are Recovered Through an Increase in the Income Tax

		Unconstrained Period		Constrained Period			
Row	Income Tax Rate	Annual Welfare Loss	Total Welfare Loss	Annual Welfare Gain	Total Welfare Gain	Net Life-Cycle Change in Welfare	Net Change in Welfare Table 1
A	34%	$84	$1,942	$586	$1,532	$ - 410	$131
B	33	49	1,340	396	1,611	271	642
C	34	84	3,360	586	5,860	2,500	3,150
D	31	43	1,720	286	2,860	1,140	1,315
E	34	53	2,120	586	5,860	3,740	4,650
A'	34	84	1,568	586	1,532	-36	-
B'	33	49	1,165	396	1,611	446	-

In order not to violate our annual balanced budget constraint, the increase in revenue from the tax on labor income must equal the lost revenue from the earnings test

$$e(w_2'L_2 - Nd) = w_1 t_b L'_1 + w'_2 t_b L'_2 - w_1 tL_1 - w'_2 tL_2 \qquad (8)$$

where L'_1 and L_2' represent the new after-tax hours worked in the two periods. The wage in the second period, w'_2, is undiscounted, and Nd represents the number of older workers multiplied by the earnings test exemption amount. Recognizing the dependence of L'_1 and L'_2 on the net wages in both periods, equation (8) can be rewritten as

$$\begin{aligned} e(w_2'L_2 - Nd) = \; & t_b\Big(w_1L_1\big(1 + (t_b - t)\,\varepsilon_{L_1w_1} + (t_b - t - e)\varepsilon_{L_1w_2}\big) \\ & + w_2'L_2\big(1 + (t_b - t - e)\varepsilon_{L_2w_2} + (t_b - t)\varepsilon_{L_2w_1}\big)\Big) \qquad (9) \\ & - t(w_1L_1 + w_2'L_2), \end{aligned}$$

and using the quadratic formula a value for t_b can be found. Equation (9) makes it clear that the new marginal income tax rate is sensitive to both the value of labor in the two periods and the labor supply elasticities chosen.[11] In Table 2, the new marginal tax rates necessary to replace revenue lost from removing the earnings test vary from 31% to 34%, an increase of from 1 to 4 percentage points in the marginal personal income tax, where each row uses the same assumptions as its corresponding row in Table 1.

Table 2 confirms the fact that, if we use an income tax rather than a lump sum tax to replace revenues lost from removing the earnings test, welfare gains in the constrained period fall and welfare losses in the unconstrained period increase. For example, using our original assumptions from row C, the income tax rate is increased to 34%, causing welfare gains in the constrained period to fall from $5.5 billion to $5.3 billion and welfare losses in the unconstrained period to increase from $6.1 billion to $6.8 billion. While all the calculations in Table 1 consistent with a lifetime increase in hours worked showed that such an action resulted in a welfare gain, the same assumptions in Table 2 show that even a small welfare loss is possible, if the earnings test is replaced by an income tax.

Up to this point we have assumed that the increase in hours worked during the unconstrained period is constant throughout that period. Clearly this need not be the case. It is easy to imagine that the across-period substitution of labor between ages 60 and 62 is higher than that between ages 25 and 62. Workers may be uncertain about future wage rates, health, or changes in the earnings test. So in rows A' and B' we are retaining our assumption concerning the average cross-substitution to the unconstrained period; but letting the yearly cross-substitution increase linearly over the entire unconstrained period.[12] In the undiscounted case, such changes in the pattern of labor supply do not affect the welfare calculations. When there is a positive discount rate (row A and row B), however, the greater the share of substitution during older unconstrained ages, the greater is the welfare gain from removing the earnings test.

4. CONCLUSIONS

Removing the earnings test results in a substantial welfare gain for workers during the constrained period of their lives. But in a two-period model, the net effect is ambiguous, since removing the earnings test has an intertemporal labor supply effect. In the presence of a personal income tax, the across-period substitution effect on work at younger ages results in a welfare loss.

Given the crudeness of the assumptions necessary to make the calculations, the net effect of these two changes in life-cycle welfare cannot be firmly determined. But from our analysis it is clear that any estimate of the net effect of OASI which does not take this across-life substitution effect into account greatly overestimates the true welfare costs of OASI. Furthermore, across our range of estimates, the impact of removing the earnings test on welfare appears to be small, especially when it is replaced with a higher personal income tax.

NOTES

[1]Hanoch and Honig (1978) demonstrate that for some individuals an increase in the earnings test may have a positive effect on labor supplied during that period. Empirical studies of retirement seem to indicate that few people are affected in this way.

