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Transition Losses of Partially Mobile Industry-Specific Capital

Don Fullerton, *University of Illinois at Urbana-Champaign*

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DON FULLERTON

In estimating the economic effects of public policy, comparative static models typically assume homogenous factors that are either mobile or immobile. For changes designed to improve factor allocations, the former assumption would overstate welfare gains, while the latter would understate them. The model in this paper restricts each industry's capital reduction to its rate of depreciation. The stock of depreciated capital represents an industry-specific type of capital that may earn a lower equilibrium return. This model suggests that previous estimates of efficiency gains from integration of U. S. personal and corporate income taxes are overstated by $5 billion.

Welfare effects of public policy are typically measured by comparing the resource allocations associated with alternative policies. Direct comparison of two allocations, however, cannot capture the adjustment costs associated with the relocation of factors from one allocation to the other. This paper develops and implements a computational model to capture some of these adjustment costs. It will not try to measure transaction costs per se, retooling expenses, or temporary unemployment. Instead, it focuses on the low returns that can be earned in equilibrium by factors incapable of moving immediately to newly expanding sectors. One plausible concept for factor mobility is that investment is specific to each industry: tractors are purchased for agriculture, and looms for textiles. As tractors cannot be reconstructed into looms, the textile industry can expand only as fast as the gross savings of the economy.

The model in this paper is designed to measure static and dynamic effects of U. S. tax policy in a comparative equilibrium framework. It is an adaptation from the model of Fullerton, Shoven, and Whalley [1978] (hereinafter F-S-W), which takes 1973 data to form a consistent "benchmark" equilibrium. It incorporates all U. S. taxes as affecting economic behavior. The "standard" model is one in which both labor and capital are viewed as homogeneous and perfectly mobile. The "new" model is one in which the depreciated industry-specific capital stocks from the benchmark equilibrium are viewed as quantity constraints for each industry. The constraint is

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not binding for an increase or only slight decrease in the industry's use of capital. For an industry with a decreased demand for its output and a binding constraint on its disinvestment, the rental price could fall dramatically, even though the old capital has lost none of its physical productivity. Total welfare is lower than in the case with perfect mobility. The model allows further depreciation in the following periods, constraints disappear, and the economy approaches a new steady state.

The point of this exercise, then, is to develop a methodology for measuring the size and duration of some of these transition costs, in an equilibrium setting. The general equilibrium setting is important for large tax changes because of the interactive nature of the price mechanism. Competition among firms within the expanding industries in this model ensures zero excess profits, but factor owners there could earn a higher equilibrium return. Similarly, competition among firms in shrinking industries ensures zero profits, lower output prices, and lower factor returns. All new prices jointly determine producer and consumer behavior with respect to consumption, investment, and factor supplies.

If those who gain are not the same as those who lose, then differential income effects can further influence commodity demands and relative prices. Since data on individual holdings by industry are not generally available, this model assumes that each of the twelve consumer groups allocate their capital among all industries in the same proportions that total capital is allocated. This balanced portfolio behavior is compatible with utility-maximizing risk-avoidance, since all capital earns the same return in the equilibrium prior to any tax change.[1] The model does capture differential holdings of labor and total capital, however. The methodology could be adapted for industry-specific labor types, since there exist special trade skills that also depreciate, but no attempt will be made to do so here.

For two reasons, this paper uses the full integration of U. S. corporate and personal taxes as an example of the new methodology. First, this proposed tax change is expected to have large interindustry reallocations and factor price adjustments for which the general equilibrium setting is important. Second, this example will permit direct comparison with published results of the "standard" model.[2] As shown below, the efficiency gains of this reform were indeed overstated by about $5 billion when transition losses were ignored.

1. The model in Fullerton and Gordon [1983] includes different risk premiums by industry and accounts for portfolio effects. Slemrod [1983] has an explicit model of portfolio adjustment in response to a tax change.

2. See Fullerton, King, Shoven, and Whalley [1981].

Section I briefly reviews other models of factor mobility and further motivates the model in this paper. Section II discusses modeling changes and problems associated with industry-specific capital, using the F-S-W model as a starting point. That model is described in the Appendix, along with some of the detailed derivation of the new model. Section III begins the full integration example with a determination of the minimum capital constraints for each industry. Section IV reports results of the new model together with estimates of the effects of integration from the standard model. Finally, Section V provides concluding remarks about the limitations of this approach.

I. Other Literature

General equilibrium tax incidence models since Harberger's [1962] path-breaking analytical model have typically assumed perfectly mobile factor supplies in a comparative static framework. McLure [1971] extended the analytical model to include immobile factors, but still in fixed total supply. He obtained the now-familiar result that an immobile factor is less able to escape taxation whether imposed on that factor, on output, or indeed on the other factor in a sector with a low substitution elasticity. This model compared two short-run static equilibria, so the factor was never given a chance to move between sectors.

