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Chapter Author: James R. Hines, Jr., R. Glen Hubbard, Joel Slemrod

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5 On the Sensitivity of R&D to Delicate Tax Changes: The Behavior of U.S. Multinationals in the 1980s

James R. Hines, Jr.

The U.S. government has a long-standing interest in encouraging research and development (R&D) by American companies. Congress feels that the common-property nature of the know-how produced by R&D, and the competitive advantage that greater R&D affords U.S. firms in global markets, means that too little R&D is likely to be undertaken by private firms in the absence of strong government support.[1] Concern over the sluggish rate of U.S. productivity growth in the 1970s, combined with alarm over rising foreign competition, led Congress to enact two tax changes in 1981 designed to stimulate R&D.[2] The first, the research and experimentation tax credit, established a 25 percent credit for new research expenditures by U.S. firms. The second change, a suspension of Treasury regulation §1.861-8, offered very generous tax treatment of R&D performed in the United States by certain multinational corporations.

In this paper, I examine the incentives introduced by this second change—the suspension of §1.861-8—and the way that American multinationals re-

James R. Hines, Jr., is associate professor of public policy at the John F. Kennedy School of Government, Harvard University, and a faculty research fellow of the National Bureau of Economic Research.

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1. In theory, the welfare consequences of subsidizing R&D are ambiguous, because some industries might attract too much competitive R&D and the presence of foreign competitors raises the possibility that foreigners could benefit from domestic subsidies (or in other ways influence the domestic market). See Dixit (1988) and Reinganum (1989) for surveys of the theory. The position of the U.S. Congress is that R&D generates significant positive externalities, a view that is consistent with the empirical literature surveyed in Griliches (1991).

2. Congressional sentiment is described in U.S. Congress (1981).

sponded to those incentives. The §1.861-8 rules were modified several times between 1986 and 1990 in a manner that affected only certain firms, so it is possible to infer the effect of the law by observing the responses of different companies to the changes. Based on these results, it appears that American multinationals significantly changed their R&D expenditures in response to tax policy in the 1980s. Nevertheless, the 1981 change may not have had the intended effect of greatly increasing R&D activity in the United States. In part, this may be due to some misunderstandings about the incentives that were embodied in the law prior to 1981 (and in its modifications after 1986).

The U.S. government has yet to settle on a permanent tax policy toward the R&D activities of multinational corporations. Congress enacted temporary changes in the R&D rules in 1984, 1985, 1986, 1988, 1989, and 1990; currently, the political process is at an impasse in which all sides agree that a long-range policy is needed but in which there is no agreement on the policy to pursue. This indecisiveness is due in part to the general complexity of taxing multinational corporations and in part to the difficulty of forging a coherent approach to R&D performed by multinationals. The government would like to encourage R&D, but there is a feeling that some of the benefits of R&D undertaken by U.S. multinationals accrue not to Americans but to foreigners who buy products produced by the R&D (and to foreign governments who tax the proceeds of those sales). These issues are important in designing national R&D policy, since U.S. multinationals perform most of the privately financed R&D in the United States.

There are two reasons why it is instructive to explore the reactions of U.S. multinationals to the tax changes. The first is that these firms reveal the price sensitivity of their demand for R&D by their reactions to the tax changes. There is considerable interest in learning the impact of the cost of R&D on the level of R&D performed, both for its own sake and to identify the effect of other, nonprice, factors such as scientific opportunities on the rate and direction of R&D. The second reason is that, in designing laws to tax their resident multinational corporations, governments must decide on the extent to which to permit firms to deduct general expenses against their own tax bases. R&D is one important category of such expenses, but there are others, such as interest charges and administrative overhead. Greater deductions may encourage more business activity but could do so at the cost of lost tax revenue. By estimating the price responsiveness of R&D, it is possible to learn what tradeoffs are involved in designing policy.

In this paper, I analyze the behavior of a panel of manufacturing firms for which comprehensive data are available on R&D histories and foreign business operations. Due to the peculiarities of the tax code, firms differed in the degrees to which they were affected by the legislative changes after 1986. These differences are based largely on the tax rates they face in foreign countries. As a result, the legislative changes introduced in the 1980s offer a not quite natural experiment by changing the after-tax prices of R&D for a subset of firms that is close to randomly selected. The results suggest that the 1986 and subsequent changes had the predicted effect of discouraging R&D, though not dramatically.

Section 5.1 of the paper reviews some of the history of R&D undertaken by U.S. multinational firms. Section 5.2 summarizes elements of the tax system that are relevant to R&D by U.S. multinationals. Section 5.3 then explores the incentives introduced by U.S. law, and section 5.4 estimates the responsiveness of U.S. firms to those incentives over the period 1984–89. Section 5.5 compares the consequences of current U.S. law to some major alternative tax treatments of R&D. Section 5.6 is the conclusion.

5.1 R&D by U.S. Multinational Firms

The U.S. government's 1981 decision to increase the tax subsidy for R&D performed in the United States is best understood in the context of the relatively weak American R&D performance in the 1970s. Table 5.1 contains data on annual movements in R&D/GNP for the United States, France, West Germany, Japan, and the United Kingdom over the period 1961–87. For the United States, this ratio steadily declined, starting at a value of 2.9 percent in 1965 and finding its nadir at 2.1 percent in 1977–78. Over the same period, France and the United Kingdom were holding steady at their somewhat lower levels of R&D relative to GNP, while West Germany and Japan exhibited growing R&D intensity. Because Congress feels that an erosion in technological leadership is not in the interest of the United States, it is understandable that it was eager to prevent further relative decline in U.S. R&D activity.

Another concern that appears to have motivated Congress is the possibility that U.S. firms would move their R&D operations to offshore locations that offered more attractive tax or regulatory environments. Of course, few low-tax foreign locations offer the scientific infrastructure and proximity to important markets available in the United States. Nevertheless, U.S. firms perform some of their R&D offshore, and it was feared that the foreign share of R&D performed by American companies would rise in the 1980s along with the general trend to globalize U.S. business.

The prediction proved false. The foreign share of R&D performed by U.S. companies, which has never been very large, remained small throughout the 1980s despite the rapid growth of foreign sales by U.S. firms. Figure 5.1 illustrates this pattern.[3] In 1974, R&D performed abroad by foreign affiliates equaled 8.1 percent of the total foreign and domestic R&D expenditures of

3. The data on which fig. 5.1 is based come from a National Science Foundation (1991) survey of virtually all firms in the United States with annual R&D expenditures of $1 million or more. The survey is directed at R&D performed in the United States and, partly for that reason, has a somewhat disappointing response rate to its questions about R&D performed by foreign affiliates. There are other omissions as well. Cohen and Levin (1989) note that R&D reported in Compustat files is 12 percent higher than R&D reported in the NSF survey, and there is a view that the Compustat figures are the more reliable ones. Nevertheless, the NSF surveys cover the foreign R&D undertaken by the largest firms and appear to capture the important aggregate trends in R&D activity.

Table 5.1 **R&D Expenditure as a Percentage of GNP: 1961–1987**

	France	West Germany	Japan	United Kingdom	United States
1961	1.4%	—	1.4%	2.5%	2.7%
1962	1.5	1.2%	1.5	—	2.7
1963	1.6	1.4	1.5	—	2.8
1964	1.8	1.6	1.5	2.3	2.9
1965	2.0	1.7	1.6	—	2.8
1966	2.1	1.8	1.5	2.3	2.8
1967	2.2	2.0	1.6	2.3	2.8
1968	2.1	2.0	1.7	2.2	2.8
1969	2.0	1.8	1.7	2.3	2.7
1970	1.9	2.1	1.9	—	2.6
1971	1.9	2.2	1.9	—	2.4
1972	1.9	2.2	1.9	2.1	2.3
1973	1.8	2.1	2.0	—	2.3
1974	1.8	2.1	2.0	—	2.2
1975	1.8	2.2	2.0	2.1	2.2
1976	1.8	2.1	2.0	—	2.2
1977	1.8	2.1	2.0	—	2.1
1978	1.8	2.2	2.0	2.2	2.1
1979	1.8	2.4	2.1	—	2.2
1980	1.8	2.4	2.2	—	2.3
1981	2.0	2.5	2.3	2.4	2.4
1982	2.1	2.6	2.4	—	2.5
1983	2.1	2.6	2.6	2.2	2.6
1984	2.2	2.6	2.6	—	2.6
1985	2.3	2.8	2.8	2.3	2.7
1986	2.3	2.7	2.8	2.4	2.7
1987	2.3	2.8	2.9	—	2.6

Source: National Science Board (1989).
Note: French data are based on gross domestic product (GNP); consequently, percentages may be slightly overstated, compared to GNP. Omissions (—) indicate that R&D data are unavilable.

U.S. firms. This ratio grew to 9.7 percent by 1979 but fell steadily to 7.2 percent in 1982 and 6.0 percent in 1985. After 1985, the foreign share of R&D rose somewhat but was only 8.5 percent by 1989. U.S. firms chose not to move their R&D operations out of the country *en masse* in the 1980s.

It would be possible to infer from figure 5.1 that tax policy was partly responsible for the movement in the foreign share of R&D undertaken by U.S. companies. The foreign share fell at about the same time that Congress made R&D in the United States more attractive from a tax standpoint, and it rose again after 1986, when some of the tax benefits for R&D in the United States were removed. But foreign exchange rate movements may represent a more compelling explanation of much of the pattern visible in figure 5.1. Using a trade-weighted foreign exchange rate index to measure all foreign and domestic expenditures in 1974 dollars, figure 5.2 presents the ratio of real (using

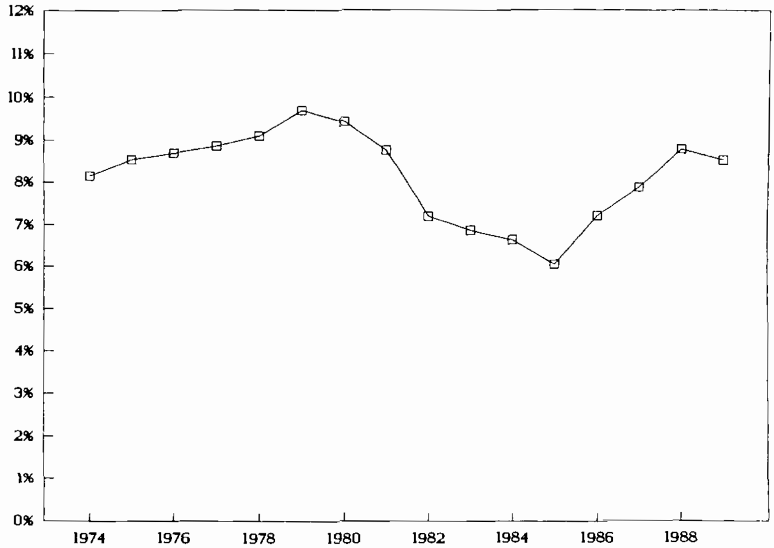

Fig. 5.1 Foreign affiliate R&D share, based on nominal exchange rate

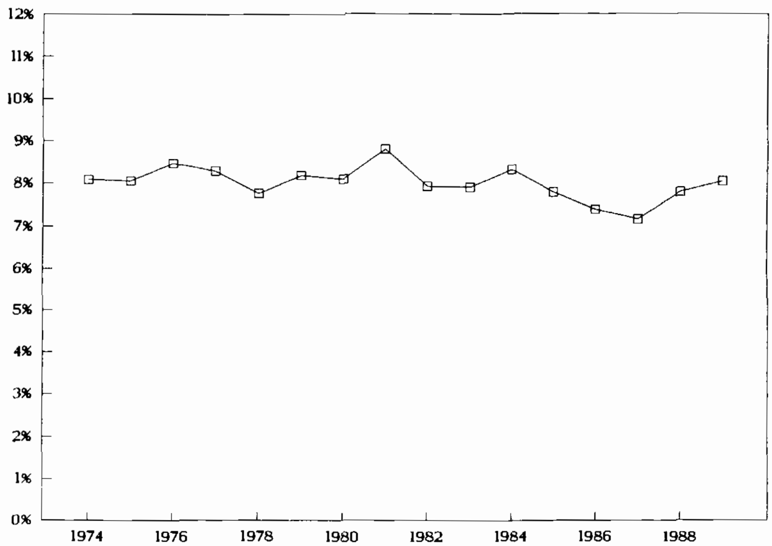

Fig. 5.2 Foreign affiliate R&D share, based on real exchange rate

1974 as the numeraire) foreign to total R&D expenditures. Over the period 1974–89, there is very little movement in this ratio from the 8.1 percent value it took in 1974.

U.S. tax policy may very well have influenced the foreign R&D activities of U.S. firms over the 1974–89 time period but could have done so in ways that were just offset by foreign market conditions (or, for that matter, foreign tax changes). Nevertheless, it is clear from the relative magnitudes involved that U.S. government policy reforms such as those enacted in 1981 and 1986 are likely to induce greater changes in R&D performed by U.S. firms in the United States than in their R&D performed abroad. In order to understand how the incentives U.S. firms face have changed over time, it is helpful to consider the U.S. system of taxing multinational corporations.

5.2 R&D and the Law

This section reviews the tax treatment of R&D by U.S. corporations, with particular emphasis on the tax treatment of firms with international income.

5.2.1 General Treatment of R&D

Expenditures on research and development by firms in the United States are deductible for income tax purposes.[4] Because a firm's stock of R&D usually has the character of a capital good, in that it generates revenues both currently and over a number of future years, immediate expensing of R&D is an attractive tax feature.[5] By contrast, physical capital such as plant and equipment is depreciated for tax purposes and, despite occasional inducements such as the investment tax credit, has always been tax-disfavored relative to R&D.[6] Generally speaking, the effective rate of tax on R&D is zero, because firms will choose R&D expenditures that equate the (after-tax) marginal product of R&D to the (after-tax) cost of R&D. Because the same tax rate applies to both the marginal product of R&D and the marginal cost, the tax rate should not influence the level of R&D.

The research and experimentation (R&E) credit was introduced in 1981 to

4. An exception is that expenditures for the acquisition or improvement of depreciable property, or land, used in conjunction with research are not deductible. Assets other than land can be depreciated for tax purposes at rapid rates. For example, the Tax Reform Act of 1986 classifies equipment used for research as five-year recovery property. Special rules apply to certain industries.

5. Ravenscraft and Scherer (1982) find that the profitability of the firms in their sample appeared to be influenced by R&D expenditures lagged four to six years. Griliches and Mairesse (1984) estimate firm productivity to be a function of the stock of accumulated R&D capital, which they take to depreciate at a rate of 15 percent per year. In their study of patent renewals, Pakes and Schankerman (1984b) find evidence of a somewhat higher depreciation rate for R&D capital, 25 percent per year, but one that is much below the 100 percent rate that is implied in the tax law.