[2]Throughout our analysis we make the following conventional assumptions: (1) a labor supply curve that is income-compensated; (2) full employment; and (3) constant costs. We simplify the analysis by assuming that all older workers are on the earnings test segment of their segmented budget constraint.

[3]The OASI earnings test is similar to a tax on capital income in that both affect intertemporal relative prices. A variation of this two period Harberger model is used by Feldstein (1978) to estimate the welfare cost of capital income taxation. However, Feldstein assumes all labor must occur in the first period and ignores intertemporal labor supply effects.

[4]This model can be extended by considering the welfare cost of life-cycle changes in consumption induced by the earnings test. A tax on capital income is equivalent in a two-period model to a tax on a second period consumption (see Feldstein, 1978). Assuming there is no tax on first-period consumption, equation (4) would be expanded to include the term $- \varepsilon_{C_2 w_2} C_2 t^* p_2 e$ where t^* is the tax on second-period consumption and p_2 is the discounted price of second-period consumption. The sign of this term depends on the sign of the compensated cross-elasticity

$\varepsilon_{C_2w_2}$, which is ambiguous. The sign of $\varepsilon_{C_2w_2}$ depends on whether goods and time are substitutes or complements within the second-period and on the effect of the earnings test on the length of the second period. There is no welfare cost associated with changes in first-period consumption induced by the earnings test, assuming that first-period consumption is not taxed.

[5]Alternative values for these elasticities can be found in the literature. Smith (1975) suggests that the supply elasticity of older workers is higher than that of younger workers. Later we also use a .2 value for older workers to make the comparison with Browning more relevant.

[6]Denison (1974) estimates that 4.2% of total labor share is currently produced by those 65 and over. This can be used as a lower bound for the share of GNP that would have been produced by those aged 62 to 72 in the absence of the earnings test. An upper bound would be the wages and salary earned by those 62 to 72 in the absence of the earnings test. To estimate this upper bound we assume that in the absence of the earnings test the labor force participation rate of those 62 to 72 is the same as those aged 55 to 60. Using DRI data for 1974 we estimate the total contribution of this group to be $67 billion. Using the figure of 4.2% for the share of older workers in total earnings and Browning's (1976) data for total labor earnings, we estimate that $711 billion would have been the earnings for younger workers in the absence of the earnings test.

[7]The change in the relative wage across age is affected by both the earnings test tax and the payroll tax. The payroll tax has been small historically. For those below the taxable maximum the marginal tax from 1937 to 1950 was only 2%, half on the employer and half on the employee, and by 1974 it was 8.75%. This compared with a marginal tax of 100% or higher on earnings for most of the years from 1937 to 1972 and 50% since 1972 for those accepting OASI benefits.

[8]Using Ghez and Becker (1975) estimates for the intertemporal elasticity of substitution, we (Burkhauser and Turner, 1978) simulate a range of compensated cross-elasticities of labor supply ($\varepsilon_{L_1 w_2}$) between -.02 and -.09. Although our empirical results are consistent with the values within this range, a more precise value cannot be given with certainty. Our results do suggest that OASI has raised the workweek over 2 hours above what it otherwise would be for younger workers. But this change in hours is a function of both a substitution and a wealth effect.

If the Barro (1974) argument is correct, there is no OASI wealth effect, and this response is due solely to the substitution effect. In such a case the uncompensated cross-elasticity varies between -.06 and -.03 depending on the relevant earnings test tax (50% to 100%) for the period. We use these uncompensated elasticities as first approximations of the compensated elasticities.

[9] $PVW = \sum_{n=1}^{t} g(1 + r)^{-n}$

where

PVW = life-cycle present value of changes in welfare owing to OASI

g = yearly welfare gain or loss in the n^{th} period

r = discount rate.

A more sophisticated model would allow for a nonzero probability of death in each year.

[10] The examples in Table 1 were constrained to those cases in which total income-compensated lifetime labor supply increased when the earnings test was removed.

[11] Calculations for Table 2 use the same assumptions with respect to discount rate, length of the two periods, and $\varepsilon_{L_1w_2}$. Given these previous assumptions, the value of $\varepsilon_{L_2w_1}$ can be found, since appropriately discounted compensated cross-elasticities are equal.

$$\varepsilon_{L_2w_1} = \gamma\, \varepsilon_{L_1w_2}$$

$$\text{where } \gamma = \frac{\sum_{t=0}^{39}(1 + r)^{-t}}{\sum_{t=40}^{49}(1 + r)^{-t}}.$$

For instance when $r = 0$ and $\varepsilon_{L_1w_2} = -.03$, $\varepsilon_{L_2w_1} = -.12$.

[12] The equation of note 9 becomes $PVW = \sum_{n=1}^{40} \left(\frac{2n - 1}{40}\right) g\ (1 + r)^{-n}$.

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