At least two models incorporate partial mobility. McLure [1970] used an elasticity of mobility that relates the percentage change in the ratio of a factor's use in two sectors to the percentage change in the ratio of prices that it can receive in the two sectors. Zero and infinite elasticities provide the special cases of immobile and perfectly mobile factors. In general, this elasticity will depend on the time allowed for adjustment. Grossman [1980] hypothesized that capital is instantaneously transferable, but differs in the relative addition that it makes to efficiency units in the other sector. Again, the model has only two sectors and does not account for increased mobility as time passes.[3]

The size of the tax incidence problem was expanded by computational models in Shoven and Whalley [1972], and again in F-S-W

3. Adelman and Robinson [1978] incorporate "credit-worthiness" constraints in a formal banking sector, with further borrowing possible at higher interest rates in a secondary capital market. They also model rural-urban migration as a function of income differentials, though there is an upper limit on the annual rate of migration. Other development models make similar constraints on factor mobility or factor prices, including de Melo [1978] and Dervis [1979].

[1978]. These models have more sectors and other extensions, but are still comparatively static with perfect factor mobility. Fullerton, King, Shoven, and Whalley [1981] (hereinafter F-K-S-W) use a dynamic version of the model to evaluate the integration of personal and corporate income taxes in the United States. The dynamic model allows the saving response of one static equilibrium to affect the capital stock of the next static equilibrium in a sequence of calculations. In any given equilibrium, however, there are a fixed total capital stock and no barriers to factor mobility. In particular, the capital endowment in the first period of the original (base-case) sequence is used as the stock available in the first period of the simulated (revise-case) sequence. Incidence estimates are obtained by comparing the time path of the economy with the original tax system to the path of the economy resulting from the hypothetical or proposed tax system.

An immobile factor model can predict only the immediate effects of a tax change (unless the factor is permanently immobile). Strictly speaking, the two partial mobility models are valid only for particular time frames. Comparative growth models such as Feldstein [1974a,b] can provide long-run effects. None of these models, however, considers a temporarily immobile factor or incorporates the increased mobility of factors over time.[4]

II. Constrained Factor Movements

Important features of the "standard" equilibrium model of F-S-W [1978] and F-K-S-W [1981] have been mentioned above. The first part of the Appendix summarizes other features. This section describes changes to that model which were necessary to build the new (constrained capital) model. Features of the standard model that are not specifically mentioned in this section were left intact.

Consider the general case with M sectors or industries. The economy has reached a long-run equilibrium with the old tax regime, and thus has no mobility problems. Let K_i^0 $(i = 1, \ldots, M)$ represent the ith sector's use of capital in this original (benchmark) equilibrium. The total supply of capital is given by K_T^0, the sum of K_i^0 over M sectors. For a particular tax change, such as integration, some industries will desire more capital, and others less. Suppose, however, that N

4. Also, comparative static models are inconsistent when they compare two long-run (post-adjustment) equilibria assuming the same capital in each. If the two tax regimes have different incomes and factor prices associated with them, and if saving has a positive elasticity with respect to either income or the rate of return, then capital would grow faster during one of the adjustment periods. The industry-specific capital model considers the adjustment from the status quo to a new tax regime.

industries are constrained in their attempts to disinvest. Let K_i^c ($i = 1, \ldots, N$) denote the fixed supply of industry-specific capital that cannot be used outside the ith sector.

To model perfectly immobile capital in an industry, one might let K_i^c equal K_i^0. Or, with data on the particular assets used by each industry, one could base K_i^c on the proportion of assets deemed mobile or immobile.[5] In the computational example below, however, K_i^c are derived from the depreciated capital stocks of the original equilibrium. The advantages of this approach are that depreciation rates are available for each industry, K_i^c can be further depreciated in successive periods, and overall growth can easily be incorporated. The particular constraints for integration are derived in the next section.

Capital that is not constrained for use in a specific sector may be used in any sector. Denote this mobile capital by K. With a discrete time model, K might be net saving that is not yet invested or depreciation that is not yet reinvested. The total supply of new or mobile capital is

$$K_T = K_T^0 - \sum_{i=1}^{N} K_i^c. \tag{1}$$

One type of labor is still mobile and homogeneous.

Although there are now $N + 2$ factors of production, at most three of these appear in the production function of any one industry. In a world with no capital-embodied technological change, old and new capital would be perfect substitutes in an industry. The two types of capital together could be imperfectly substitutable for labor.[6] Abstracting from the possibility of a corner solution, there is a positive equilibrium price at which all of the old capital of an industry gets used there. Where K_i denotes the demand for an industry-specific capital type, and K_i^c denotes its fixed supply, the market is assumed to clear at a price P_{Ki}. If $P_{Ki} < P_K$, then none of the new capital would be used, since the two are perfect substitutes. If $P_{Ki} > P_K$, however, firms would demand none of the old capital, driving down its equilibrium price until $P_{Ki} \leq P_K$ and K_i^c is used.

A computational problem arises with this modeling, due to dis-

5. Tractors may not be usable outside of agriculture, but any industry could easily move out of office space, delivery trucks, and warehouses.