6. See Auerbach (1983) for a historical survey of the effective tax rates on investments in plant and equipment. The relative attractiveness of the immediate expensing of R&D expenditures is the basis of Fullerton and Lyon's (1988) estimates of the efficiency cost of "excessive" R&D (relative to investments in tangible capital) in the United States.

stimulate additional R&D activity in the United States.[7] The R&E credit initially offered a 25 percent tax credit for R&D expenditures above a base level determined by the average of a firm's previous three years' worth of R&D expenditures. The idea behind the design of the credit was to offer an incentive for marginal research activities, but one that did not subsidize inframarginal research. Of course, in practice, matters are not so simple, and the R&E credit can often have the perverse effect of discouraging research and development or of providing only trivial incentives to undertake marginal R&D, because by undertaking additional R&D activities today a firm may reduce the credit it would otherwise receive in future years. Furthermore, various limits built into the credit reduce the incentive it provides in certain cases.[8]

The R&E credit came under fire from various arguments that implied that it was not a cost-effective way of stimulating R&D.[9] Partly in response, the Tax Reform Act of 1986 reduced the R&E credit to 20 percent and tightened some of the definitions of R&D eligible for the credit. The 1988 tax act further reduced the subsidy afforded by the R&E credit by making half of the credit amount taxable income, and the 1989 tax act made the credit amount 100 percent taxable. In addition, the 1989 act changed the way that the base was calculated, so that, starting in 1990, additional R&D expenditure in one year does not reduce a firm's tax credit in subsequent years. The R&E tax credit limped through the 1980s on the basis of temporary extensions (in 1986, 1988, 1989, and 1990) that may have strengthened its impact by introducing uncertainty about whether any credit at all would be available in the future, but the credit seems unlikely to have had an important effect on overall R&D activities. More important for the present study, the R&E credit was available to all firms without regard to their foreign activities (indeed, offshore R&D was ineligible for the credit). In order to analyze those tax changes in the 1980s that did influence firms on the basis of their foreign activities, it is necessary to consider some of the international features of the U.S. tax system.[10]

7. There are some small distinctions between activities that qualify for the R&E credit and R&D that is deductible but must be allocated according to §1.861-8. The Tax Reform Act of 1986 tightened the definition of R&D that is eligible for the tax credit.

8. For example, R&D expenditures in excess of 200 percent of the base amount are eligible for only half the credit rate, even though they raise the base for future years. Furthermore, firms must have taxable profits (or the potential to carry credits forward or back against taxable profits) to benefit from the credit. See Eisner, Albert, and Sullivan (1984) and Altshuler (1988) for analyses of the effective rates of subsidy provided by the R&E credit. Eisner, Albert, and Sullivan estimate the average effective credit rate for 1981 to be zero and for 1982 to be 4 percent. Altshuler, using a slightly different methodology, finds the effective credit rate for 1981 to be between 1 percent and 2 percent.

9. See, for example, Mansfield (1986), who argues that the R&E credit had only a very small effect on R&D in the United States and that it reduced tax collections by an amount equal to three times the additional R&D it generated. Wozny (1989) and the U.S. General Accounting Office (1989) report similar findings for a GAO-conducted study of the R&E credit.

10. Parts of the following brief description of the tax system are excerpted from Hines (1990).

5.2.2 U.S. Taxation of Foreign Income

The United States taxes income on a "residence" basis, meaning that U.S. corporations and individuals owe taxes to the U.S. government on all of their worldwide income, whether earned in the United States or not. Because foreign profits are usually taxed in host countries, U.S. law provides a foreign tax credit for income taxes (and related taxes) paid to foreign governments, in order not to subject U.S. multinationals to double taxation. With the foreign tax credit, a U.S. corporation that earns $100 in a foreign country with a 12 percent tax rate (and a foreign tax obligation of $12) pays only $22 to the U.S. government, because its U.S. corporate tax liability of $34 (34 percent of $100) is reduced to $22 by the foreign tax credit of $12. The foreign tax credit is, however, limited to U.S. tax liability on foreign income. If, in the example, the foreign tax rate were 50 percent, then the firm pays $50 to the foreign government, but its U.S. foreign tax credit is limited to $34. Hence, a U.S. firm receives full tax credits for its foreign taxes paid only when it is in a "deficit credit" position—that is, when its average foreign tax rate is less than its tax rate on domestic operations. A firm has "excess credits" if its available foreign tax credits exceed U.S. tax liability on its foreign income.[11] Firms average together their taxable incomes and taxes paid in all of their foreign operations in calculating their foreign tax credits and the foreign tax credit limit.

Deferral of U.S. taxation of certain foreign earnings is another important feature of the U.S. international tax system. A U.S. parent firm is taxed on its subsidiaries' foreign income only when that income is returned ("repatriated") to the parent corporation. This type of deferral is available only to foreign operations that are separately incorporated in foreign countries ("subsidiaries" of the parent) and not to consolidated ("branch") operations. The U.S. government taxes branch profits as they are earned, just as it would profits earned within the United States.

The deferral of U.S. taxation may create incentives for firms with lightly taxed foreign earnings to delay repatriating dividends from their foreign subsidiaries.[12] This incentive arises in those cases in which firms expect never to repatriate their foreign earnings or anticipate that future years will be more

11. Furthermore, income is broken into different functional "baskets" in the calculation of applicable credits and limits. In order to qualify for the foreign tax credit, firms must own at least 10 percent of a foreign affiliate, and only those taxes that qualify as income taxes are creditable.

12. The incentive to defer repatriation of lightly taxed subsidiary earnings is attenuated by the Subpart F provisions, introduced in U.S. law in 1962, that treat a subsidiary's passive income, and income invested in U.S. property, as if it were distributed to its U.S. owners, thereby subjecting it to immediate U.S. taxation. The Subpart F rules apply to controlled foreign corporations, which are foreign corporations owned at least 50 percent by U.S. persons holding stakes of at least 10 percent each. Controlled foreign corporations that reinvest their foreign earnings in active businesses can continue to defer their U.S. tax liability on these earnings. See Hines and Rice (1990) and Scholes and Wolfson (1991) for the behavioral implications of these rules.

attractive for repatriation (either because domestic tax rates will be lower or because future sources of foreign income will generate excess foreign tax credits that can be used to offset U.S. tax liability on the dividends).[13] It appears that, in practice, U.S. multinationals choose their dividend repatriations selectively, and they generally pay dividends out of their more heavily taxed foreign earnings first.[14] Consequently, the average tax rate that firms face on their foreign income need not exactly equal the average foreign tax rate faced by their branches and subsidiaries abroad.

Branch earnings and dividends from subsidiaries represent only two forms of foreign income for U.S. income tax purposes. Interest received from foreign sources also represents foreign income, although foreign interest receipts are often classified within their own basket and hence are not averaged with other income in calculating the foreign tax credit. Royalty income received from foreigners, including foreign affiliates of U.S. firms, is also foreign-source income. Foreign governments often impose moderate taxes on dividend, interest, and royalty payments from foreign affiliates to their U.S. parent companies; these withholding taxes are fully creditable against a U.S. taxpayer's U.S. tax liability on foreign income.

5.2.3 Interaction of R&D and Foreign Income Rules

U.S. firms with foreign income are generally not permitted to deduct all of their R&D expenditures in the United States against their domestic taxable incomes. Instead, the law provides for various methods of allocating R&D expenses between domestic and foreign income. The intention of the law is to retain the relatively generous treatment of R&D, but only for that part of a firm's R&D expenditures that is devoted to production for domestic markets. R&D-performing firms with foreign sales and foreign income are presumed to be doing at least some of their R&D to enhance their foreign profitability.

From the standpoint of taxpaying firms, the U.S. tax law's distinction between domestic and foreign R&D deductions is potentially quite important. If an R&D expense is deemed to be domestic, then it is deductible against the taxpayer's U.S. taxable income. Alternatively, if it is deemed to be foreign, then the R&D expense reduces foreign taxable income *for the purposes of U.S. income taxation only.* Foreign governments do not use U.S. methods of calculating R&D deductions and generally do not permit U.S. firms to reduce their taxable incomes in foreign countries on the basis of R&D undertaken in the United States. Consequently, an R&D expense deduction allocated against foreign income is valuable to a U.S. firm only if it has deficit foreign tax credits. If it does have deficit credits, then some of the firm's foreign income is subject to U.S. tax, and any additional dollar of R&D deduction allocated

13. The deferral of U.S. tax liability does not itself create an incentive to delay paying dividends from foreign subsidiaries, because the U.S. tax must be paid eventually. See Hartman (1985).

14. See the evidence presented in Hines and Hubbard (1990).

against foreign income reduces the firm's U.S. taxable income by a dollar.[15] With deficit credits, firms are indifferent between allocating R&D expenses against foreign income and allocating it against domestic income.[16] If, on the other hand, firms have excess foreign tax credits, then R&D expense allocated against foreign income does them no good, since foreign income generates no U.S. tax liability anyway.

The tax law governing the allocation of R&D expenses was for years rather vague but was codified by U.S. Treasury regulation §1.861-8 in 1977. The 1977 rules provide for several stages in allocating R&D expenditures for tax purposes. R&D in the U.S. that is undertaken to meet certain legal requirements (such as R&D devoted to meeting pollution standards) can be 100 percent allocated against domestic income. Firms that perform more than half of their (other than legally required) R&D in the United States are permitted to allocate 30 percent of that R&D against U.S. income. The remaining 70 percent is then to be allocated between domestic and foreign sources on the basis of sales (including the sales of controlled foreign corporations). R&D is generally allocated according to activities within product lines (defined similarly to two-digit SIC codes), so that a corporation need not allocate part of its chemical R&D against foreign income simply because the electronics part of its business has foreign sales.

There are several options available to taxpayers who are unsatisfied with the outcome of the R&D allocation method just described. Firms are permitted to apportion more than 30 percent of their domestic R&D against U.S. income if they can establish that it is reasonable to expect the R&D so apportioned to have very limited application outside of the country; the remaining portion of the R&D expenses are then allocated on the basis of sales. Alternatively, firms are permitted to allocate their R&D on the basis of total foreign and domestic income (though without the 30 percent initial allocation to U.S. source) so that firms with foreign operations that generate sales but not income (relative to domestic operations) might prefer the income allocation method. There is, however, a limit to the income allocation method: firms are not permitted to reduce their R&D allocation to foreign source to less than 50 percent of the allocation that would have been produced by the sales method (including the 30 percent initial apportionment).

The Economic Recovery Act in 1981 changed these rules by permitting U.S. firms to allocate 100 percent of their R&D performed in the United States against U.S. income. This change was intended to be temporary (two years) in order to offer strong R&D incentives while affording Congress the

15. Curiously, the law is written so that the additional dollar of R&D deduction reduces taxable income without reducing the foreign tax credits available for foreign income taxes paid.

16. This statement, along with much of the analysis described in the paper, abstracts from the ability of firms to carry excess foreign tax credits backward two years and forward five years. Firms that can exploit carryforwards or carrybacks may (depending on specific circumstances) face incentives that are intermediate between those of deficit credit and excess credit firms.

opportunity to rethink its R&D policy. At the end of that time, the U.S. Department of the Treasury (1983) produced a study concluding that the tax change offered a small R&D incentive to U.S. firms and was desirable on that basis.[17] In 1984 and 1985, Congress extended the temporary change permitting 100 percent deductibility of U.S. R&D expenses against U.S. income, so these rules remained in place until the end of the 1986 tax year.

The Tax Reform Act of 1986 removed the 100 percent deductibility of U.S. R&D expenses, replacing it with a new, and again temporary, system of R&D expense allocation.[18] Under the act, 50 percent of U.S. R&D expenses (other than for R&D to meet regulations, which were 100 percent allocated to domestic source) were allocated to domestic source, with the remaining 50 percent allocated on the basis of sales or of income, at the taxpayer's choice. There was no limit imposed on the degree to which allocation on the basis of gross income could reduce foreign allocation relative to the sales method. These rules, it turned out, were in effect only for 1987.

The Technical and Miscellaneous Revenue Act of 1988 greatly complicates the analyst's task of understanding the incentives to undertake R&D in 1988. For the first four months of the year, firms were permitted to allocate 64 percent of U.S. R&D expenses against U.S. domestic income, with the remaining 36 percent allocated between foreign and domestic sources on the basis of either sales or income (at the taxpayer's choice). The 1988 act further provides that if the 36 percent were allocated on the basis of income, then the R&D allocation against foreign income must equal at least 30 percent of the foreign allocation that would have been produced by the sales method. For the remaining eight months of the year, taxpayers were required to use the allocation method set forth in §1.861-8 as of 1977 (and described above).

The Omnibus Budget Reconciliation Act of 1989 again changed the R&D allocation rules, this time reintroducing the same rules that applied for the first four months of 1988. A temporary extension in 1990 extended this treatment of R&D through 1991. Consequently, 64 percent of domestically performed R&D in 1989–91 can be allocated against domestic income, with the remaining 36 percent allocated on the basis either of sales or of income (though income allocation to foreign source must not be less than 30 percent of what the sales allocation would have been).

It would be difficult not to conclude from this brief history of the R&D

17. The Treasury study based its conclusions on a range of assumed elasticities of R&D with respect to price changes; there was no attempt made to ascertain how firms responded to the changes introduced in 1981. The study is a very careful analysis of firm-level tax return data and the significant issues involved in the §1.861-8 change. On the other hand, the study uses the average price reduction introduced by the 1981 tax law change, rather than the changes in marginal prices of R&D and other inputs, to estimate the effects of the law.

18. The Tax Reform Act of 1986 also introduced a number of other changes relevant to R&D investment decisions, including reducing the statutory corporate tax rate from 46 percent (the rate from 1979 to 1986) to 40 percent in 1987 and 34 percent for 1988 and subsequent years. The 1986 act also removed a number of investment incentives such as accelerated depreciation of capital assets and the investment tax credit for new equipment purchases.

expense allocation rules that they are intricate, confusing, and subject to frequent changes. For the purpose of analyzing the effects of legislative changes, however, we can discern a clear pattern. All U.S. firms could deduct their R&D expenses against domestic income from 1981 to 1986. Starting in 1987, multinational firms with excess foreign tax credits have been able to use only some of their R&D deductions, because part is allocated against foreign income (and thereby does not reduce their overall tax liabilities). For firms with deficit foreign tax credits, however, the period since 1987 is just as attractive as 1981–86; even though some of their R&D expenses are allocated against foreign income, this foreign allocation reduces their U.S. tax liabilities by just as much as would an allocation against domestic income.

5.3 Some Curious Incentives

The incentives built into current and proposed tax treatments of R&D are rather complicated and require some elaboration. In this section, in order to simplify matters, I focus on the allocation rules governing R&D (§1.861-8 and its temporary modifications) and not on the R&E credit.

It is helpful to separate the research activities of multinationals into three types in order to isolate the incentives for each. The first type is R&D performed in the U.S. that generates only domestic sales and income. The second type is R&D undertaken in the U.S. that generates only foreign sales and income. The third type is the offshore R&D activities of U.S. multinationals. There is no doubt that this separation is somewhat artificial in that the same R&D project often generates both foreign and domestic income; for that matter, firms frequently undertake R&D without complete knowledge of what kind of output will result, much less whether the ensuing sales will occur in the United States or abroad. Nevertheless, the incentives for each type of R&D can differ significantly, and it clarifies the analysis to divide projects this way.

5.3.1 Domestic R&D for Domestic Markets

The first type of R&D is a major source of concern among critics of the §1.861-8 system of allocation. The fear is that by allocating a fraction of new R&D expenditures against foreign income, the law may discourage domestic R&D intended for domestic markets.

