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MACROECONOMIC EFFECTS OF A 10-YEAR INFRASTRUCTURE AND TAX PLAN

John W. Diamond, Ph.D.
Edward A. and Hermina Hancock Kelly Fellow in Public Finance and Director, Center for Public Finance, Rice University's Baker Institute

George R. Zodrow, Ph.D.
Allyn R. and Gladys M. Cline Chair of Economics and Baker Institute Rice Faculty Scholar, Rice University
International Research Fellow, Oxford University Centre for Public Finance

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George R. Zodrow, Ph.D.
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Executive Summary

In this paper, we use the Diamond-Zodrow computable general equilibrium model of the U.S. economy to simulate the dynamic macroeconomic effects of a fiscal plan that uses revenues from various tax changes proposed by the Joe Biden 2020 presidential campaign ($3.3 trillion over 10 years, as estimated by the Tax Foundation [Watson, Li, and LaJoie, 2020]) to finance 10 years of public investment. Public investment leads to an increase in the public capital stock, which is assumed to enhance the productivity of private factors of production. Once the increase in public investment ends after 10 years, we assume that the tax changes are permanent and the revenues are used to cover depreciation on the incremental increase in the public capital stock so that the size of the public capital stock is held constant, with all remaining revenues used to finance increases in transfer payments.

The macroeconomic effects of the plan reflect the net impact of (1) the rise in productivity associated with the increase in the public capital stock as well as the effects of the subsequent increase in government transfers, and (2) the increases in distortionary taxation of business, capital, and labor income used to finance those expenditures. Our simulation results indicate that these net macroeconomic effects depend significantly on the extent to which the increase in the public capital stock increases the productivity of private capital and labor, which depends on the output elasticity of public capital, θ_G.

When this elasticity is set at the central estimate (θ_G = 0.05) used in a recent analysis of infrastructure investment by Ramey (2020), the increases in output associated with the increase in productivity due to the larger public capital stock are not quite large enough to offset the distortionary costs of the taxes used to finance the increase in public investment as well as the subsequent increase in transfer payments. As a result, GDP declines by 0.2% 10 years after enactment and in the long run, private investment falls by 5.3% 10 years after enactment and by 2.5% in the long run, and the stock of ordinary capital declines by 1.3% 10 years after enactment and by 1.4% in the long run, while labor supply increases by 1.0% 10 years after enactment and by 0.7% in the long run. Relatively mobile firm-specific capital declines by 2.9% 10 years after enactment and by 1.5% in the long run.

By comparison, when the output elasticity of public capital is set at the higher end of the range of empirical estimates reviewed by Ramey (θ_G = 0.12), the increases in output associated with the increase in productivity due to the larger public capital stock more than offset the distortionary costs of the taxes used to finance the increase in public investment and subsequent transfer payments. In this case, GDP increases by 0.4% 10 years after enactment and by 1.1% in the long run, private investment falls by 5.2% 10 years after enactment and by 1.3% in the long run, and the stock of ordinary capital declines by 1.4% 10 years after enactment and by 0.3% in the long run, while labor supply increases by 0.9% 10 years after enactment and by 0.7% in the long run. Relatively mobile firm-specific capital declines by 3.7% 10 years after enactment and by 2.4% in the long run.

I. Overview

In this paper we examine the dynamic macroeconomic effects of a fiscal plan that involves 10 years of government investment that permanently expands the stock of public capital and is fully financed with higher taxes. The amounts of government investment spending and tax revenue raised are assumed to be $3.3 trillion over 10 years, which corresponds to the Tax Foundation's (Watson, Li, and LaJoie, 2020) static estimate of the revenues that would be raised under the initial tax plan proposed by the 2020 presidential campaign of Joe Biden, as detailed below. We assume that all of the revenues are used to finance public investment, which leads to an increase in the public capital stock that is assumed to enhance the productivity of the private factors of production. The Congressional Budget Office (CBO) (2016) argues that such public investment expenditures include spending on traditional infrastructure, on research and development (R&D), and on education, but do not include expenditures on health care.[1] Our modeling of public capital most closely reflects the effects of spending on traditional infrastructure.

We perform our analysis within the context of an extended version of the Diamond-Zodrow (DZ) dynamic, overlapping generations, computable general equilibrium (CGE) model of the U.S. economy. The basic model is designed to examine both the short-run and the long-run macroeconomic effects of tax policy changes. In this analysis, we extend the model to include government investment expenditures that increase the public capital stock and enhance the productivity of private labor and capital.

The paper proceeds as follows. In the following section, we describe the features of the 10-year tax-financed government investment plan that we analyze. Section III provides a brief description of our computable general equilibrium model, including the incorporation of government investment expenditures. Our simulation results are reported in Section IV. The final section summarizes the results and offers some caveats.