6. Rental of an old loom, for example, is equivalent to rental of a new loom in the textile industry. If the industry is not expanding, then none of the net saving is used to purchase new looms (none of the new capital is used there). If the new tax rates would cause the industry to contract faster than its rate of depreciation, however, there will be "too many" old looms available with an equilibrium rental price that is lower than that of new capital.

continuity in demands. Because K_i and K are perfect substitutes in the ith sector, demand for capital shifts entirely from one type to the other around a single relative price. The solution algorithm takes finite steps in its search for an equilibrium price vector and may iterate forever around $P_{Ki} = P_K$, which would allow the use of both capital types.[7] This problem can be solved by using imperfect substitutability. With a high elasticity of substitution between old and new capital, one can model large but continuous shifts between capital types as their relative prices change. The adjustment is similar to that described above, but it is smoother.

In particular, firms are assumed to minimize the unit cost of output in a nested CES production process. In the outer nest, output Q is produced via a combination of labor L and composite capital $\overline{K}$:[8]

$$Q = A\,[\alpha L^{(\sigma-1)/\sigma} + (1-\alpha)\overline{K}^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)}, \tag{2}$$

where α and A are production parameters, and σ is the elasticity of substitution between labor and composite capital. For industries without specific capital types, $\overline{K}$ is just equal to the mobile capital that they use. For the other N sectors, the inner nest is given by

$$\overline{K} = [K^{(\sigma_K-1)/\sigma_K} + K^{(\sigma_K-1)/\sigma_K}]^{\sigma_K/(\sigma_K-1)}, \tag{3}$$

where the parameter σ_K is the arbitrarily high elasticity of substitution between capital types.[9]

The second part of the Appendix shows the factor demand functions that result from this behavior. First, producers minimize $\overline{P}_K$, the cost of composite capital. Second, they minimize the unit cost of output. The resulting factor demand ratio is given by

$$\frac{K}{K_i} = \left[\frac{P_{Ki}}{P_K}\right]^{\sigma_K}. \tag{4}$$

7. When the algorithm tries a P_{Ki} that is slightly less than P_K, all demand for capital falls on K_i. If this demand exceeds K_i^s supply, the next iteration tries a higher P_{Ki}. If the next P_{Ki} exceeds P_K, there will be no demand for old capital and a large excess supply. The next iteration tries a lower P_{Ki}, possibly equal to the first attempt above. Thus, the algorithm can cycle.

8. All variables in these production functions differ by industry, but indices are suppressed for expositional simplicity. Only σ_K will be the same for all industries. The α and A parameters are derived from the data by backward solution, as described in the Appendix. This function is the same as in the standard model, except that homogeneous capital is replaced by the composite $\overline{K}$.

9. Results reported below use a σ_K of 40 because the computer was unable to solve the model for higher values. Unreported results reveal that when the two factors become closer substitutes, the industry decreases demand for K and increases demand for K_i, which has the lower price. The greater demand for K_i relative to its fixed supply results in a higher equilibrium price. Since P_{Ki} levels off as σ_K is increased, it is fair to presume that perfectly substitutable capital stocks would still show P_{Ki} less than P_K.

For a high enough σ_K, this behavioral rule has the desired property that P_{Ki} slightly lower than P_K causes demand for old capital that is much greater than that of new capital. With σ_K less than infinite, however, producers will always use some K in addition to their K_i.[10]

Some adaptations are also required for dynamic sequencing. The first period of the revised sequence uses specific capital types K_i^c that are based on the depreciated capital stocks of the previous period. Mobile capital K is given by equation (1), and the equilibrium is calculated with a new set of tax schedule specifications. The net saving response of the first period is still used to augment the total capital stock for the next period, but it augments the mobile capital stock in particular. The constraints K_i^c are depreciated again, and the depreciation is also used to augment mobile capital.

If $K > K_i$ in a constrained industry, (4) indicates that P_{Ki} could exceed P_K. To avoid this possibility and to save computation expenses, the model should eliminate constraints when they become nonbinding. The form of the production function provides a neat procedure for checking constraints, since all industries must use some of the mobile capital. If a substantial amount is used in one period, then it is logical to presume that the constraint will not be binding in the next period. Thus, if an industry uses more new capital than its total depreciation, the constraint is eliminated, the old capital is added to mobile capital, and the dimension size is reduced by one.

When all industries are off their constraints, the short-run adjustment period has ended. A single period's fixed capital stock is now properly allocated among sectors. However, long-run adjustments will continue, while the saving response pushes the economy's overall capital-labor ratio toward the new steady state.

III. Derivation of Constraints

The standard model is first used with the new tax regime to calculate the unconstrained allocation of capital, K_i^u $(i = 1, \ldots, M)$. This vector is compared to the vector of depreciated capital stocks from the benchmark equilibrium to determine which industries would disinvest faster than their depreciation rates. Old capital stocks need be considered only in these industries. This procedure limits computation expenses that increase rapidly with the number of factor

10. This behavior seems reasonable if investors buy some new capital (perhaps to test), even though excess old capital exists. The price of new capital will always exceed the price of old capital, unless significant amounts of new capital are used.

prices. It also avoids problems with equation (4), as mentioned above.