To evaluate this argument, consider the behavior of a profit-maximizing firm with domestic sales that are a function of its variable inputs (I) and its R&D expenditures devoted to products sold domestically (R). For the time being, consider the case in which this domestic R&D does not influence the firm's foreign profitability and in which domestic sales are unaffected by foreign R&D. Let R_f denote the domestic R&D that the firm undertakes to generate foreign sales and $\underline{R}$ the firm's total domestic R&D (so that

$R + R_f = \underline{R}$). The domestic sales function is $S(R, I)$. The firm's after-tax profits from its domestic operations equal[19]

$$(1) \qquad [S(R, I) - I - R - \pi R\tau/(1 - \tau)]\,(1 - \tau)\,,$$

in which τ is the domestic tax rate facing the firm and π represents the fraction of the firm's domestic R&D expenditures that is not deductible against domestic taxes. If the firm has deficit foreign tax credits, then $\pi = 0$ under the tax systems in effect during the 1980s. Suppose instead that the firm has excess foreign tax credits, and let $(1 - \alpha)$ denote the fraction of a firm's R&D that is immediately allocated against domestic income, with the remaining α allocated on the basis of domestic and foreign sales. Denote foreign sales by S^*. Then $\pi = \alpha S^*/(S + S^*)$. The firm's first-order condition that corresponds to maximizing equation (1) over the choice of R is

$$(2) \qquad \partial S/\partial R - 1 - \pi\tau/(1 - \tau) - (\partial\pi/\partial R)\underline{R}\tau/(1 - \tau) = 0\,.$$

The corresponding first-order condition for the choice of I is

$$(3) \qquad \partial S/\partial I - 1 - (\partial\pi/\partial I)\underline{R}\tau/(1 - \tau) = 0\,.$$

And the derivatives of the allocation function (π) are

$$(4) \qquad \partial\pi/\partial R = -\alpha(\partial S/\partial R)S^*/(S + S^*)^2$$

and

$$(5) \qquad \partial\pi/\partial I = -\alpha(\partial S/\partial I)S^*/(S + S^*)^2\,.$$

Combining (2) and (4) yields

$$(6) \qquad \frac{\partial S}{\partial R} = \frac{1 - \tau\left[1 - \dfrac{\alpha S^*}{(S + S^*)}\right]}{1 - \tau\left[1 - \dfrac{\alpha \underline{R} S^*}{(S + S^*)^2}\right]} \equiv PR\,,$$

in which PR is the after-tax cost of domestic R&D. Equations (3) and (5) together yield

19. The distinction between the domestic and foreign source of profits is somewhat arbitrary, because the output of an R&D project may contribute to domestic and foreign profits and even the firms undertaking the R&D project might not know in advance whether domestic or foreign markets will be more suitable for the product ultimately produced. Nevertheless, the tax incentives for the two types of projects differ significantly, and if firms are able to estimate the likely location of the future sales generated by their R&D, then R&D should be sensitive to this difference. As a more minor matter, it is not quite correct to describe the profit-maximizing choice of R by differentiating (1), since R also affects (through its impact on S) the allocation (π) of deductions for R_f (because the same π applies to both R and R_f). This complication is the reason that $\underline{R}$, rather than R, appears in (2), (3), (6), (7), (9), (10), (13), and (14).

$$\frac{\partial S}{\partial I} = \frac{1 - \tau}{1 - \tau\left[1 - \frac{\alpha \underline{R} S^*}{(S + S^*)^2}\right]} \equiv PI . \tag{7}$$

There are two notable features of the first-order conditions (6) and (7). The first is that the marginal product of R&D, which equals the right side of (6), exceeds one as long as the ratio $\underline{R}/(S + S^*)$ is less than one. This value reflects the direct effect of the allocation rule in discouraging domestic R&D by permitting only a fraction of it to be deducted against domestic taxable income. As a consequence, the required return on a dollar of marginal R&D is higher than it would be in the absence of taxation.

The second feature of equations (6) and (7) is that the marginal product of variable inputs other than R&D—*PI* in equation (7)—is always less than one. The reason is that the R&D allocation rule encourages the use of ordinary domestic inputs to generate domestic sales, since greater domestic sales permit a higher fraction of the firm's inframarginal R&D to be allocated against domestic income. This effect is greater, the larger is $\underline{R}/(S + S^*)$. In practice, $\underline{R}/(S + S^*)$ takes a value of something like 4 percent.

It is likely that this second effect—the subsidy to ordinary domestic inputs—encourages domestic R&D and has such an impact that it partly undoes the first, more direct, effect on the level of R&D. The reason is that ordinary inputs and R&D are likely to be complementary in the firm's production function, so that a subsidy to one indirectly encourages the use of the other. The subsidy to ordinary inputs operates through the level of inframarginal R&D, while the direct tax on R&D operates through its effect on the marginal product of R&D. The more R&D-intensive a firm's operations are, the more of an incentive the firm faces to expand its domestic operations in order to allocate a high fraction of that R&D against domestic taxable income. If the firms with greater R&D intensity are also those firms with the most total R&D, then the tax rules might have the effect of not discouraging R&D to the degree that a simple calculation based on the fraction deductible might suggest.[20]

5.3.2 Domestic R&D for Foreign Markets

The analysis so far has addressed the incentives to undertake domestic R&D intended to stimulate sales in domestic markets. Of course, part of the premise of §1.861-8 and other legislation is that multinational firms doing R&D in the United States are able to use the fruits of that R&D to stimulate the profitability of their foreign business operations. This section considers the incentives created by the allocation rules in such a case.

20. A third feature of (6) and (7) is that the marginal products of R&D and of other inputs are endogenously determined, since $\underline{R}$ and S are elements of (6) and (7). As a consequence, it is not correct to treat *PR* and *PI* as exogenous tax prices of R&D and other inputs unless instruments are available for $\underline{R}$ and S. The difficulty is that an hypothesized linear relationship between R and *PR* becomes nonlinear once it is acknowledged that *PR* is a function of $\underline{R}$. The small magnitude of $\underline{R}/(S + S^*)$ may, however, make linearization with an instrument acceptable in practice.

Let $S^*(R_f, I^*)$ denote the firm's foreign sales function, in which R_f represents domestic R&D performed to stimulate foreign sales and I^* represents ordinary foreign inputs. Suppose that the firm operates its foreign sales through foreign subsidiaries that are required to remit to their U.S. parent firms royalties equal to the value of the R&D that generates their sales. If the royalties are calculated on the basis of arm's-length prices, as U.S. and almost all foreign laws provide,[21] then the subsidiary should retain, after royalties, just enough of its sales revenue to cover the cost of its expenditures on I^*. All of the profits on foreign sales are returned as royalties and are subject to withholding taxes imposed at rate w^* by the foreign country. If the U.S. firm has excess foreign tax credits, then this withholding tax is the only tax it pays on the profits generated by its foreign sales. If, instead, the firm has deficit foreign tax credits, then the royalties generate a tax liability to the U.S. government (and the withholding taxes generate a foreign tax credit), so foreign profits are effectively taxed at the domestic tax rate. In the case of a firm with excess foreign tax credits, its objective is to maximize[22]

$$(8) \qquad \{[S^*(R_f, I^*) - I^*](1 - w^*)\} - (1 - \tau)R_f - \pi R_f \tau .$$

The firm's first-order condition over the choice of R_f is

$$(9) \qquad (1 - w^*)\partial S^*/\partial R_f - (1 - \tau + \pi\tau) - (\partial\pi/\partial R_f)\underline{R}\tau = 0 ,$$

and the corresponding first-order condition over the choice of I^* is

$$(10) \qquad (1 - w^*)(\partial S^*/\partial I^* - 1) - (\partial\pi/\partial I^*)\underline{R}\tau = 0 .$$

R&D deductions are allocated in the same way for R_f as they are for R, so $\pi = \alpha S^*/(S + S^*)$, and the derivatives of the allocation function are

$$(11) \qquad \partial\pi/\partial R_f = \alpha(\partial S^*/\partial R_f)S/(S + S^*)^2$$

and

$$(12) \qquad \partial\pi/\partial I^* = \alpha(\partial S^*/\partial I^*)S/(S + S^*)^2 .$$

Combining (9) and (11) yields

$$(13) \qquad \frac{\partial S^*}{\partial R_f} = \frac{1 - \tau\left[1 - \dfrac{\alpha S^*}{(S + S^*)}\right]}{1 - w^* - \dfrac{\tau\alpha\underline{R}S}{(S + S^*)^2}} \equiv PR^* ,$$

21. Of the twenty-five industrialized countries surveyed by Lawlor (1985), twenty-four applied to the arm's length principle to the taxation of related-party transactions; Hong Kong was the exception.

22. If, instead, the firm has deficit foreign tax credits, then expression (8) must be modified by setting $\pi = 0$ and $w^* = \tau$. It is then straightforward to show that, with deficit foreign tax credits, the tax prices PR^* and PI^* both equal one.

in which PR is the after-tax cost of domestic R&D. Equations (10) and (12) together imply

$$(14) \qquad \frac{\partial S^*}{\partial I^*} = \frac{1 - w^*}{1 - w^* - \dfrac{\tau\alpha \underline{R} S}{(S + S^*)^2}} \equiv PI^* .$$

There are several differences between the tax-induced incentives to undertake domestic R&D generating foreign sales—as revealed by (13) and (14)—and those for domestic R&D directed at domestic sales. The term w^* in the denominator of (13) reflects the extremely generous treatment of royalty exports by U.S. firms with excess foreign tax credits. Royalty income is considered to have foreign source under U.S. law. Hence, if a U.S. firm has excess foreign tax credits, it can use the credits to eliminate its U.S. tax liability on the royalty income. As a result, the firm is subject only to whatever withholding taxes are imposed by foreign governments on royalties paid to the United States. At the same time, the firm can deduct a considerable fraction of its U.S. R&D expenditures against its taxable U.S. income.

In practice, the withholding tax rates applied to royalties remitted to U.S. firms are, on average, very low. Table 5.2 lists the withholding rates charged by twenty-one other major countries on royalty payments to the U.S. in 1990. Many of these countries do not impose any withholding tax at all, and the average withholding tax rate, calculated using weights based on 1984 royalties, is 4.9 percent.

Domestic R&D directed at foreign markets is therefore very lightly taxed but is not favorably treated by the R&D expense allocation rules after 1986. The allocation rules are responsible for the third term in the numerator of (13), which increases the numerator, and the third term in the denominator of (13), which decreases the denominator, relative to a system of 100 percent domestic deductibility. Consequently, the required marginal product of domestic R&D for foreign markets is higher than it would be under 100 percent domestic allocation. Similarly, the system of less than 100 percent domestic deductibility reduces the denominator of (14), raising the required before-tax marginal product of ordinary foreign inputs for the same output.[23] As a result, for firms with excess foreign tax credits, the tax law after 1986 can be expected to discourage R&D directed at foreign markets, relative to the incentives those firms enjoyed prior to 1986. It is interesting to note, however, that after 1986 domestic R&D directed at foreign markets may still be subsidized by the U.S.

23. Equation (14) indicates that foreign inputs have required marginal products that exceed one, since the foreign sales they generate raise π and thereby reduce domestic R&D tax deductions. The firm forgoes some foreign profits in order to keep π down. The specification of (8) assumes that in losing foreign profits the firm also reduces the royalty it must pay; if, instead, the royalty is set by the amount that an unaffiliated firm (with the same production function) would pay to exploit R_f, then the firm's maximand will change slightly, and (14) will appear with τ^* in place of w^* in both the numerator and the denominator.

Table 5.2 Withholding Tax Rates on Royalties Paid to the United States

Country	1990 Tax Rate	1984 Royalties ($ millions)
Argentina	36%	$ 68.3
Australia	10	297.6
Austria	0	48.1
Belgium	0	170.9
Brazil	0	56.6
Canada	10	818.1
Finland	5	50.0
France	5	642.0
Germany	0	722.2
Hong Kong	0	42.5
Ireland	0	46.1
Italy	10	372.5
Japan	10	1,213.8
Korea	15	48.4
Netherlands	0	326.4
New Zealand	10	42.3
Norway	0	1,236.4
Singapore	31	49.9
Spain	10	108.9
Switzerland	0	138.0
United Kingdom	0	1,022.6

Sources: Price Waterhouse (1991); Mose (1989/1990).

tax system even for excess credit firms, since (13) is likely to take a value well below one (though [14] will exceed one).

Foreign R&D by U.S. Firms

There remains the issue of R&D performed by U.S. firms in foreign countries. R&D preformed abroad is generally subject to foreign tax rules (as well as U.S. rules for purposes of U.S. income taxation). Because foreign tax rates and tax rules pertaining to R&D were changing at the same time that U.S. law changed, it is difficult to summarize even the direction taken by the incentives for U.S. firms to do R&D offshore. To make matters worse, firm-level data on R&D performed abroad are not available. Consequently, the remainder of this study avoids specific consideration of the incentives U.S. firms have to undertake R&D abroad, noting that aggregate offshore R&D is small relative to domestic R&D and taking as a working assumption that foreign R&D grows at a steady rate that is unaffected by events in the United States.

5.4 Behavior of U.S. Firms

This section evaluates the responses of U.S. firms to changes in the R&D allocation rules over the period 1984–89, using the framework sketched in section 5.3.

5.4.1 Incentives

In order to determine how firms responded to the tax changes after 1986, it is helpful to outline a simple structure for their production relationships. Consider a firm i with a production function that generates sales as a Cobb-Douglas function of its R&D and ordinary inputs (including labor and capital). Such a function looks thus:

$$(15) \qquad S_{it}(R_{it}, I_{it}) = R_{it}^{\gamma} I_{it}^{\mu} \exp(\phi_t + \psi_i + u_{it}) ,$$

in which ϕ_t is a parameter common to all firms in period t, ψ_i is a fixed effect for firm i, and u_{it} is a normally distributed error term. Differentiating (15) with respect to R and I and imposing (6) and (7) yields

$$(16) \qquad \ln(R_{it}) = (1 - \mu - \gamma)^{-1} [\phi_t + \psi_i + (1 - \mu)\ln(\gamma) + \mu\ln(\mu) - (1 - \mu)\ln(PR) - \mu\ln(PI) + u_{it}] .$$

Equation (16) indicates that the level of R&D a firm will choose is a negative function of the tax price of R&D and a negative function of the tax price of other inputs.[24] The relative magnitude of the effects of these two prices depends on the size of μ, which reflects the contribution of inputs other than R&D to firm sales. Griliches (1986) estimates a cross-sectional relationship for the years 1967, 1972, and 1977 in which firm value added is a Cobb-Douglas function of inputs including R&D, finding the share of other inputs, μ in (16), to range between 0.8 and 0.9. Jaffe (1988) obtains similar results with sales on the left side and using within-firm changes in inputs from 1972 to 1977 to estimate production parameters (including technological spillovers from other firms as an input). Given that the relationship in (15) is specified in terms of sales and not value added, one might expect the relative difference between the coefficients on PR and PI to be on the high side of this range, around 1:9.[25]

24. As written, equation (16) expresses the demand for R&D as a function of tax prices (PR and PI) only. It is also true that movements in the real market prices of inputs and outputs should be expected to influence a firm's desired R&D. Relative prices of R&D inputs are notoriously difficult to measure (for an important attempt, see Mansfield, Romeo, and Switzer 1983), as are output prices. If relative price movements are similar for all multinational firms, however, then this effect is likely to be captured by the year constant ϕ_t.