II. Details of the Fiscal Plan Analyzed

The tax and the expenditure components of the fiscal plan we analyze are detailed below.

A. Tax Changes

We model all of the major elements of the tax plan initially proposed by the Biden campaign.[2] Static estimates of the revenue raised by the original plan vary considerably. For example, the Tax Policy Center (Mermin et al., 2020) estimates a total revenue gain

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[1] CBO (2016, p. 3) treats expenditures on health care as government transfers on the grounds that "the link between productivity and health care expenditures is much less clear in the empirical literature than the link between productivity and spending on physical capital, education and R&D."

[2] Many of these provisions are also included in the current tax plan proposed by the Biden administration to finance the proposed $2.25 trillion American Jobs Plan.

over nine years (2022–2030) of $2.1 trillion or roughly $2.3 trillion over 10 years, the Tax Foundation (Watson, Li, and LaJoie, 2020) estimates a revenue gain of $3.3 trillion over the 10-year period 2021–2030, the Penn-Wharton Budget Model (2020) estimates revenues of $3.4 trillion over the same period, and the American Enterprise Institute (Pomerleau, DeBacker and Evans, 2020; Pomerleau and Seiter, 2020) has the highest revenue estimate—$3.8 trillion over 2021–2030. Because the Tax Foundation estimate roughly equals the average of these estimates and includes a detailed year-by-year breakdown of revenue increases, we use those estimates in our simulations; they are reproduced in Table II.1 below.

As shown in the table, the major provisions of the tax plan we analyze are

- Social Security payroll taxation at a rate of 12.4% on earnings in excess of $400,000 (under the current system, 2021 wage earnings in excess of a cap of $140,000 are not subject to tax);
- An increase in the top personal income tax rate from its current level of 37% back to the pre-TCJA rate of 39.6% (this rate increase is currently scheduled to occur at the end of 2025);
- Reintroduction of the "Pease limitation" on itemized deductions for incomes in excess of $400,000;
- Taxation of capital gains and dividends at personal income tax rates for incomes in excess of $1 million and the replacement of step-up of basis for capital gains transferred at death with carryover of basis;
- Limiting the tax benefit of itemized deductions to 28% of the value of the deduction for incomes in excess of $400,000;
- Phasing out of the 20% of qualified business income deduction for pass-through business entities for incomes in excess of $400,000;
- An expansion of the child tax credit to a maximum of $3,000 with a $600 bonus for children under the age of 6 and full refundability;
- An expansion of the child and dependent care tax credit to a maximum value of $8000 with up to 50% refundability;
- The introduction of a first-time home buyer tax credit of up to $15,000;
- A restoration of the exemption levels and tax rates under the gift and estate tax to 2009 levels;
- An increase in the corporate income tax rate to 28% from its current level of 21%;
- The imposition of a 15% corporate minimum tax on financial income; and
- The doubling of the effective tax rate on global intangible low-taxed income (GILTI) to 21%, coupled with the elimination of the exemption of a deemed 10% return on qualified business asset investments, and the imposition of GILTI on a country-by-country basis.

The Tax Foundation's static estimates of the revenue effects of these provisions are provided in Table II.1.

Table II.1 Revenue Estimates for the Biden Tax Plan

Conventional and Preliminary Dynamic Revenue Effect of Biden's Tax Plans (Billions of Dollars)