Another result of this procedure is that the industries to be constrained will depend on the tax change considered. Because of depreciation, overall growth, and built-in flexibility, however, a major tax policy change may be required before minimum capital constraints have a perceptible influence on capital allocations. A good example of such a major tax change is the "full integration" of personal and corporate income tax systems.[11] When the "double taxation" of capital income in the corporate industries is eliminated, they will draw mobile capital from other industries in an effort to expand faster than the overall rate of growth. Efficiency gains of the new-tax regime cannot be fully realized if capital cannot fully reallocate.

The $M = 20$ sectors of this model are defined in column (A) of Table I. Government enterprises is an industry comparable to the other private industries, except that it receives a large output subsidy. General government collects taxes and has final demand for goods and factors. The K_i^0 vector in column (B) indicates the use of capital in the original equilibrium. These quantities are defined using the convention that a unit of capital services earns one dollar net of all taxes in the benchmark year. Estimates of economic depreciation for 1973 are shown in column (C) in millions of 1973 dollars.[12] The rates of depreciation d_i implied by these numbers are shown in column (D). The average depreciation rate for private industry is used for the government enterprises industry and for general government. For comparison, the unconstrained uses of capital under the full integration tax replacement K_i^u are shown in column (E).

The size of the K_i^c constraints depends on the length of each period and the timing of investment. If, for example, the industries are notified of the tax change just after they had made investment decisions, then constraints would be given by $K_i^c = K_i^0$, the quantity of capital ready to begin the period under the expectations of the old tax regime. Comparison of columns (B) and (E) indicates that under such a modeling, seven sectors (numbers 1, 3, 8, 17, 18, 19, and 20) would hit their respective constraints. However, producers get signals

11. Several integration plans are discussed in McLure [1979]. The model-equivalent treatment of full integration is documented in F-K-S-W [1981].

12. For manufacturing industries, Coen [1980] provides estimates of economic depreciation. For other industries, the July 1976 *Survey of Current Business* provides the capital consumption allowance. The capital consumption adjustment is subtracted, when possible, to better approximate economic depreciation. These figures are multiplied by γ, the average net-of-tax rate of return, to get depreciation of capital services units. The dollar depreciation numbers are part of gross saving and must be converted like consumers' net saving to get new units of capital.

TABLE I

CAPITAL ALLOCATION, DEPRECIATION, AND CONSTRAINTS

(A) Industry	(B) K_i^0	(C) Depreciation	(D) d_i	(E) K_i^u	(F) $K_i^0\left(\frac{1-d_i}{1+n}\right)^1$	(G) $K_i^0\left(\frac{1-d_i}{1+n}\right)^2$	(H) K_i for $N = 5$	(I) K for $N = 5$
(1) Agriculture, forestry, fisheries	22,768	8,867	0.01558	22,203	21,812	20,896	21,812	585
(2) Mining	875	1,222	0.05588	896	804	738	—	846
(3) Crude petroleum and gas	2,464	613	0.00995	2,416	2,374	2,288	—	2,326
(4) Construction	836	3,529	0.16886	1,304	676	547	—	1,216
(5) Food and tobacco	1,308	2,300	0.07032	1,860	1,184	1,071	—	1,769
(6) Textile, apparel, leather	803	1,149	0.05725	1,224	737	676	—	1,144
(7) Paper and printing	2,097	2,344	0.04471	2,720	1,950	1,813	—	2,560
(8) Petroleum refining	6,556	1,231	0.00751	6,494	6,332	6,116	—	6,343
(9) Chemicals and rubber	2,965	3,851	0.05196	4,099	2,735	2,524	—	3,864
(10) Lumber, furniture, stone	3,311	1,907	0.02304	3,703	3,148	2,993	—	3,510
(11) Metals, machinery	7,900	8,217	0.04160	10,068	7,368	6,872	—	9,593
(12) Transportation equipment	101	888	0.35200	173	64	40	—	162
(13) Motor vehicles	3,684	1,338	0.01453	4,547	3,534	3,389	—	4,314
(14) Transportation, communication, utilities	9,881	20,086	0.08131	10,742	8,834	7,898	—	10,083
(15) Trade	7,516	9,561	0.05089	9,897	6,942	6,412	—	9,214
(16) Finance and insurance	6,126	3,655	0.02386	6,800	5,820	5,528	—	6,385
(17) Real estate	52,616	32,192	0.02447	50,070	49,952	47,422	49,952	908
(18) Services	9,457	8,889	0.03760	9,206	8,857	8,295	8,857	345
(19) Government enterprises	6,181	—	0.03167	5,769	5,824	5,489	5,824	71
(20) General government	97,961	—	0.03167	91,215	92,314	86,992	92,314	1,407
Total	245,406	111,849	0.03167	245,405	231,259	217,999	178,759	66,645