25. In separate cross-sectional production function regressions (not elsewhere reported) on the subset of firms in my sample reporting total labor expenses (amounting to fifty-two firms in the 1986 sample), the 1986 results were

$$\ln(S + S^*) = \underset{(0.13)}{1.39} + \underset{(0.04)}{0.28} \ln(CG) + \underset{(0.06)}{0.35} \ln(L) + \underset{(0.05)}{0.28} \ln(PPE) + \underset{(0.04)}{0.07} \ln(RD) \quad R^2 = 0.983 ,$$

in which L is labor expense; PPE is book property, plant, and equipment; RD is the firm's R&D stock in 1986; and CG represents the accounting entry "cost of goods sold," minus the other inputs

Suppose that the same firm i also generates its foreign sales by a Cobb-Douglas function of R&D devoted to foreign products and other foreign inputs. Such a function looks like:

$$(17) \qquad S^*_{it}(R_{fit}, I^*_{it}) = R_{fit}^{\gamma^*} I_{it}^{\mu^*} \exp(\phi^*_t + \psi^*_i + u^*_{it}) ,$$

and when differentiated and combined with (13) and (14) it yields

$$(18) \qquad \ln(R_{fit}) = (1 - \mu^* - \gamma^*)^{-1}[\phi^*_t + \psi^*_i + (1 - \mu^*)\ln(\gamma^*) + \mu^*\ln(\mu^*) - (1 - \mu^*)\ln(PR^*) - \mu^*\ln(PI^*) + u^*_{it}] .$$

Unfortunately, (16) and (18) cannot be estimated directly, because even though $\underline{R}$ is observable it is not possible to observe its components R_{it} and R_{fit} separately. Taking antilogs of (16) and (18) and adding them does produce an equation specified in terms of observable variables but, in doing so, removes some of the attractive linearity of the system. An alternative approximation is available that maintains the linearity of the system for those cases in which R_f is not too large relative to R. Assume that this is the case. Then, from the definition of $\underline{R}$,

$$(19) \qquad \underline{R}_{it} = R_{it} + R_{fit} = R_{it}(1 + R_{fit}/R_{it}) .$$

Taking logs and using a first-order Taylor approximation,

$$(20) \qquad \ln(\underline{R}_{it}) \approx \ln(R_{it}) + R_{fit}/R_{it}$$

Taking period zero to be the base period in a short panel, the ratio on the right side of (20) can be written

$$(21) \qquad R_{fit}/R_{it} = \{R_{fi0}[1 + (R_{fit} - R_{fi0})/R_{fi0}]\}/\{R_{i0}[1 + (R_{it} - R_{i0})/R_{i0}]\} ,$$

and for small differences over time it becomes

$$(22) \qquad R_{fit}/R_{it} \approx (R_{fi0}/R_{i0})(1 + (R_{fit} - R_{fi0})/R_{fi0} - (R_{it} - R_{i0})/R_{i0}) .$$

Then, using the approximation that $(R_{it} - R_{i0})/R_{i0} \approx \ln(R_{it}) - \ln(R_{i0})$, (22) becomes

$$(23) \qquad R_{fit}/R_{it} \approx (R_{fi0}/R_{i0})[1 + \ln(R_{fit}) - \ln(R_{fi0}) - \ln(R_{it}) + \ln(R_{i0})] .$$

Combining (23) and (20),

$$(24) \qquad \ln(\underline{R}_{it}) \approx 1 - (R_{fi0}/R_{i0}) \ln(R_{it}) + (\underline{R}_{fi0}/R_{i0}) \ln(R_{fit}) + \theta_i ,$$

in which θ_i is a firm-specific constant equal to (R_{fi0}/R_{i0}) $[1 + \ln(R_{i0}) - \ln(R_{fi0})]$. Combining (24), (16), and (18) then yields

included in the regression. Similar regressions on other years and with different specifications produced similar results. Although cross-sectional results based on accounting data should be viewed skeptically (because firm-specific factors are obscured and the regression is subject to the problem noted by Schankerman [1981], that many of the R&D inputs are included among other right-side variables and consequently double counted), they suggest that it is not unreasonable to expect μ to take a value around 0.9.

$$(25)\quad \ln(\underline{R}_{it}) = \lambda_t + \eta_i + \xi_t\nu_i + \beta_1(1 - \nu_i)\ln(PR) + \beta_2(1 - \nu_i)\ln(PI) + \beta_3\nu_i\ln(PR^*) + \beta_4\nu_i\ln(PI^*) + \varepsilon_{it},$$

in which $\nu_i \equiv R_{fi0}/R_{i0}$ is the ratio of foreign to domestic application of R&D in the base period, and additional information about production parameters implies further restrictions among the coefficients $\beta_1 - \beta_4$. The prices *PR, PI, PR**, and *PI** differ among firms and over years for the same firm; the values of the domestic prices *PR* and *PI* are equal to one over the 1981–86 period and for firms with deficit tax credits equal to one after 1986. The parameters λ_t and η_i are new combined year and individual effects, while the term ξ_t premultiplying ν_i reflects year-specific shocks that affect foreign and domestic markets differently. The equation (25) is then in a form that permits linear estimation of the responses of firms to the four (potentially) changing prices on its right side.

The only remaining difficulty in estimating (25) is that the term $\nu_i = R_{fi0}/R_{i0}$ is unobservable, since firms do not report (and indeed might not be able to report if they wanted to) the fraction of their R&D devoted to foreign markets. On the other hand, each firm's ratio of foreign to domestic sales is observable, and over the period 1981–86 should be unaffected by the R&D allocation rules, since the rules were the same for all firms. Suppose that

$$(26)\quad R_{fi0}/R_{i0} = \rho(S^*_{i0}/S_{i0})\ \forall\ i.$$

Then it is possible to use values of (S^*_{i0}/S_{i0}) from the 1981–86 period for ν_i on the right side of (25) and to estimate the equation while simultaneously estimating the value of ρ. One additional assumption is necessary in order to linearize this estimation. If the foreign and domestic production functions have the same production shares for R&D and other inputs, so that $\gamma = \gamma^*$ and $\mu = \mu^*$, then from (16) and (18) it should be the case that $\beta_1 = \beta_3$ and $\beta_2 = \beta_4$ in (25). Imposing this restriction, using (26), and defining $\sigma_i \equiv (S^*_{i0}/S_{i0})$, equation (25) becomes

$$(27)\quad \ln(\underline{R}_{it}) = \lambda_t + \eta_i + \xi_t\sigma_i + \beta_1\ln(PR) + \beta_2\ln(PI) + \beta_3\sigma_i[\ln(PR^*) - \ln(PR)] + \beta_4\sigma_i[\ln(PI^*) - \ln(PI)] + \varepsilon_{it}.$$

In this form of the estimating equation, the ratios β_3/β_1 and β_4/β_2 are estimates of ρ.

5.4.2 The Data

The analysis in this section uses a panel of firm-level data reported in Compustat over the period 1984–89. As a special project initiated in 1984, Compustat culls from a subset of its firms' information on their foreign pretax earnings and foreign income taxes paid. Firms are not required to report the countries in which they earned their profits, nor are they required to indicate if profits were repatriated or reinvested abroad. In a sample of 2,800 firms, foreign earnings and tax data are available for approximately 500 firms for each of the reporting years.

Unfortunately, the main Compustat file does not include data on firms' foreign sales. In order to obtain foreign sales information, it was necessary to use the Compustat Geographic Segment File, which reports separate business segments for certain firms with major foreign operations. This file contains data on foreign sales of U.S. firms, though it offers little other detail on foreign operations.[26] In order to identify those firms that are likely to have excess foreign tax credits, it is necessary to construct estimates of the foreign tax rates they face; this is possible only if firms report their foreign tax liabilities along with their (positive) foreign incomes. Firms were excluded from the sample if they did not report their domestic and (positive) foreign income and sales, along with their R&D expenditures, continuously from 1984–89. Firms involved in major mergers—those in which firm sales rose by 50 percent or more—were also omitted. These exclusions left a sample of 116 firms.

These 116 firms were at least three times the size of average firms in Compustat, with U.S. federal tax liabilities in 1989 averaging $91.9 million (versus $30.4 million for the Compustat average). In addition, the sample firms had average foreign tax liabilities of $121.9 million. Column 1 of table 5.3 is a list of some of the sample's characteristics.

In order to construct the tax prices firms face, it is necessary to establish whether or not they have excess foreign tax credits.[27] Unfortunately, the only way to do so precisely is to examine their U.S. federal income tax returns, which are confidential.[28] Given the data at hand, it is necessary instead to treat each firm as though all of its foreign income were taxed at the same, average, rate, so that firms with average foreign tax rates above the U.S. statutory rate are considered to have excess foreign tax credits. This ignores the endogeneity of a firm's dividend repatriation decision and, perhaps more important, ignores the separation of some of its foreign income into separate baskets for the purposes of the foreign tax credit calculation.[29] Column 2 of table 5.3

26. In particular, the Geographic Segment File does not indicate the magnitude of a firm's foreign R&D. Information about sales and profits in individual foreign countries is available only sporadically.

27. It is also necessary to construct tax prices for firms that would prefer to use one of the alternatives to the sales allocation method. These prices were constructed and applied for those firms that would do better to use one of the alternative methods.

28. Even with access to a firm's income tax records, it is still difficult to identify its foreign tax credit status for purposes of estimation, because the magnitude of creditable foreign taxes claimed by the firm in part depends on its dividend repatriations and other discretionary choices that may be endogenous to the policies under study. By contrast, the average foreign tax rate the firm faces may be much closer to an exogenous variable for some firms.

29. One way to correct for this problem would be to adjust a firm's observed foreign tax rate downward in determining its excess credit status. A number of the regressions reported in tables 5.5–5.12 were run with foreign tax rates adjusted downward by 0.02 and 0.04, with virtually identical results to those in the tables. An alternative correction would be to adjust the foreign tax rates *upward,* because firms can choose the pattern of their dividend repatriations from foreign subsidiaries and, all other things equal, are more likely to repatriate dividends from locations with higher tax rates (as Hines and Hubbard [1990] find to be the case for dividend repatriations by U.S. multinationals in 1984). Even the post-1986 tightening of the basket definitions could justify

Table 5.3 Characteristics of Subsamples in 1989 ($ millions)

Sample Characteristic	Whole Sample	Deficit FTC*	Nonmerging Firms†
Mean sales in 1989	$6,280.6	$5,694.5	$6,036.8
Percent foreign-source sales	35.4%	37.5%	37.8%
Mean income in 1989	$569.5	$591.7	$598.0
Percent foreign-source income	57.2%	50.9%	67.3%
Mean R&D expenditure in 1989	$259.3	$278.2	$310.0
Number of firms	116	21	40

*Firms having deficit foreign tax credits every year from 1987 to 1989.
†Firms exhibiting no merger activity over the 1984–89 period.

presents summary statistics of those firms that have deficit foreign tax credits continuously over the 1987–89 period. They look quite similar to the 116 firms in the main sample.

Merger and acquisition activity represents another potential difficulty facing the estimation of (27). The model is specified under the assumption that a firm's characteristics are reasonably stable over a short time span. Firms that acquire other firms presumably absorb not only the acquired firm's accumulated R&D stock and tax characteristics but also its firm-specific production function characteristics. The changes induced by mergers may introduce noise, if not bias, into the estimation of (27),[30] so a separate sample of 40 firms with no merger activity at all over the 1984–89 period was created. Column 3 of table 5.3 describes the properties of the nonmerger sample, which is slightly more R&D-intensive than the sample of 116 firms but is otherwise similar.

One final specification issue in estimating (27) is the choice of left-side variable. Plausible cases could be made for including either R&D stock or R&D flow on the left side of this equation. The argument for estimating (27) on the stock of R&D rests on the appropriateness of R&D stock as an argu-

an upward adjustment in the sample's foreign tax rate, because certain low-tax foreign-income sources are segregated into their own basket. But, on net, important high-tax items with their own baskets—such as oil income and high withholding tax interest income—make a downward adjustment more likely to capture the incentives firms face.

30. The direction of potential bias is not clear. As a general matter, Hall (1988) finds no difference between the mean growth rates of R&D intensity of firms involved in mergers and those not involved. Griliches and Mairesse (1984) find that firms with mergers produce significantly different panel estimates of productivity growth equations than do nonmerger firms; they argue on that basis that merger firms should not be excluded from productivity regressions. A successful merger increases the size of the acquiring firm, which might be expected to influence R&D intensity, though the evidence (Cohen, Levin, and Mowery 1987) suggests that size alone has very little effect.

ment of the sales function in (15). The difficulty with estimating (27) with the stock variable on the left side is that stock adjustment costs are implicitly assumed to be equal to zero, so that desired equals actual stock in every year. Although the price changes—and consequently the induced changes in desired stocks—are small over this time period, it may be unreasonable to expect immediate adjustment. Unfortunately, the time dimension in the panel does not permit reliable estimation of adjustment costs. An alternative is to use *current* R&D expenditures as the argument of the sales function (15) and on the left side of the factor demand equation (27); this specification is somewhat less compelling from the standpoint of the underlying production function but is less subject to the problem of slow adjustment. Consequently, each specification of (27) was estimated twice, first with R&D stock as a dependent variable and second with R&D flow; the results were not greatly affected by the choice of dependent variable.[31]

Table 5.4 describes characteristics of the tax prices faced by subsets of firms in the sample over the 1987–89 period. The data suggest that there is considerable variation both within and between industrial classifications (the first thirteen lines in the table present summaries by the most populated two-digit standard industrial classifications) in the tax prices firms face. The last six lines of the table exhibit average prices faced by the whole sample of 116 firms and the restricted sample of 38 nonmerging firms that is used in much of the estimation. For the average firm in the sample, the own-price of R&D [ln(*PR*)] increased approximately 5 percent in response to the 1986 tax change. For the 38 nonmerging firms, the average price rise was slightly higher (5.5 percent). These changes in own-prices of R&D were offset by reductions in cross-prices of R&D [ln(*PI*)] that were on average 3–4 percent of the magnitude of the own-price changes. While these cross-price movements are small, examination of (27) reveals that small changes on these prices have considerable impact on R&D levels and partly attenuate the effects of the own-price changes during 1987–89.

5.4.3 Their Behavior

Table 5.5 presents estimates of (27) for the sample of forty firms that did not exhibit merger activity over the 1984–89 period. The first two columns report the coefficients from the model in which R&D stock is the dependent variable, while columns 3 and 4 report results from regressions on R&D flow. Columns 1 and 3 present ordinary least squares (OLS) estimates of (27). As predicted, both domestic prices exert negative and significant effects on R&D activity, and the coefficient on the *PI* term is substantially larger (in absolute value) than the coefficient on the *PR* term (though this coefficient is impre-

31. R&D capital stocks were constructed using a perpetual inventory method, starting with R&D expenditures in 1975 (in constant 1984 dollars) and—following Griliches and Mairesse (1984) and Jaffe (1986)—applying a 15 percent rate of geometric decay to old stocks.