Column (A) gives the aggregation of U. S. production and government activity to twenty sectors; (B) K_i^0 is the allocation of capital in the original equilibrium; also equals after-tax capital income in millions of 1973 dollars; (C) depreciation is in millions of 1973 dollars; derivation is described in the text; (D) d_i is the depreciation rate, equal to column (C) multiplied by $\gamma = 0.04$ and divided by column (B); (E) K_i^u is the allocation of capital in the unconstrained "full integration" equilibrium; (F) minimum capital constraints after one year; (G) minimum capital constraints after two years; (H) use of old capital under full integration with five constrained sectors; (I) use of mobile capital under full integration with five constrained sectors. Totals may not match because of rounding or because of the specified accuracy for equilibrium calculations.

of pending tax change proposals and may hold back investment plans until tax rate uncertainty has been resolved. If so, constraints would be given by the depreciated capital stocks of the previous period:[13]

$$K_i^c = K_i^0 \left[\frac{1 - d_i}{1 + n}\right]^{NYRS}, \tag{5}$$

where $NYRS$ is the number of years in each period. Notice that the two rules are identical for $NYRS = 0$. In computations below, $NYRS$ is set to 1 partly to account for the exposed nature of tax policymaking and partly to save computation expenses. The minimum capital constraints are lower with the one-year advance notice because gross investment is "mobile," including both depreciation at rate d_i and net investment at the steady state rate n. Transition cost estimates would be greater with more constraints, so in this sense the estimates below are understated.

With periods of one year, the constraints are shown in column (F) of Table I. Comparing these to the unconstrained simulation, it appears that only two constraints are transgressed (numbers 19 and 20). This comparison of columns (E) and (F) is not necessarily an accurate guide to the number of binding constraints, however, since K_i^u were completely mobile. If one sector were compelled to use more capital, then less is available to other industries. These other sectors may hit constraints, as shown below. Column (G) gives the constraints after two years. Surprisingly, none of the sectors is restrained after such a short period. Growth of effective labor at rate n turns out to provide an easy means to a lower capital-labor ratio.[14]

IV. Simulation Results

Previous simulations of full integration used dynamic sequences with five periods of ten years each.[15] Because ten-year periods are sufficient to depreciate away all constraints, however, full integration was resimulated on the old model for ten periods of one year each. The

13. The benchmark equilibrium is assumed to be part of a steady state growth path where n is the annual growth rate. The previous year's use of capital must have been $K_i^0/(1 + n)$ to grow at this rate and yield K_i^0. When the previous year's capital is depreciated, we have (5).

14. A more dramatic tax change might involve greater capital shifts and longer binding constraints. Charles McLure has suggested that the industry-specific capital model might be usefully employed with an industry-specific tax change such as the imposition of a windfall profits tax on oil. Unfortunately, the other features of the model are not yet well adapted for energy policy. Adequate evaluation could require a better trade sector and energy as a primary input for production.

15. See F-K-S-W [1981]. Appropriate terminal conditions account for years beyond those calculated.

present value of efficiency gains (EG) then is $174.4 billion, taken as the standard of comparison for the constrained model's results. If the new present value of efficiency gains is lower, then the difference (ΔEG) is taken as the loss due to imperfectly mobile capital.

An array of results is displayed in Table II. The left-hand column includes the unconstrained efficiency gain just mentioned and the three relative "prices" of the equilibrium solution. All prices are normalized to the price of labor, taken as one. The other two dimensions give the relative price of capital and the tax scalar used for equal yield calculations. The scalar of 1.123 indicates that personal tax rates must be 12.3 percent higher to recoup lost revenue. The price of capital rises from 1.0 to 1.105 when integration is imposed, but falls over ten years to 1.092 as capital deepening takes place.

The first constraint considered was for general government because this user of capital seemed to be farthest below its depreciated old capital in the unconstrained simulation. Once this single constraint takes effect, however, several more industries' capital demands fall below their constraints. The columns of Table II show the results of different simulations where additional constraints are successively imposed.[16] The order of consideration is essentially arbitrary, but they generally appear in declining order of importance.

With one constraint for sector 20, the return to old capital is indeed lower than that of new capital, as seen from comparison of rows (4a) and (5a). Government does not want that much capital, so its price falls to 1.049 in relative terms. With government capital restricted, there is less mobile capital for other users, and its price rises to 1.149 in the new equilibrium. The tax scalar falls to 1.096 because government's cost of capital is lower. Its composite price of capital is 1.067, based on equation (9) in the Appendix. Finally, the efficiency gains of this computation are $172.4 billion, lower by $2 billion than the unconstrained computation.

Once general government (sector 20) is constrained, the capital demands of agriculture (1), real estate (17), government enterprises (19), and services (18) also fall below their depreciated old capital stocks.[17] As these constraints are imposed, row (4a) of Table II shows

16. As expected, additional simplex dimensions increase computer cost more than proportionately. However, there seems to be an acceleration in the rate of increase. At first, costs rise by about the square of the number of dimensions, but the addition of the eighth price raises cost by more than the cube. These geometrically increasing costs serve to reinforce the adoption of ad hoc assumptions made earlier to limit the number of dimensions.

17. Integration does not raise effective tax rates on these sectors, but it does lower rates for industries that are heavily incorporated. The noncorporate sectors use less capital because the other industries bid up the price of it.

TABLE II

THE RESULTS OF FULL INTEGRATION FOR SIMULATIONS WITH $N = 0$ TO $N = 5$

	Number of constraints					
	None	One	Two	Three	Four	Five
(1) Number of dimensions	3	4	5	6	7	8
(2) Tax scalar	1.123	1.096	1.101	1.113	1.114	1.115
(3) Price of labor	1.000	1.000	1.000	1.000	1.000	1.000
(4) Price of mobile capital						
a. period one	1.105	1.149	1.155	1.176	1.181	1.189
b. period ten	1.092	1.092	1.092	1.092	1.092	1.092
(5) Price of old capital						
a. sector 20	...	1.049	1.053	1.065	1.067	1.071
b. sector 1	...	...	1.064	1.078	1.081	1.086
c. sector 17	...	...	...	1.068	1.071	1.075
d. sector 19	...	...	...	...	1.062	1.065
e. sector 18	...	...	...	...	...	1.096
(6) *EG:* Efficiency gain, in billions of 1973 $	174.402	172.443	171.704	169.774	169.729	169.206
(7) ΔEG: Transition losses of partially mobile capital, in billions of 1973 $	...	1.959	2.698	4.628	4.673	5.196

that P_K rises. Less mobile capital is available to other industries. The demand for and price of government-specific capital also rise, since government's small relative demand for mobile capital gets even smaller as P_K rises. The more costly nature of government's capital causes a higher tax revenue scalar, as shown in row (2). Looking across sub-rows of (5) indicates that any industry-specific capital type earns a higher return when other industries are also constrained. Every additional constraint reduces the quantity of mobile capital in the model, drives up its price, and makes the old capital relatively more desirable. In all cases, new capital demand exceeds depreciation, so the model removes constraints for the second period.

Rows (6) and (7) show the reduced efficiency gains of full integration as more types of capital are partially immobile.[18] Though the \$5 billion EG reduction for $N = 5$ is a large absolute number, it seems small compared with the \$174 billion present value. This comparison depends heavily on the discount rate, however, since the \$5 billion is really a loss in the first period. A higher discount rate makes the present value smaller and increases the relative size of the first-period loss.

Further sectoral results are displayed in the last two columns of Table I. Column (H) shows the use of old capital, exactly matching its supply for the five constrained sectors (as shown in column (F)). Almost three fourths of total capital was constrained for use in these five sectors because they have capital-intensive production processes, because they paid the least corporate tax before integration, and because they have relatively low depreciation rates. After integration, column (I) shows that they use some new capital, in accordance with equation (4). All other sectors use only mobile capital, but always less

18. Row (7) of Table II seems to imply the marginal costs of each constraint that are shown in the left-hand column of the tabulation below.

Number	Sector	\$ Billions	\$ Billions
20	General government	1.959	—
1	Agriculture	0.739	0.739
17	Real estate	1.930	1.812
19	Government enterprises	0.045	0.317
18	Services	0.523	0.311
	Total	5.196	

The order of consideration is arbitrary, however, for once sector 20 is constrained, all four other sector demands for capital fall below K_i^s. When sector 20 is paired with each other sector, the right-hand marginal costs result. This comparison emphasizes interlinking effects for which a general equilibrium model is required.

than they would without constraints on disinvestors (see K_i^y in column (E)).

V. Concluding Remarks

The malleable capital assumption of comparative equilibrium models causes overstatement of efficiency gains from policies designed to improve factor allocation. Immobile factor models would understate such gains. The model in this paper attempts to bridge this gap by restricting each industry's capital reduction to its rate of depreciation. When such restrictions are imposed on the evaluation of full personal and corporate tax integration in the U. S., efficiency gain estimates are reduced by about $5 billion. Because overall growth allows flexible factor ratios, however, these constraints may only apply for about one year.

The size and duration of these estimates provide important information to those who must balance simplicity and validity in modeling the mobility of productive factors. There are, however, limitations in the present study. Like other equilibrium models, it ignores price rigidities, involuntary unemployment, underutilization of capacity, and other disequilibrium influences. Although the model introduces heterogeneous capital types by industry, it assumes homogeneity within each type. The model also uses fairly simple treatments of tax rates, depreciation, growth, trade, and other features.

An interesting extension of this model would consider capital-labor ratios that are flexible ex ante but fixed ex post. This treatment would not affect the benchmark that is a post-adjustment equilibrium, but it would significantly affect the adjustment to a new tax regime. With integration, for example, every industry desires a new capital-labor ratio. Every industry could thus have an old capital type, fixed in the wrong ratio to labor, which could earn an equilibrium return lower than that of flexible new capital. Furthermore, the adjustment period would last not just until each industry achieved the right quantity of capital as above, but until all of the old capital types were scrapped. With time-dated capital types in all twenty sectors, computation could be prohibitively expensive.

Another extension would consider individuals with disproportionate holdings of industry-specific capital. Constrained capital was shown above to have a net welfare effect of a $5 billion loss, but holders of only new mobile capital may actually gain. If so, a "homeowner" group with real estate capital or a "rural" group with agricultural capital may lose more than that net effect. More data and modeling effort would be required to investigate these and other extensions.