Table 5.4 Characteristics of Tax Prices, 1987–1989

Industry	Number of Firms	Price	Mean	Standard Deviation	Minimum	Maximum
Food and tobacco	3	ln(*PR*)	0.0181	0.0337	0	0.1024
Paper products	5	ln(*PR*)	0.0372	0.0430	0	0.1184
Chemicals	27	ln(*PR*)	0.0512	0.0541	0	0.1977
Petroleum	5	ln(*PR*)	0.0536	0.0486	0	0.1651
Rubber products	5	ln(*PR*)	0.0548	0.0475	0	0.1230
Stone and glass	3	ln(*PR*)	0.0325	0.0202	0	0.0548
Primary metals	2	ln(*PR*)	0.0079	0.0193	0	0.0474
Fabricated metals	7	ln(*PR*)	0.0318	0.0328	0	0.0857
Machinery	26	ln(*PR*)	0.0644	0.0587	0	0.2208
Electrical equipment	8	ln(*PR*)	0.0350	0.0550	0	0.1566
Transportation equipment	8	ln(*PR*)	0.0409	0.0315	0	0.0967
Scientific instruments	13	ln(*PR*)	0.0769	0.0722	0	0.2303
Other manufacturing	2	ln(*PR*)	0.0313	0.0485	0	0.0963
All firms	116	ln(*PI*)	0.0507	0.0544	0	0.2303
All firms	116	ln(*PI*)	−0.0015	0.0030	−0.0159	0
All firms	116	ln(*PR**)	−0.1615	0.1286	−0.3517	0
Nonmerging firms	38	ln(*PR*)	0.0550	0.0575	0	0.2194
Nonmerging firms	38	ln(*PI*)	−0.0023	0.0039	−0.0159	0
Nonmerging firms	38	ln(*PR**)	−0.1659	0.1271	−0.3517	0

cisely measured in the R&D stock regression). Domestic R&D appears to respond much more strongly to domestic price terms than it does to foreign price terms, suggesting a value of ρ that is imprecisely measured but in the neighborhood of 0.2–0.3. The estimated own-price elasticity of domestic R&D for domestic purposes is -1.3 in the R&D stock regression and -1.7 in the flow regression.

There is an important difficulty that arises in interpreting the OLS results, in that the tax prices (for firms with excess foreign tax credits) are endogenous to R&D expenditure levels. In order to reduce the bias that accompanies this endogeneity, columns 2 and 4 present instrumental variables (*IV*) estimates of (27), with instruments constructed by using values of $\underline{R}/(S + S^*)$ and $S^*/(S + S^*)$ for the 1984–86 period for each firm in place of their yearly values in constructing price instruments. The *IV* estimates yield results that are quite similar to their OLS counterparts, though the cross-price effects fall in magnitude and the estimated effect of the price of R&D directed at foreign markets is now significant in the R&D stock regression. The estimated own-price elasticity of domestic R&D for domestic markets is -1.3 in the stock regression and -1.8 in the flow regression.

Table 5.6 presents results of the same regressions run on the whole sample of 116 firms. The *IV* estimates suggest an own-price elasticity of domestic R&D for domestic purposes that is somewhat smaller in magnitude, around

Table 5.5 **R&D Price Responsiveness in Nonmerging Firms, 1984–1989**

	Dependent Variable: ln (R&D stock)		Dependent Variable: ln (R&D flow)	
	OLS	IV	OLS	IV
ln(*PR*)	−1.2947	−1.2670	−1.6874	−1.7954
	(0.3982)	(0.4167)	(0.5595)	(0.5845)
ln(*PI*)	−22.3221	−12.8442	−63.2821	−59.0972
	(11.4838)	(12.3754)	(16.1359)	(17.3570)
ln(*PR**)	−0.2881	−0.3166	−0.4250	−0.4605
	(0.1501)	(0.1511)	(0.2110)	(0.2119)
ln(*PI**)	−10.1741	−6.5294	−37.1077	−35.5633
	(6.8583)	(7.0852)	(9.6367)	(9.9373)
Y85(*S**/*S*)	−0.0666	−0.0665	−0.0452	−0.0503
	(0.1215)	(0.1218)	(0.1707)	(0.1709)
Y86(*S**/*S*)	−0.0732	−0.0705	0.0452	0.0473
	(0.1211)	(0.1214)	(0.1701)	(0.1703)
Y87(*S**/*S*)	−0.0641	−0.0373	0.2410	0.2601
	(0.1313)	(0.1322)	(0.1845)	(0.1854)
Y88(*S**/*S*)	−0.0591	−0.0249	0.3367	0.3608
	(0.1334)	(0.1346)	(0.1874)	(0.1887)
Y89(*S**/*S*)	−0.0192	−0.0025	0.4644	0.4770
	(0.1259)	(0.1264)	(0.1769)	(0.1773)
Firm dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Number of firms	40	40	40	40
$\hat{\sigma}$	0.1359	0.1362	0.1909	0.1911

Note: Values in parentheses are standard errors. *PR* and *PI* are the two domestic tax prices relevant to R&D, while *PR** and *PI** are their foreign counterparts (and are premultiplied by [*S**/*S*]). See text for description.

−0.6 for the R&D stock and −0.8 for R&D flow. In the stock regression, the other price coefficients have estimated standard errors that make them insignificant, and (except for the coefficient on *PI*) they are roughly half the size of the estimates in table 5.5. In the R&D flow regression, the coefficients on other prices are somewhat smaller than in the regression reported in table 5.5, although (except for the coefficient on *PR**) they remain significant. The sample of 116 firms would appear to exhibit less well defined responsiveness of R&D to changes in the tax prices of R&D, which may in part reflect the randomness introduced by the characteristics of their acquired assets and lines of business.

One of the difficulties that arise in estimating (27) is that the price terms on the right side are likely to exhibit considerable multicollinearity. The firms that experience substantial movements in one price term are likely to show simultaneous movements in others. One way to tighten the precision of the estimates is to restrict the coefficients still further. An attractive restriction to

Table 5.6 R&D Price Responsiveness in 116 Firms, 1984–1989

	Dependent Variable: ln (R&D stock)		Dependent Variable: ln (R&D flow)	
	OLS	IV	OLS	IV
ln(*PR*)	−0.6645	−0.6425	−0.8566	−0.8082
	(0.2242)	(0.2727)	(0.3754)	(0.4567)
ln(*PI*)	−17.3433	−13.3606	−46.5677	−41.9770
	(6.5991)	(10.1127)	(14.3947)	(16.9387)
ln(*PR**)	−0.1155	−0.1587	−0.2611	−0.3734
	(0.0828)	(0.1196)	(0.1386)	(0.2003)
ln(*PI**)	−9.5135	−9.0595	−28.0481	−29.6616
	(4.9956)	(5.6233)	(8.3625)	(9.4189)
Y85(*S**/*S*)	−0.0608	−0.0661	−0.1334	−0.1480
	(0.0611)	(0.0624)	(0.1022)	(0.1045)
Y86(*S**/*S*)	−0.0600	−0.0595	−0.0464	−0.0454
	(0.0593)	(0.0593)	(0.0993)	(0.0994)
Y87(*S**/*S*)	−0.0503	−0.0409	0.0170	0.0385
	(0.0611)	(0.0612)	(0.1022)	(0.1025)
Y88(*S**/*S*)	−0.0204	−0.0150	0.1207	0.1343
	(0.0626)	(0.0627)	(0.1047)	(0.1050)
Y89(*S**/*S*)	−0.0177	−0.0138	0.1705	0.1805
	(0.0607)	(0.0608)	(0.1015)	(0.1019)
Firm dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Number of firms	116	116	116	116
$\hat{\sigma}$	0.1331	0.1332	0.2228	0.2231

Note: Values in parentheses are standard errors. *PR* and *PI* are the two domestic tax prices relevant to R&D, while *PR** and *PI** are their foreign counterparts (and are premultiplied by [*S**/*S*]). See text for description.

impose is to force $\mu = \mu^*$ and set their value equal to 0.9. Then (27) can be reestimated with both domestic price terms combined into a new term, $P \equiv (1 - \mu)\ln(PR) + \mu\ln(PI)$, and similarly for the foreign price terms $P^* \equiv (1 - \mu^*)[\ln(PR^*) - \ln(PR)] + \mu^*[\ln(PI^*) - \ln(PI)]$.[32]

Table 5.7 presents estimates of the restricted regression on a sample of thirty-eight of the firms without mergers.[33] The *IV* coefficient estimates are quite similar to their values in table 5.5 (recalling that the price terms are premultiplied by new coefficients), suggesting an own-price elasticity of do-

32. Some specification testing suggested that $\mu = 0.9$ fit the R&D stock specification quite well. Judging from the results reported in tables 5.5–5.12, it may be that an appropriate choice of μ for the R&D flow equation would be somewhat larger than 0.9.

33. Two firms were removed from the sample because there were no others in their two-digit SIC industries (in the nonmerging sample) and they had to be dropped for the regressions (table 5.11) that include industry dummy variables. In order to put the regressions reported in tables 5.7, 5.9, and 5.11 on a comparable basis, these firms were not included in the earlier regressions either. When the two additional firms were included, the results in tables 5.7 and 5.9 were virtually unchanged.

Table 5.7 Response to Domestic and Foreign Tax Prices by 38 Nonmerging Firms, 1984–1989

	Dependent Variable: ln (R&D stock)		Dependent Variable: ln (R&D flow)	
	OLS	IV	OLS	IV
ln(P)	−11.2955	−11.6830	−15.1322	−16.3360
	(3.1643)	(3.2860)	(5.5772)	(5.7931)
ln(P^*)	−2.4655	−2.6773	−4.4408	−5.2222
	(1.1912)	(1.1973)	(2.0996)	(2.1110)
Y85(S^*/S)	−0.0332	−0.0369	−0.0218	−0.0353
	(0.0983)	(0.0983)	(0.1732)	(0.1733)
Y86(S^*/S)	−0.0212	−0.0209	0.0884	0.0896
	(0.0981)	(0.0982)	(0.1730)	(0.1731)
Y87(S^*/S)	−0.0109	−0.0103	0.2528	0.2557
	(0.0986)	(0.0986)	(0.1737)	(0.1738)
Y88(S^*/S)	0.0168	0.0169	0.3853	0.3861
	(0.0982)	(0.0982)	(0.1731)	(0.1732)
Y89(S^*/S)	0.0653	0.0660	0.4840	0.4866
	(0.0984)	(0.0984)	(0.1734)	(0.1735)
Firm dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Number of firms	38	38	38	38
$\hat{\sigma}$	0.1081	0.1081	0.1905	0.1906

Note: Values in parentheses are standard errors. P is the domestic tax price relevant to R&D, while P^* is its foreign counterpart (and is premultiplied by $[S^*/S]$). See text for description.

mestic R&D for domestic markets of −1.2 in the stock regression and −1.6 in the flow regression. The price sensitivity of domestic R&D directed at foreign markets is considerably lower, again implying a value of ρ between 0.2 and 0.33.

Table 5.8 repeats the estimation of this system for the whole sample of 116 firms. The combined domestic price term in the stock regression is significant and slightly smaller in magnitude than its estimated counterparts in earlier regressions, implying an own-price elasticity of domestic R&D for domestic markets of −0.6. The foreign price effect in the stock regression is estimated to be much smaller, again between 0.2 and .25 of the domestic price effect, and is not significantly different from zero. The domestic price term in the R&D flow equation is considerably smaller than in the estimates reported in table 5.6, implying an estimated elasticity of −0.5 that is not significantly different from zero. The foreign price term in this regression is again smaller than the domestic price term but is also insignificant.

One of the difficulties that confronts this analysis is the problem of measuring the tax price faced by firms in the sample. The tax prices that underlie the results reported in tables 5.4 through 5.8 were constructed under the assumption that firms use the foreign and domestic income figures reported in their

Table 5.8 Response to Domestic and Foreign Tax Prices by 116 Firms, 1984–1989

	Dependent Variable: ln (R&D stock)		Dependent Variable: ln (R&D flow)	
	OLS	IV	OLS	IV
ln(*P*)	−5.9925	−5.6212	−6.3367	−4.9683
	(2.1829)	(2.5556)	(3.6761)	(4.3043)
ln(*P**)	−0.9737	−1.3783	−2.1102	−2.7268
	(0.8212)	(1.1900)	(1.3831)	(2.0043)
Y85(S*/S)	−0.0578	−0.0637	−0.1237	−0.1328
	(0.0611)	(0.0623)	(0.1029)	(0.1050)
Y86(S*/S)	−0.0599	−0.0598	−0.0452	−0.0452
	(0.0594)	(0.0594)	(0.1000)	(0.1000)
Y87(*S**/*S*)	−0.0650	−0.0650	−0.0098	−0.0099
	(0.0594)	(0.0594)	(0.1000)	(0.1000)
Y88(*S**/*S*)	−0.0457	−0.0501	0.0626	0.0532
	(0.0599)	(0.0600)	(0.1008)	(0.1011)
Y89 (*S**/*S*)	−0.0339	−0.0359	0.1337	0.1305
	(0.0595)	(0.0596)	(0.1002)	(0.1005)
Firm dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Number of firms	116	116	116	116
$\hat{\sigma}$	0.1332	0.1333	0.2244	0.2245

Note: Values in parentheses are standard errors. *P* is the domestic tax price relevant to R&D, while *P** is its foreign counterpart (and is premultiplied by [*S**/*S*]). See text for description.

10-Ks for R&D allocation on their tax returns. Unfortunately, the definitions differ, and they do so in ways that cannot be identified from publicly available information. A firm's tax situation depends on a number of rather subtle choices by the firm, and legal distinctions between observationally similar activities of the firm, that make it very difficult to identify their incentives.[34]

In order to check the robustness of the results presented in tables 5.5 through 5.8 to changes in the specification of tax prices, tables 5.9 and 5.10 report the results of reestimating (27) under the assumption that all firms use the income allocation method to reduce their tax obligations to the point that the fractional sales constraint binds. The estimated price elasticities for the nonmerging sample of thirty-eight firms, reported in table 5.9, are about half

34. The U.S. Department of the Treasury (1983) found that for the small number (twenty-four) of firms for which enough data were available on tax returns and in 10-K filings to observe their R&D allocation procedures, it appeared that those firms took more R&D deductions against their U.S. taxable income than even the most generous treatment (full use of the income method) would have indicated. This does not mean that these firms necessarily took excessive R&D deductions, because there are several circumstances in which firms are permitted to allocate more R&D against their domestic income than is provided by the allocation rule, if the deductions can be justified. All of this points to the difficulty of using available data—even confidential tax return data—to measure tax prices exactly. But at the same time, observable tax prices can offer useful approximations to the prices firms face.