APPENDIX

1. *Carryover Features from the Standard Model*

The production side of the model includes nineteen profit-maximizing producer goods industries that each use labor and capital in a constant elasticity of substitution (CES) or Cobb-Douglas production function. The *Survey of Current Business* and other 1973 Commerce Department data are used to obtain a fixed coefficient input-output matrix as well as each industry's payments for labor and capital. An ad valorem tax on each industry's use of capital is comprised of the corporation income tax, state corporate franchise taxes, and local property taxes.[19] The Social Security tax and workmen's compensation are modeled as ad valorem taxes on industry use of labor. Various Federal excise taxes and indirect business taxes are modeled as output tax rates, while state and local sales taxes apply to each of the fifteen consumer goods in the model.

Each producer good can be used directly by government, for export, or for investment. Each can be used indirectly for consumption through a fixed-coefficient **Z** matrix of transition into one of fifteen consumer goods with suitable definition for consumer demand. This transition is necessary because the Commerce Department data include such industries as mining and trade, while the Labor Department's Survey of Consumer Expenditures provides data on purchases of goods like furniture and appliances.[20] The Treasury Department's Merged Tax File provides information on labor income, capital income, and personal tax payments for each of the twelve consumer classes. It also provides an estimate of τ_j, the average marginal income tax rate for each group, ranging from 1 percent to 40 percent. A progressive income tax system is then modeled as a series of linear schedules, one for each group. Pensions, IRA, and Keogh plans are modeled as a 30 percent saving subsidy, to capture the proportion of saving that now has such tax sheltered treatment. Further tax advantages are modeled in the "personal factor tax," a construct designed to capture industry-discriminating features of the personal income tax. The model thus favors industries with a high proportion of retained earnings, industries with noncorporate investment tax credit, and the housing industry.

Expanded income of each consumer is given by his transfer in-

19. The effective tax rate in each industry is equal to capital taxes paid over capital income. For a comparison of this "average" tax rate with an alternative "marginal" treatment in this model, see Fullerton and Gordon [1983].

20. The **Z** matrix derives from data in the February 1974 *Survey of Current Business*. An unfortunate effect of using this matrix is that differential price effects are dampened. Each of the fifteen consumer goods is a weighted average of the nineteen producer goods, with weights given by each column of the **Z** matrix. The implicit capital-labor ratios in the construction of each consumer good must therefore vary less than the capital-labor ratios of producer goods. When factor prices vary, consumer good prices will vary less than producer prices; consumer purchases will vary less than if consumers bought producers goods directly. Weights differ enough to capture substantial effects, however.

come plus capital and labor endowments.[21] The latter is defined as 7/4 of labor income to reflect a possible seventy-hour week while working forty hours. Consumer demands are based on budget constrained maximization of the nested CES utility function:[22]

$$U = U\left[H\left(\prod_{i=1}^{15} X_i^{\lambda_i}, l\right), C_f\right]. \tag{6}$$

In the first stage, consumers save some income for future consumption C_f and allocate the rest to a subutility function H, defined over present consumption goods. In the second stage, income for H is divided between repurchase of leisure l and a Cobb-Douglas subutility function defined on the fifteen consumer goods X_i. Commodity preferences are reflected in the λ_i expenditure shares, set from observed 1973 expenditures of each group. The elasticity of substitution between l and consumer goods is based on a 0.15 estimate for the elasticity of labor supply with respect to the net-of-tax wage. The elasticity of substitution between C_f and H is based on Boskin's [1978] estimate of 0.4 for the elasticity of saving with respect to the net-of-tax rate of return. Saving is derived from consumer demand for future consumption under the expectation that all present prices, including the price of capital, will prevail in all future periods.

The foreign trade sector is modeled by the assumption that the net value of exports less imports for each producer good is constant.[23] Government revenues are acquired from selling an endowment of capital, and from the various taxes described above. Lump-sum transfers are paid to each consumer group, based on Treasury data for social security, welfare, and similar programs. Remaining revenue is used to purchase factors and commodities, based on Cobb-Douglas demand functions.

Because the data set for this model is so comprehensive, the sources are necessarily divergent. In order to use all sources together, some data are accepted as superior, and other data are adjusted to match.[24] The fully consistent data set then represents a benchmark equilibrium, where values are separated into prices and quantities by assuming that a physical unit of each good or factor is the amount that sells for one dollar. Elasticity parameters are imposed exogenously, and the model is solved backward to generate the remaining behavioral parameters. Factor employments by industry are used to derive production function weights, just as expenditures are used to derive utility and demand function weights. The resulting tax rates,

21. Portfolio effects are ignored because capital income types are summed to obtain capital endowments. Since capital is homogeneous, consumers will gain or lose according to their total endowment in the model.