Table 5.9 Response to (Constrained) Tax Prices by Nonmerging Firms, 1984–1989

	Dependent Variable: ln (R&D stock)		Dependent Variable: ln (R&D flow)	
	OLS	IV	OLS	IV
ln(*P*)	−7.9749	−7.8978	−8.7179	−8.5307
	(1.6931)	(1.6549)	(2.9895)	(2.9928)
ln(*P**)	−3.0145	−3.0766	−3.7677	−3.8940
	(1.1788)	(1.1791)	(2.1318)	(2.1324)
Y85(*S**/*S*)	−0.0419	−0.0430	−0.0096	−0.0120
	(0.0963)	(0.0963)	(0.1742)	(0.1742)
Y86(*S**/*S*)	−0.0199	−0.0199	0.0876	0.0877
	(0.0959)	(0.0959)	(0.1735)	(0.1735)
Y87(*S**/*S*)	−0.0566	−0.0564	0.1954	0.1960
	(0.0965)	(0.0965)	(0.1746)	(0.1746)
Y88(*S**/*S*)	−0.0057	−0.0061	0.3554	0.3546
	(0.0964)	(0.0964)	(0.1743)	(0.1743)
Y89(*S**/*S*)	0.0264	0.0265	0.4342	0.4346
	(0.0963)	(0.0963)	(0.1741)	(0.1741)
Firm dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Number of firms	38	38	38	38
$\hat{\sigma}$	0.1057	0.1057	0.1911	0.1911

Note: Values in parentheses are standard errors. Tax prices used in the regressions reported in this table were constructed under the assumption that all firms can reduce their tax liabilities using the income allocation method, up to the point that the sales allocation method constraint binds. *P* is the domestic tax price relevant to R&D, while *P** is its foreign counterpart (and is premultiplied by [*S**/*S*]). See text for description.

the magnitude of the corresponding elasticity estimates in table 5.7: the domestic price elasticities are −0.5 in the stock regression and −0.9 in the flow regression. The foreign price elasticities are, as in table 5.7, considerably smaller than their domestic counterparts; and in the R&D flow regression, the estimated foreign price elasticity is not significantly different from zero. The estimated price elasticities reported in table 5.10 are similar to the estimates in table 5.8, with the difference that the magnitudes are slightly smaller and the domestic price elasticities are both significantly different from zero (−0.4 in the stock regression and −0.5 in the flow regression) in table 5.10.

Another difficulty in interpreting (27) is the omission of industry-specific effects. Firms in some industries are more likely than those in others to have operations in high-tax foreign locations and to have high $R/(S + S^*)$ ratios. If those industries also are the ones that are shrinking relative to other manufacturing industries over the 1987–89 period (for ordinary business reasons unrelated to §1.861–8), then one might mistakenly interpret negative coefficients on the price terms to imply an important price effect on R&D when no effect is present. One way to avoid such a misinterpretation would be to run (27) with industry dummy variables, interacted with time trends, on the right

Table 5.10 Response to (Constrained) Tax Prices by 116 Firms, 1984–1989

	Dependent Variable: ln (R&D stock)		Dependent Variable: ln (R&D flow)	
	OLS	IV	OLS	IV
ln(*P*)	−4.1080	−4.0382	−4.9362	−4.7330
	(1.1683)	(1.1697)	(1.9713)	(1.9737)
ln(*P**)	−1.1207	−1.1768	−2.1105	−2.2168
	(0.8152)	(0.8154)	(1.3755)	(1.3759)
Y85(*S**/*S*)	−0.0595	−0.0604	−0.1232	−0.1249
	(0.0609)	(0.0609)	(0.1027)	(0.1027)
Y86(*S**/*S*)	−0.0596	−0.0596	−0.0450	−0.0450
	(0.0591)	(0.0591)	(0.0997)	(0.0997)
Y87(*S**/*S*)	−0.0817	−0.0818	−0.0331	−0.0330
	(0.0594)	(0.0594)	(0.1002)	(0.1002)
Y88(*S**/*S*)	−0.0707	−0.0714	0.0334	0.0320
	(0.0600)	(0.0600)	(0.1012)	(0.1012)
Y89(*S**/*S*)	−0.0507	−0.0510	0.1109	0.1104
	(0.0599)	(0.0599)	(0.1010)	(0.1010)
Firm dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Number of firms	116	116	116	116
$\hat{\sigma}$	0.1327	0.1327	0.2239	0.2239

Note: Values in parentheses are standard errors. Tax prices used in the regressions reported in this table were constructed under the assumption that all firms can reduce their tax liabilities using the income allocation method, up to the point that the sales allocation method constraint binds. *P* is the domestic tax price relevant to R&D, while *P** is its foreign counterpart (and is premultiplied by [*S**/*S*]). See text for description.

side, thereby removing average industry effects on R&D growth. The disadvantage of this approach is that it also removes the average industry price variation, leaving only within-industry variation with which to identify the effect of tax prices on R&D. The remaining variation may not always be adequate to identify price effects precisely.

Tables 5.11 and 5.12 present estimates of (27) that include on the right side time trends interacted with industry dummy variables for each of the two-digit SIC manufacturing industries listed in table 5.4.[35] Because these regressions are intended to probe the robustness of the specification of (27), the tax prices used in these regressions were constructed under the assumption that all firms use the income method (up to the sales method constraint) to allocate their R&D deductions.[36] The estimated coefficients on tax price variables in tables

35. To be specific, the industry growth dummy variables take values of zero for firms outside the (two-digit SIC) industry, while for firms in the industry the values are one in 1985, two in 1986, and so on. For a more subtle treatment of interindustry differences in R&D growth rates, see Pakes and Schankerman (1984a).

36. Very similar results were obtained in specifications with industry growth variables included on the right side but tax prices calculated in the standard manner (as in tables 5.7 and 5.8).

Table 5.11 Response to (Constrained) Tax Prices, Industry Effects Removed, by Nonmerging Firms, 1984–1989

	Dependent Variable: ln (R&D stock)		Dependent Variable: ln (R&D flow)	
	OLS	IV	OLS	IV
ln(P)	−5.3825	−5.2497	−4.7604	−4.4716
	(1.4439)	(1.4456)	(2.7846)	(2.7878)
ln(P^*)	−2.6111	−2.6551	−2.7488	−2.8342
	(0.9919)	(0.9922)	(1.9129)	(1.9134)
Y85(S^*/S)	0.0241	−0.0249	0.0268	0.0252
	(0.0809)	(0.0809)	(0.1559)	(0.1559)
Y86(S^*/S)	0.0344	0.0343	0.1811	0.1809
	(0.0814)	(0.0814)	(0.1571)	(0.1571)
Y87(S^*/S)	0.0468	0.0472	0.3723	0.3732
	(0.0839)	(0.0839)	(0.1617)	(0.1617)
Y88(S^*/S)	0.1205	0.1200	0.5757	0.5748
	(0.0865)	(0.0865)	(0.1668)	(0.1669)
Y89(S^*/S)	0.1922	0.1923	0.7197	0.7200
	(0.0896)	(0.0896)	(0.1728)	(0.1729)
Industry growth dummies	Yes	Yes	Yes	Yes
Firm dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Number of firms	38	38	38	38
$\hat{\sigma}$	0.0881	0.0881	0.1699	0.1699

Note: Values in parentheses are standard errors. Tax prices used in the regressions reported in this table were constructed under the assumption that all firms can reduce their tax liabilities using the income allocation method, up to the point that the sales allocation method constraint binds. Industry growth dummies are industry-specific constant time trends. P is the domestic tax price relevant to R&D, while P^* is its foreign counterpart (and is premultiplied by $[S^*/S]$). See text for description.

5.11 and 5.12 remain negative but are generally only half of the magnitude of the corresponding coefficients in tables 5.9 and 5.10; also, although they are significant in the R&D stock regressions (except for the foreign price coefficient in the large sample regression reported in table 5.12), estimated price effects become insignificant in the R&D flow regressions. It appears that removing the variation in prices between industries simply leaves too little variation to identify the price effects very precisely. An alternative interpretation would be that the price effects that appear in tables 5.5 through 5.10 are simply spurious correlations, but this interpretation would not square with the results from the R&D stock regressions.

The results described in tables 5.5 through 5.12 present a consistent picture of R&D activity that is sensitive to the tax changes introduced after 1986. The evidence in the tables suggests, however, that tax changes that affected the after-tax profitability of R&D performed in the United States and directed at foreign markets had significantly less impact than the tax changes that affected

Table 5.12 **Response to (Constrained) Tax Prices, Industry Effects Removed, by 116 Firms, 1984–1989**

	Dependent Variable: ln (R&D stock)		Dependent Variable: ln (R&D flow)	
	OLS	IV	OLS	IV
ln(*P*)	−3.1211	−2.9981	−3.7319	−3.4691
	(1.0802)	(1.0815)	(1.9552)	(1.9575)
ln(*P**)	−0.5232	−0.5655	−1.0773	−1.1698
	(0.7502)	(0.7504)	(1.3579)	(1.3582)
Y85(*S**/*S*)	−0.0501	−0.0508	−0.1196	−0.1212
	(0.0550)	(0.0550)	(0.0995)	(0.0995)
Y86(*S**/*S*)	−0.0466	−0.0468	−0.0552	−0.0555
	(0.0538)	(0.0538)	(0.0973)	(0.0974)
Y87(*S**/*S*)	−0.0549	−0.0550	−0.0386	−0.0387
	(0.0549)	(0.0549)	(0.0994)	(0.0994)
Y88(*S**/*S*)	−0.0333	−0.0341	0.0299	0.0281
	(0.0568)	(0.0568)	(0.1027)	(0.1027)
Y89(*S**/*S*)	−0.0039	−0.0043	0.1045	0.1035
	(0.0581)	(0.0581)	(0.1051)	(0.1051)
Industry growth dummies	Yes	Yes	Yes	Yes
Firm dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Number of firms	116	116	116	116
$\hat{\sigma}$	0.1193	0.1193	0.2159	0.2159

Note: Values in parentheses are standard errors. Tax prices used in the regressions reported in this table were constructed under the assumption that all firms can reduce their tax liabilities using the income allocation method, up to the point that the sales allocation method constraint binds. Industry growth dummies are industry-specific constant time trends. *P* is the domestic tax price relevant to R&D, while *P** is its foreign counterpart (and is premultiplied by [*S**/*S*]). See text for description.

the after-tax profitability of R&D performed in the United States and directed at the American market. The foreign market effect is smaller than that for the domestic market, even when corrected for firms' relative sales in the two markets.

Why the foreign market effect should be so much smaller is unclear. One possibility is that measurement error reduces the estimated magnitude of what is truly a substantial effect. There is no doubt that the heterogeneity of foreign markets, and foreign tax rates, makes the average foreign price measures *PR** and *PI** only approximations to the true tax prices of performing R&D for foreign markets. Another possibility is that the analysis might fail to find the true effect because it is not possible to identify separately the changes in offshore R&D performed by subsidiaries of U.S. firms.[37] But the third, and per-

37. For an exploratory study of the determinants of offshore R&D by U.S. firms, see Mansfield, Teece, and Romeo (1979).

Table 5.13 Royalties Paid versus R&D Devoted to Foreign Sources, based on Relative Sales (current $ millions)

Year	Affiliate Sales	Parent Sales	Affiliate Sales Share	U.S. R&D	Affiliate R&D Share	Royalties
1982	$271,099	$1,017,591	21.0%	$40,105	$ 8,437	$3,308
1983	270,363	1,080,267	20.0	44,588	8,925	3,597
1984	285,970	1,207,297	19.2	51,404	9,844	3,921
1985	293,989	1,246,401	19.1	57,043	10,887	4,096
1986	335,700	1,264,513	21.0	59,932	12,573	5,518
1987	388,424	1,338,593	22.5	62,806	14,126	7,039
1988	464,112	1,429,967	24.5	66,463	16,286	8,455

Source: U.S. Department of Commerce (various years); National Science Foundation (1991).
Note: Data are limited to manufacturing industries only.

haps most likely, possibility is that firms do not concentrate on foreign tax factors when undertaking R&D in the United States. This is likely to be the case if, in fact, domestic R&D does not greatly promote foreign profitability relative to its effect on domestic profitability.[38]

It is difficult to assess this third possibility, because some R&D performed in the United States clearly is directed primarily at foreign markets, whereas other R&D activities are directed at the U.S. market. Table 5.13 offers some aggregate evidence on the relationship between the foreign sales share of U.S. affiliates (multiplied by U.S. domestic R&D), and their use of domestic U.S. technology, as reflected in royalty payments to the United States. It appears that royalty payments equal only about half of the foreign share based on a simple sales formula. There are, of course, several possible explanations for the pattern displayed in table 5.13. The aggregate R&D figures represent the sum of firms with and without foreign affiliates. There might be long delays between expenditures on R&D and the production of know-how that would merit the payment of a royalty. Firms may not pay the royalties that they should according to arm's-length pricing principles.[39] But another possibility is that R&D in the United States is directed primarily at domestic markets.

38. Or if its effects on foreign profitability appears only after considerable time has elapsed. Mansfield and Romeo (1980) find that new technologies developed in the United States are transferred to industrialized foreign countries six years, on average, after they are first used in U.S. production. It would undoubtedly be a mistake to conclude that domestic R&D has no influence on foreign profitability; for example, Flaherty (1984) documents the importance of technological leadership for market shares of foreign affiliates of U.S. firms. Furthermore, manufacturing executives undertake R&D projects anticipating that a substantial fraction (though less than half) of the returns will come in foreign markets, according to the survey results presented in Mansfield, Romeo, and Wagner (1979).

39. Kopits (1976) offers evidence that multinationals systematically adjust their royalty payments to pursue global tax-minimizing strategies. Given the tax-favored status of royalty receipts in the United States, this argument implies that the royalty might be overstated rather than understated.

5.5 Alternative Tax Structures

The price responsiveness of R&D as estimated in tables 5.7 and 5.8 suggests that proposed changes in the tax treatment of R&D might have observable, if small, effects on the R&D efforts of U.S. multinationals. In this section, I examine the likely consequences of two reforms. One alternative to the current tax system is to restore the system that existed from 1981 to 1986, in which U.S. multinationals effectively could deduct 100 percent of their R&D for tax purposes. The second proposal, advocated by McIntyre (1989) and others, is to allocate U.S. R&D expenses on the basis of foreign and domestic sales without an initial fractional apportionment against U.S. income and without optional income apportionment.

Table 5.14 presents both proposals' estimated effects on revenue and R&D levels, based on data from a somewhat expanded set of 189 firms for 1989. (Firms were included if enough data were available to construct their responses to the proposed tax changes in 1989.) Collectively, these 189 firms had $41 billion of R&D expenditures in 1989, representing half of the total R&D expenditure reported for all 2,800 Compustat firms in 1989. The revenue consequences of the proposed reforms were calculated on the assumption that any tax-induced changes in levels of R&D represent flows of resources between equally taxed activities and hence do not affect tax revenues. In order to convert changes in R&D stocks into yearly flows for presentation in table 5.14, the 1989 ratio of aggregate R&D expenditure to aggregate R&D stock (20.8 percent) was multiplied by the implied changes in R&D stocks from the reforms.

Using reported foreign and domestic incomes and foreign tax rates to calculate tax liabilities, a reform that permitted firms to deduct 100 percent of their R&D expenses against U.S. income would have cost the U.S. Treasury $1.2 billion from these 189 firms in 1989. In return, U.S. firms would have increased their domestic R&D expenditures by somewhere between $1.4 billion and $2.2 billion, in which the $2.2 billion figure is constructed from the estimated elasticity of R&D flow, while the $1.4 billion figure represents the change in long-run flow corresponding to the stock change constructed from stock demand estimates.[40]

The alternative of apportioning R&D expenses 100 percent on the basis of foreign and domestic sales would have even more dramatic consequences. Again taking observed foreign tax rates to be reliable, sales apportionment would yield an additional $2.5 billion in tax revenue from these 189 firms. As a consequence of sales apportionment, these firms would be expected to re-

40. R&D responses reported in table 5.14 are based on coefficients estimated using the nonmerging sample; they are reported in table 5.7, columns 2 and 4. The estimated change in R&D stock from moving to 100 percent domestic deductibility is $7.0 billion. If there are no adjustment costs, then the first-year change in R&D expenditure might be of this magnitude, with the (smaller) figure in the text indicating the annual flow to which this corresponds.

Table 5.14 Estimated Effects of Two Policy Reforms on R&D and Tax Revenue (current $ millions)

		Change in R&D	
Contemplated Reform	Change in Tax Revenue	Flow Estimates	Stock Estimates
100 percent domestic deductibility	$ −1,166	$2,230	$1,444
Pure sales apportionment	2,542	−2,590	−1,783

Note: Figures are based on 189 multinational firms with $41 billion of R&D expenditures in 1989. Firms are assumed to use the sales apportionment method to allocate their R&D deductions. The flow estimates of R&D change are constructed from the estimated price responsiveness of the nonmerging sample (table 5.7, col. 4). The stock estimates of R&D change are also constructed from the estimated price responsiveness of the nonmerging sample (table 5.7, col. 2), with the estimated stock adjustment converted into an annual flow equivalent by applying the 1989 ratio of R&D flow to R&D stock.

duce their domestic R&D by between $1.8 billion (constructed from stock demand estimates) and $2.6 billion (constructed from flow demand estimates).[41]

These results suggest that R&D undertaken by U.S. multinationals is not likely to change dramatically in response to either of the contemplated tax reforms, largely because the changes themselves are rather minor when framed in the broader context of R&D policy. Nevertheless, the changes in R&D that would accompany the reforms slightly exceed the tax revenue changes they would induce. The U.S. Department of the Treasury (1983) study offers similar findings, though it does so from different premises.[42] In particular, the estimates of R&D price elasticities that can be found in the literature are so small that they would not typically support the kind of conclusions presented in this paper or assumed in the Treasury study.[43] The reason may have to do with the difficulty of finding exogenous price changes. Researchers typically use time-series variation in prices, making it impossible to

41. The stock estimates correspond to a change in R&D stock demand of $8.6 billion.

42. The Treasury study uses the rather low range of elasticities available in the literature but applies them to the *average*, rather than *marginal*, prices firms face; these two differences from the present study roughly equal each other, so the final results are similar (though they can differ by a factor of two).

43. See, for example, Bernstein and Nadiri (1989), who estimate R&D price elasticities to be between −0.4 and −0.5 for a sample of manufacturing firms, while Nadiri and Prucha (1989) find the R&D price elasticity to be much closer to zero for the U.S. Bell System. In a study of Canadian firms, Bernstein (1985) reports estimated R&D price elasticities of between −0.1 and −0.4. Mansfield (1986) and the GAO study (U.S. General Accounting Office 1989) summarize the literature with the conclusion that the consensus range of price elasticities is −0.2 to −0.5. The price elasticity one expects may be a matter of judgment, but many observers find the −0.2 to −0.5 range to be unreasonably close to zero. Certainly firms *claim* to be influenced by after-tax prices; Brown (1984) reports that two-thirds of the executives included in a 1984 Conference Board survey anticipated that tax incentives would influence their R&D expenditures over the next one to three years.

exploit firm-specific variations and raising a number of problems related to omitted variables and the endogeneity of prices.

It is important to interpret the policy simulations with caution. The 189 firms on which the calculations are based do not represent all of the firms that would be affected by the envisioned changes, though these firms perform half of the country's R&D and, because these are the firms with (on average) the highest foreign sales concentrations, they are likely to represent by far the majority of the impact of §1.861–8 changes. There are, however, some limitations in the way that the revenue implications are calculated[44] and also some restrictive assumptions built into the estimated R&D responses to the tax changes.[45]

5.6 Conclusion

The ability of U.S. multinationals to deduct their U.S. R&D expenses against U.S. income for tax purposes has changed many times over the past fifteen years. It appears that U.S. multinationals have changed their R&D spending behavior, albeit mildly, in response. The estimates presented in this paper imply that domestic R&D spending responds to changes in the after-tax price of R&D with an elasticity between -1.2 and -1.6. This elasticity is considerably higher than estimates found in the literature.

44. Some of the firms in the sample may have (in 1989) used the income allocation method to a greater degree than it appears from their financial data. Under the assumption that all of the 189 firms were able to exploit the income allocation method to the limit in 1989, replacing the existing system with 100 percent domestic deductibility was estimated to reduce tax revenues by $368 million a year, while moving to pure sales allocation would raise revenues by $3.341 billion. A second adjustment to estimated tax revenues might come in response to induced changes in R&D. The revenue estimates are constructed to show the first-order revenue effect of changing the deductibility of current levels of R&D; any induced changes are assumed to be financed by reducing the level of other similarly taxed activities. If, instead, greater R&D in the economy generates greater tax revenue, either by drawing resources out of untaxed activities or by stimulating greater aggregate productivity through spillovers into other firms and industries, then tax cuts that stimulate R&D do not reduce tax revenues by as much as first-order calculations suggest.

45. The contemplated policy reforms would influence aggregate R&D, and the endogeneity of the prices of products produced by R&D attenuate the effects of the tax changes on R&D. The model is estimated on the basis of firms' reported R&D; if firms have some flexibility in what they call R&D, then some part of the estimated responsiveness of R&D may reflect reporting choices rather than resource allocations. The estimation of the elasticity parameters ignores the role of the R&D tax credit, which may (or may not) serve to accentuate the incentives created by changes in §1.861-8; consequently, the estimated elasticities could be too great. On the other hand, the estimates also ignore the role of foreign tax credit carryforwards and carrybacks, which probably biases the estimates toward zero. A number of tax changes introduced in 1986 discouraged investment in plant and equipment and may thereby have influenced R&D spending; for an analysis of the interaction between R&D and other capital, see Lach and Schankerman (1989) and Hall and Hayashi (1989). The data are unable to distinguish domestic from foreign R&D, so a firm might reduce its domestic R&D in response to the tax changes and nevertheless appear to be unaffected. The role of aggregate R&D incentives in changing the strategic environments in which firms operate (see, for example, Meron and Caves 1990) is ignored, as are effects of direct government funding of private R&D (for analyses, see Levy and Terleckyj 1983; Scott 1984; and Lichtenberg 1987). It appears that the weight of these limitations is to bias the estimated R&D price elasticities toward zero, but it is difficult to know for sure.

These estimates imply that some proposed changes in the tax treatment of R&D are unlikely to have an enormous impact on the level of research and development in the United States. Nevertheless, by making R&D performed in the United States 100 percent deductible against U.S. taxes, Congress would stimulate between $1.4 billion and $2.2 billion in additional annual R&D spending. This change would reduce U.S. government tax revenues by $1.2 billion annually. An alternative policy of requiring multinationals to allocate their R&D deductions purely on the basis of foreign and domestic sales would reduce their annual R&D by between $1.8 billion and $2.6 billion but would raise $2.5 billion in yearly tax revenues. Whether either of these reform plans represent likely future alternatives may well depend on whether Congress feels that increased R&D or increased tax revenue is a more important national goal.

References

Altshuler, Rosanne. 1988. A dynamic analysis of the research and experimentation credit. *National Tax Journal* 41:453–66.

Auerbach, Alan J. 1983. Corporate taxation in the United States. *Brookings Papers on Economic Activity* 2:451–505.

Bernstein, Jeffrey I. 1985. Research and development, patents, and grant and tax policies in Canada. In *Technological change in Canadian industry*, ed. D. G. McFetridge. Toronto: University of Toronto Press.

Bernstein, Jeffrey I., and M. Ishaq Nadiri. 1989. Rates of return on physical and R&D capital and structure of production process: Cross section and time series evidence. In *Advances in econometrics and modeling*, ed. B. Raj. Dordrecht: Kluwer.

Brown, James K. 1984. *The impact of technological change on corporate and R&D management*. Research Bulletin 170. New York: Conference Board.

Cohen, Wesley M., and Richard C. Levin. 1989. Empirical studies of innovation and market structure. In *Handbook of industrial organization*, ed. R. Schmalensee and R. D. Willig. vol. 2. Amsterdam: North-Holland.

Cohen, Wesley M., Richard C. Levin, and David C. Mowery. 1987. Firm size and R&D intensity: A re-examination. *Journal of Industrial Economics* 35:543–65.

Dixit, Avinash. 1988. International R&D competition and policy. In *International competitiveness*, ed. A. M. Spence and H. A. Hazard. Cambridge, Mass.: Ballinger.

Eisner, Robert, Steven H. Albert, and Martin A. Sullivan. 1984. The new incremental tax credit for R&D: Incentive or disincentive? *National Tax Journal* 37:171–83.

Flaherty, M. Therese. 1984. Market share determination in international semiconductor markets. Working Paper 1-782-004. Cambridge, Mass.: Harvard Business School.

Fullerton, Don, and Andrew B. Lyon. 1988. Tax neutrality and intangible capital. In *Tax policy and the economy*, ed. L. H. Summers. Vol. 2. Cambridge, Mass.: MIT Press.

Griliches, Zvi. 1986. Productivity, R&D, and basic research at the firm level in the 1970s. *American Economic Review* 76:141–54.

———. 1991. The search for R&D spillovers. NBER Working Paper no. 3768. Cambridge, Mass.: National Bureau of Economic Research.

Griliches, Zvi, and Jacques Mairesse. 1984. Productivity and R&D at the firm level. In *R&D, patents, and productivity,* ed. Z. Griliches. Chicago: University of Chicago Press.

Hall, Bronwyn H. 1988. The effect of takeover activity on corporate research and development. In *Corporate takeovers: Causes and consequences,* ed. A. J. Auerbach. Chicago: University of Chicago Press.

Hall, Bronwyn H., and Fumio Hayashi. 1989. Research and development as an investment. NBER Working Paper no. 2973. Cambridge, Mass.: National Bureau of Economic Research.

Hartman, David G. 1985. Tax policy and foreign direct investment. *Journal of Public Economics* 26:107–21.

Hines, James R., Jr. 1990. The flight paths of migratory corporations. Olin Discussion Paper no. 65. Princeton, N.J.: Princeton University.

Hines, James R., Jr., and R. Glenn Hubbard. 1990. Coming home to America: Dividend repatriations by U.S. multinationals. In *Taxation in the global economy,* ed. A. Razin and J. Slemrod. Chicago: University of Chicago Press.

Hines, James R., Jr., and Eric M. Rice. 1990. Fiscal paradise: Foreign tax havens and American business. NBER Working Paper no. 3477. Cambridge, Mass.: National Bureau of Economic Research.

Jaffe, Adam B. 1986. Technological opportunity and spillovers of R&D: Evidence from firms' patents, profits, and market value. *American Economic Review* 76:984–1001.

———. 1988. Demand and supply influences in R&D intensity and productivity growth. *Review of Economics and Statistics* 70:431–37.

Kopits, George F. 1976. Intra-firm royalties crossing frontiers and transfer-pricing behaviour. *Economic Journal* 86:791–805.

Lach, Saul, and Mark Schankerman. 1989. Dynamics of R&D and investment in the scientific sector. *Journal of Political Economy* 97:880–904.

Lawlor, William R., ed. 1985. *Cross-border transactions between related companies: A summary of tax rules.* Deventer: Kluwer.

Levy, David M., and Nestor E. Terleckyj. 1983. Effects of government R&D on private R&D investment and productivity: A macroeconomic analysis. *Bell Journal of Economics* 14:551–61.

Lichtenberg, Frank R. 1987. The effect of government funding on private industrial research and development: A re-assessment. *Journal of Industrial Economics* 36:97–104.

Mansfield, Edwin. 1986. The R&D tax credit and other technology policy issues. *American Economic Review* 76:190–94.

Mansfield, Edwin and Anthony Romeo. 1980. Technology transfer to overseas subsidiaries by U.S.-based firms. *Quarterly Journal of Economics* 94:737–50.

Mansfield, Edwin, Anthony Romeo, and Lorne Switzer. 1983. R&D price indexes and real R&D expenditures in the United States. *Research Policy* 12:105–12.

Mansfield, Edwin, Anthony Romeo, and Samuel Wagner. 1979. Foreign trade and U.S. research and development. *Review of Economics and Statistics* 61:49–57.

Mansfield, Edwin, David Teece, and Anthony Romeo. 1979. Overseas research and development by U.S.-based firms. *Economica* 46:187–96.

McIntyre, Robert S. 1989. Tax Americana. *New Republic* 200 (March 27) 18–20.

Meron, Amos, and Richard E. Caves. 1990. Rivalry among firms in research and development outlays. Harvard University. Mimeograph.

Mose, Vergie. 1989/1990. Corporate foreign tax credit, by industry, 1984. *S.O.I. Bulletin* 9:57–90.

Nadiri, M. Ishaq, and Ingmar R. Prucha. 1989. Dynamic factor demand models, productivity measurement, and rates of return: Theory and an empirical application to

the U.S. Bell System. NBER Working Paper no. 3041. Cambridge, Mass.: National Bureau of Economic Research.
National Science Board. 1989. *Science and engineering indicators—1989*. Washington, D.C.: U.S. Government Printing Office.
National Science Foundation. 1991. *Selected data on research and development in industry: 1989*. Washington, D.C.: NSF.
Pakes, Ariel, and Mark Schankerman. 1984a. An exploration into the determinants of research intensity. In *R&D, patents, and productivity*, ed. Z. Griliches. Chicago: University of Chicago Press.
———. 1984b. The rate of obsolescence of patents, research gestation lags, and the private rate of return to research resources. In *R&D, patents, and productivity*, ed. Z. Griliches. Chicago: University of Chicago Press.
Price Waterhouse. 1991. *Corporate taxes: A worldwide summary* and various individual country guides. New York: Price Waterhouse.
Ravenscraft, D., and F. M. Scherer. 1982. The lag structure of returns to research and development. *Applied Economics* 14:603–20.
Reinganum, Jennifer F. 1989. The timing of innovation: Research, development, and diffusion. In *Handbook of industrial organization*, ed. R. Schmalensee and R. D. Willig. Vol. 1. Amsterdam: North-Holland.
Schankerman, Mark. 1981. The effects of double-counting and expensing on the measured returns to R&D. *Review of Economics and Statistics* 63:454–58.
Scholes, Myron S., and Mark A. Wolfson. 1991. *Taxes and business strategy: A planning approach*. Englewood Cliffs, N.J.: Prentice Hall.
Scott, John T. 1984. Firm versus industry variability in R&D intensity. In *R&D, patents, and productivity*, ed. Z. Griliches. Chicago: University of Chicago Press.
U.S. Congress, Joint Committee on Taxation. 1981. *General explanation of the Economic Recovery Tax Act of 1981*. Washington, D.C.: U.S. Government Printing Office.
U.S. Department of Commerce, Bureau of Economic Analysis. *Survey of current business*. various issues.
U.S. Department of the Treasury. 1983. *The impact of the section 861–8 regulation on U.S. research and development*. Washington, D.C.: U.S. Government Printing Office.
U.S. General Accounting Office. 1989. *The research tax credit has stimulated some additional research spending*. Report GAO/GGD-89-114. Washington, D.C.
Wozny, James A. 1989. The research tax credit: New evidence on its effect. *Proceedings of the National Tax Association* 82:223–28.