22. All variables in this utility function differ by consumer group. Indices are suppressed for expositional simplicity.

23. For alternative treatments of trade in this model, see Goulder, Shoven, and Whalley [1983].

24. All industry and government uses of factors are taken to be fixed, so consumers' factor incomes and expenditures must be scaled. Tax receipts, transfers, and government endowments are fixed, so government expenditures must be scaled. Similar adjustments insure that supply equals demand for all goods and factors.

parameters, and endowments can be used to solve the model forward, perfectly replicating the benchmark equilibrium. This particular calibration allows for a test of the solution procedure and insures that the various agents' behaviors are mutually consistent.

A variant of Scarf's [1973] algorithm is used to solve for the three "prices" of labor, capital, and government revenue, since a knowledge of these is sufficient to evaluate all agent behavior.[25] Since it is not based on differential calculus, the computational model can evaluate discrete tax changes. It can handle any number of market distortions such as quotas or externalities by adding simplex dimensions appropriately. For now, however, the model assumes no involuntary unemployment of factors, no externalities and no other distortions.

The dynamic model is derived by assuming that the 1973 benchmark equilibrium lies on a steady state growth path. Observed saving behavior relative to the initial capital endowment implies an annual growth rate for capital n, also attributed to effective labor units. The benchmark sequence of equilibria is then calculated by maintaining all tax rates and preferences fixed, increasing labor exogenously, and allowing saving to augment capital endowments over time.[26] By construction, this sequence will have constant factor ratios and prices all equal to one.

Simulations are performed by altering tax rates appropriately, while retaining preference parameters and the exogenous labor growth rate. Personal tax rate adjustments insure equal yield in the sense that government can make the same real purchases as in the benchmark. Saving and other behaviors conform to the specified elasticities, growth of capital diverges from the steady state rate, and the economy begins to approach a new path with a new capital-labor ratio. Sequences are compared by discounting the H composites of instantaneous consumption, with appropriate terminal conditions. The discount rate is 4 percent, equal to γ, the real after-tax rate of return. This rate reflects the marginal time preference of consumers in the model, but results are sensitive to different values of γ. The welfare gain or loss is the aggregate compensating variation, defined as the number of dollars at new prices that would be required for each consumer to attain the old sequence of consumption.

2. *Factor Demands in the New Model*

In their two-stage production process, firms first minimize the cost of composite capital $(P_K K + P_{Ki} K_i)$ subject to the constraint that $\bar{K}$ in equation (3) is equal to one. The resulting demand functions are

$$R_K = [(P_{Ki}/P_K)^{1-\sigma_K} + 1]^{\sigma_K/(1-\sigma_K)}, \tag{7}$$

25. Producer good prices are based on factor prices and zero profits, while consumer good prices are based on producer good prices through the **Z** transition matrix. A complete set of prices, quantities, incomes, and allocations is calculated for every equilibrium.

26. The model assumes that $25 of saving can purchase a capital asset that will earn one dollar per period net of depreciation and taxes. That is, 0.04 is used for γ, the real after-tax rate of return.

and

$$R_{K_i} = [(P_K/P_{K_i})^{1-\sigma_K} + 1]^{\sigma_K/(1-\sigma_K)}, \tag{8}$$

giving the new and old capital requirements per unit of the $\overline{K}$ composite. Solving for the Lagrangean multiplier in this process gives the appropriate composite price index for capital:

$$\overline{P}_K = [P_K^{1-\sigma_K} + P_{K_i}^{1-\sigma_K}]^{1/(1-\sigma_K)}. \tag{9}$$

In the second stage, firms minimize output costs $(P_L L + \overline{P}_K \overline{K})$ subject to the constraint that Q in equation (2) is equal to one. The resulting factor demand functions are

$$R_L = A^{-1}\left[(1-\alpha)\left(\frac{\alpha\overline{P}_K}{(1-\alpha)P_L}\right)^{1-\sigma} + \alpha\right]^{\sigma/(1-\sigma)}, \tag{10}$$

and

$$R_{\overline{K}} = A^{-1}\left[\alpha\left(\frac{(1-\alpha)P_L}{\alpha\overline{P}_K}\right)^{1-\sigma} + (1-\alpha)\right]^{\sigma/(1-\sigma)}, \tag{11}$$

giving the labor and composite capital requirements per unit of output. These are identical to the standard model except for the bar above the K. It is then simple to obtain the value for K per unit of output as $(R_K R_{\overline{K}})$ and the value for K_i per unit of output as $(R_{K_i} R_{\overline{K}})$. Factor prices also determine producer good prices and endowment incomes as before.

General government does not have an overall production function like that of equation (2), but it does have a final demand for capital based on its own Cobb-Douglas utility function. This structure is easily adapted for sector-specific capital by using the standard model's capital demand functions for $\overline{K}$, using (3) for the breakdown of old and new capital, and using (9) for the government's own composite price index.

As an owner of capital, government is treated like other owners with balanced portfolios. Operationally, after-tax income from the various capital types are added together and distributed among all owners in fixed shares. The consumer share of total capital income is increased by their endogenous net saving over time, while the government share is increased by their exogenous capital accumulation at the steady state rate. An implication is that government owned capital is not just used in the government sector. It is used in all sectors in the proportions that total capital is allocated among the sectors. Similarly, government demand for capital is satisfied by all owners, in the proportions that total capital is held among owners.

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