Comment Bronwyn H. Hall

James Hines's paper addresses the question of whether the complex and frequent changes to the tax treatment of R&D performed by multinational corporations in the United States during the 1980s had any incentive effects on the actual level and direction of such R&D. Interest in this topic is motivated by a general interest in the optimal tax treatment of R&D and by specific interest in the effects of the many changes incorporated into the tax legislation of the Reagan era. Hines summarizes the features of the tax code that apply to

Bronwyn H. Hall is assistant professor of economics at the University of California at Berkeley and a faculty research fellow of the National Bureau of Economic Research.

R&D and uses them to construct tax prices for R&D directed toward domestic and foreign sales. He then estimates the factor demand equation for R&D as a function of these changing tax prices and uses the estimates to perform a series of policy simulations. His conclusions are twofold: first, the tax price elasticity of R&D expenditure is actually fairly high (approximately unit); second, the overall effects of the changes were not that large when benefits (in terms of increased R&D spending) and costs (reduced tax revenue) are canceled out.

The paper consists of two parts: a careful description of the changes in the tax treatment of R&D during the 1980s, with an emphasis on the implications of these changes for multinationals, and an empirical evaluation of the responsiveness of R&D to these changes for 116 multinational firms. The first part performs a real service to the economics research community, because these tax changes are complex and difficult to summarize in a concise way. Hines does an excellent job of presenting them and analyzing their likely impact. I do not have much to add to this presentation, except to emphasize that the most important subsidy to R&D that arises from the combined effects of the tax system facing multinationals is due to a part of the system not under control of the U.S. government: the low tax rates imposed on the income that is repatriated to the United States as royalty income (see table 5.2 of the paper). To the extent that corporations are in an excess foreign tax credit situation, as most of them are (see table 5.3 of the paper), this subsidy is substantial.

Most of my comments will be directed toward the second part of the paper, which presents empirical evidence on the effects of these tax changes. I want to emphasize at the outset that, in spite of my reservations about what can and cannot be learned from these data, I found reading and thinking about the research described in this paper extremely helpful, and I compliment Hines both on his clear presentation of complex tax laws and on the careful empirical work with which he measures their effects. My remarks begin with a general discussion of the characteristics of R&D investment and their implications for interpretation of the results here; this is followed by some discussion of the interpretation of the tax price formulas presented in the paper. Finally, I make more specific comments on the model and empirical results.

The first important fact about R&D is that its output is largely nonrivalrous, which implies that a large fraction of the results of R&D can be used in many markets simultaneously. This is in fact a major cause of the movement of corporations across borders: a desire to reap the fruits of a unique rent-producing factor (a new innovation) in a broader market. Only a small fraction of R&D will be performed specifically to satisfy the requirements of a particular market. This limits the extent to which R&D can be directed toward sales in a single foreign market and implies that one does not expect a strong tax price response of R&D expenditures to changes in allocation rules. This does not mean, however, that an overall response to changes in tax prices (which may be induced by changes in allocation rules) would not be observed, and this is exactly what Hines documents in this paper. Later in this discussion, I will come back to this issue of what Hines can and cannot measure with the data he has available.

From a policy perspective, other implications of the nonrivalrous nature of R&D spending are twofold: first, if much of the output of R&D spending is shared across domestic and foreign sales, worries about subsidizing foreign consumption as well as domestic while subsidizing R&D spending do not seem that important because the cost is small. Second, the fact that R&D has positive externalities suggests that too little R&D will be performed if the performance is left entirely to a private sector facing full prices for R&D. As Hines says, this is the view taken by Congress quite frequently when writing tax legislation. If you believe the positive externality argument, you would not choose the tax treatment of R&D as an instrument for raising tax revenue. To put it another way, the benefits due to increased R&D spending by corporations, properly measured, may exceed the cost of the tax subsidy by amounts greater than that which are measured by Hines when he simply adds up the additional R&D thus induced.

A second, frequently documented, characteristic of R&D is its relative lack of volatility compared to ordinary investment (see, among others, Bernstein and Nadiri 1989; Hall and Hayashi 1989; Lach and Schankerman 1989; Himmelberg and Petersen 1990; Hall 1992), a fact that most of these researchers interpret as implying fairly high adjustment costs for R&D spending. This view is supported by the fact that about half of R&D spending is the salaries of highly trained technical personnel, who are not easily hired and fired without losing the part of the firm's R&D capital that is embodied in their human capital. This has two implications for the Hines paper: first, the relatively large price elasticity he observes for R&D spending is somewhat surprising and worth further investigation in order to reconcile it with the results of others who have estimated factor demand equations for R&D; second, the omission of adjustment costs from his model of production could be an obstacle to interpretation of his results relative to those of others.

The centerpiece of Hines's theoretical and empirical analysis of the R&D behavior of multinationals is the derivation of the tax prices faced by these firms, which are treated as the primary predetermined instruments which shift the demand for R&D investment. These prices are derived by positing a profit-maximizing firm with a profit function which is additively separable in the foreign and domestic operations. For all the reasons I suggested earlier, the weakest part of the model is that R&D must be specifically directed toward foreign or domestic markets in this framework and that these markets are not allowed to interact. In fact, in the estimation, Hines allows the responsiveness of R&D to the foreign sales tax price to differ from that for the domestic, and the resulting estimated coefficient ($\rho \cong 0.2$) suggests that R&D directed specifically toward foreign sales is "piggybacking" on domestic R&D by a fairly wide margin (since ρ would be unity if the two markets were completely separate).

To analyze somewhat more clearly the tax prices Hines derives and the incentives for investment they provide, I make a slight change in notation. In so doing, I also subscript the variables explicitly by i (firm) and t (year) in order to highlight the sources of variation in these prices. Define the share of sales which is foreign as

$$f_{it} = S^*/(S + S^*)$$

and the worldwide R&D intensity as

$$r_{it} = \bar{R}/(S + S^*).$$

Both of these variables are observable in the data. With these definitions, text equations (6) and (7) can be written

$$\text{(C1)} \qquad PR = \frac{1 - \tau_{it} + \tau_{it}\alpha_t f_{it}}{1 - \tau_{it}(1 - \alpha_t f_{it} r_{it})}$$

and

$$PI = \frac{1 - \tau_{it}}{1 - \tau_{it}(1 - \alpha_t f_{it} r_{it})}.$$

These equations imply that, for multinationals, R&D directed only toward domestic sales is *more* expensive than other ordinary (nondepreciable) expenses to the extent that the allocation rules do not allow such R&D to be completely allocated to domestic income ($\alpha_t > 0$).[1] However, the reverse is true for R&D directed toward foreign sales. Using the same notation, text equations (13) and (14) for the foreign tax prices become

$$\text{(C2)} \qquad PR^* = \frac{1 - \tau_{it} + \tau_{it}\alpha_t f_{it}}{1 - w^* - \tau_{it}\alpha_t f_{it} r_{it}}$$

and

$$PI^* = \frac{1 - w^*}{1 - w^* - \tau_{it}\alpha_t f_{it} r_{it}},$$

where I have suppressed the firm and year subscripts for w^* because that reflects Hines's construction of this variable. These equations imply that the relative price of foreign R&D differs from that of ordinary inputs by two terms:

$$\frac{PR^*}{PI^*} = 1 - \frac{\tau_{it} - w^*}{1 - w^*} + \frac{\tau_{it}\alpha_t f_{it}}{1 - w^*}.$$

1. Such R&D will still be cheaper than ordinary investment, however, to the extent that ordinary investment must be depreciated over several years rather than expensed.

Thus, the relative price of this type of R&D is reduced by a factor proportional to the difference in tax rates in the two localities and increased by a term similar to that for domestic R&D; the latter term arises because of the allocation rules. For plausible values of the parameters, the first term dominates and R&D is subsidized relative to other inputs to the extent that it is a cost of foreign sales. Table 5A.1 emphasizes the point that the dominant difference in these tax prices is the light taxation of foreign royalty income for firms with excess foreign tax credits. To first order, the relative subsidy to foreign-directed R&D is equal to the difference in tax rates on domestic and foreign income for these firms and does not depend on the allocation rules or share of foreign sales. It is all the more unfortunate, then, that Hines does not have good measures of w^* available and must use a single value, 5 percent, for all firms.

Turning to a discussion of the measurement of the impact the tax law changes during the 1980s had on R&D spending, which is the main focus of the paper, I first point out that estimating the effects of these tax changes on R&D is a challenge, using the data that are available. From Compustat, one has relatively good data on the behavior of the multinational firm as a whole: sales, R&D spending, profit and loss statement, and so forth. However, the only data available that separate foreign and domestic activities are for sales and profits, from the Geographic Segment File. There are no public data available[2] on R&D directed toward foreign sales (or R&D performed in foreign countries), if indeed such a concept makes any sense. The implication is that ultimately the estimated response of R&D spending to two *different* tax prices, one for R&D directed toward domestic sales and one for R&D directed toward foreign sales, is identified only through strong functional form assumptions. This forces Hines to use a rather peculiar hybrid model, one that describes the investment response to R&D tax prices by deriving it from a traditional profit or production function which does not contain any costs of adjustment for R&D (or ordinary) capital and which assumes additively separable profit functions across domestic and foreign operations. For all the reasons I mentioned earlier, this latter assumption seems highly questionable in the case of R&D spending. The former leads to confusion in the estimation, since it is not clear whether the appropriate variable is the stock of R&D, which is what would enter the production or profit function, or the flow of R&D, which is what would respond to the tax price. If adjustment costs were zero, this would not matter, but most researchers have estimated very substantial adjustment costs for R&D (references cited earlier).

In spite of these reservations, I think the derivation of the actual estimating

2. The Bureau of the Census collects data at the firm level for the National Science Foundation, but such data are confidential and not released to the public except as aggregate statistics. See National Science Board (1991).

Table 5A.1 **Illustrative Tax Prices for Multinational Corporations***

Years†	alpha	r(R/S)	PR	PI	PR/PI	PR*	PI*	PR*/PI*
1982–86	0.0%	0.0%	1.00	1.00	1.00	0.63	1.00	0.63
	0.0	5.0	1.00	1.00	1.00	0.63	1.00	0.63
	0.0	10.0	1.00	1.00	1.00	0.63	1.00	0.63
1988–89	36.0	0.0	1.08	1.00	1.08	0.68	1.00	0.68
	36.0	5.0	1.08	1.00	1.08	0.69	1.00	0.68
	36.0	10.0	1.07	0.99	1.08	0.69	1.01	0.68
1987	50.0	0.0	1.12	1.00	1.12	0.71	1.00	0.71
	50.0	5.0	1.11	0.99	1.12	0.71	1.00	0.71
	50.0	10.0	1.10	0.99	1.12	0.71	1.01	0.71
1977–81	70.0	0.0	1.16	1.00	1.16	0.73	1.00	0.73
	70.0	5.0	1.15	0.99	1.16	0.74	1.01	0.73
	70.0	10.0	1.14	0.98	1.16	0.74	1.01	0.73

Note: Foreign sales = 35%; Corporate tax rate = 40%; Foreign tax rate = 5%.
*Tax prices are for a firm with excess foreign tax credits.
†Shows the period for which the allocation rule was approximately equal to alpha.

equation is a tour de force, given the lack of the variables needed for the original two-region model. Hines begins with profit functions for domestic and foreign sales separately as functions of domestic and foreign R&D and other inputs, respectively, and derives a kind of factor demand equation for total R&D as a function of tax prices for the two different types of R&D. This factor demand equation is in the dual form, where total R&D spending is a function of all four tax prices (because of substitution effects in inputs). Equation (25) of the paper makes it clear that if the production functions for the two regions, foreign and domestic, are the same, so that $\beta_1 = \beta_3$ and $\beta_2 = \beta_4$, there is in effect a single price for each input which is the weighted sum of foreign and domestic prices with weights equal to the respective shares of R&D in the total R&D expenditure. The fact that the estimated responses differ by a factor of four or so implies that the production function does not have the simple additively separable form assumed by Hines or that the measurement error in the foreign tax price of R&D is very large. I incline more toward the first explanation, although the second must also be playing a role.

Hines uses equation (27) of the paper to estimate the price responsiveness of R&D investment in several different ways; all of them involve using firm and year dummies, so that the only variability which is being used is that within firm. The key experiment is to relate movements of real R&D expenditures over time to changes in the prices of R&D, which are given by equations (C1) and (C2) (in this comment). These equations show that the key sources of variability across firms are changes in the fraction of sales that are foreign, changes in their marginal tax rates, and *changes in R&D intensity.* The tax prices are inversely proportional to this last variable; because R&D itself is the dependent variable, this means that *negative* simultaneity bias is likely to be present in the ordinary least squares estimates. For this reason, I prefer the instrumental variable estimates reported in the paper, although I think the choice of instrument (average firm R&D intensity for 1984–86) is not likely to be completely free of this bias. It is possible that the relatively large price elasticities that Hines obtains (−1.0 rather than the −0.2 to −0.5 range reported in the literature; see the paper for references) are due to this simultaneity bias.

In summary, although I have doubts about the exact methodology used and numbers reported in this paper, I think Hines has shown us the way to do a far more careful evaluation of the effects of tax policy on R&D. I would hope that future work that examines the impact of the R&D tax credit on the R&D behavior of corporations would take advantage of the tax price variability available when one studies multinational corporations, which are an increasingly large share of the firms involved in R&D. It is quite possible that changes in R&D allocation rules have a far greater impact than playing with the R&D tax credit.

References

Bernstein, J. I., and M. I. Nadiri. 1989. Rates of return on physical and R&D capital and structure of production process: Cross section and time series evidence. In *Advances in econometrics and modeling,* ed. B. Raj. Dordrecht: Kluwer.

Hall, Bronwyn H. 1992. Investment and R&D at the firm level: Does the source of financing matter? University of California at Berkeley and National Bureau of Economic Research. Photocopy.

Hall, Bronwyn H., and Fumio Hayashi. 1989. Research and development as an investment. Working Paper no. 2973. Cambridge, Mass.: National Bureau of Economic Research.

Himmelberg, Charles P., and Bruce C. Petersen. 1990. R&D and internal finance: A panel study of small firms in high-tech industries. Federal Reserve Bank of Chicago. Photocopy.

Lach, S., and M. Schankerman. 1989. Dynamics of R&D and investment in the scientific sector. *Journal of Political Economy* 97:880–904.

National Science Board. (1991). *Science and engineering indicators 1991.* Washington, D.C.: Government Printing Office.

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