Proposal	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2021-2030
1. Apply a Social Security payroll tax of 12.4% to earnings above $400,000	$73.2	$78.5	$81.3	$80.7	$79.5	$80.8	$83.9	$87.1	$88.1	$86.8	$819.9
2. Raise the top ordinary income tax rate from 37% to 39.6%	$25.1	$29.0	$30.4	$31.1	$32.5	$0.0	$0.0	$0.0	$0.0	$0.0	$148.1
3. Reactivate the Pease limitation for income above $400,000	$16.2	$18.8	$19.7	$20.4	$21.4	$0.0	$0.0	$0.0	$0.0	$0.0	$96.6
4. Tax capital gains and dividends at 39.6 percent on income over $1 million and repeal step-up in basis	$14.2	$27.1	$39.5	$42.1	$45.8	$49.5	$56.9	$61.8	$64.8	$67.6	$469.4
5. Limit the tax benefit of itemized deductions at 28% of value for those earning over $400,000	$23.7	$27.7	$28.9	$29.7	$31.2	$25.3	$27.7	$28.7	$29.7	$31.0	$283.5
6. Phase out qualified business income deductions for income over $400,000	$29.9	$34.4	$35.8	$37.3	$39.6	$0.0	$0.0	$0.0	$0.0	$0.0	$177.1
7. Expand the Child Tax Credit (CTC) to $3,000 maximum value, $600 bonus for children under 6, and make the CTC fully refundable with no phase-in thresholds	-$105.5	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	-$105.5
8. Expand the Child and Dependent Care Tax Credit (CDCTC) to a maximum value of $8,000 and increase the refundability percentage to a maximum of 50 percent	-$6.0	-$7.0	-$7.2	-$7.5	-$7.9	-$8.3	-$8.7	-$9.0	-$9.4	-$9.7	-$80.7
9. Provide a First-Time Homebuyer Credit up to $15,000 in value	-$12.0	-$14.0	-$14.5	-$15.0	-$15.9	-$16.9	-$17.8	-$18.8	-$19.4	-$20.2	-$164.6
10. Restore the gift and estate tax to 2009 levels	$26.5	$28.3	$30.0	$30.9	$32.4	$31.1	$25.5	$24.1	$25.5	$26.5	$280.7
11. Raise the corporate income tax rate to 28%	$40.9	$78.0	$96.0	$106.3	$115.8	$117.4	$118.5	$122.7	$125.8	$128.9	$1,050.8
12. Impose a 15 percent corporate minimum tax on book income	$7.9	$15.1	$18.6	$20.5	$22.3	$22.7	$22.9	$23.7	$24.3	$24.9	$202.7
13. Double the tax rate on GILTI, eliminate the exemption for deemed returns to QBAI, and impose GILTI on a country-by-country basis	$16.0	$29.5	$34.7	$39.2	$43.1	$28.5	$26.9	$26.3	$24.3	$21.2	$289.7
14. Miscellaneous credits	-$6.6	-$9.1	-$11.0	-$11.8	-$12.9	-$14.7	-$15.7	-$16.6	-$17.5	-$18.4	-$134.3
Total Conventional Revenue	**$143**	**$336**	**$382**	**$404**	**$427**	**$315**	**$320**	**$330**	**$336**	**$339**	**$3,333**
Total Dynamic Revenue	**$129**	**$284**	**$314**	**$343**	**$358**	**$306**	**$267**	**$260**	**$262**	**$259**	**$2,782**

Source: Tax Foundation (Watson, Li, and LaJoie, 2020, Table 4, p. 9).

B. Expenditure Changes

As noted above, we assume that all of the $3.3 trillion in revenues raised with these tax increases is used to finance public investment, which increases the public capital stock. Our modeling of public investment most closely reflects the effects of spending on traditional infrastructure and is not intended to model the specific public investment components of the Biden expenditure plan.

C. Taxes and Expenditures Beyond Year 10

We assume that the tax changes enacted to finance public investment in the first 10 years after enactment of the fiscal plan continue indefinitely. However, we assume that the public investment plan ends after 10 years. To minimize the allocative effects of the tax revenues raised after year 10, we assume that—beyond the revenues needed to cover depreciation on the additional increment to the public capital stock—these revenues are used to finance an increase in all income transfers other than Social Security. It should be remembered, however, that our simulations effectively analyze a spending plan that consists of 10 years of public investment followed by increased income transfers in perpetuity that also affect the simulated results, for example, by reducing labor supply as consumers "purchase" more leisure.

III. Overview of the Diamond-Zodrow Model

This section provides a short description of the model used in this analysis.[3] We first provide a description of the basic model and then describe the extensions to explicit consideration of government public investment that enhances the productivity of private sector labor and capital. Key parameter values used in the simulations are provided in the appendix.

Versions of the model have been used in analyses of tax reforms by the U.S. Department of the Treasury (President's Advisory Panel on Federal Tax Reform, 2005), the Joint Committee on Taxation (2005), and in numerous recent tax policy studies (Diamond and Zodrow, 2007, 2008, 2013, 2014, 2015, 2018, 2020, forthcoming; Diamond, Zodrow, Neubig, and Carroll, 2014; Diamond and Viard, 2008).

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[3] For more details, see Zodrow and Diamond (2013), Diamond and Zodrow (2015), and Gunning, Diamond, and Zodrow (2008). The model combines various features from other broadly similar CGE models, including those constructed by Auerbach and Kotlikoff (1987), Goulder and Summers (1989), Goulder (1989), Keuschnigg (1990), and Fullerton and Rogers (1993).

A. The Basic Model

The domestic component of the DZ model includes both corporate and noncorporate composite consumption goods and owner-occupied and rental housing. The corporate sector is subject to the corporate income tax and subdivided into domestic and multinational firms as described below, and the "noncorporate" sector—which includes S corporations as well as LLCs, LLPs, partnerships and sole-proprietorships—is taxed on a "pass-through" basis at the individual level. Firms combine labor and several different types of capital to produce their outputs at minimum after-tax costs. The time paths of investment are determined by profit-maximizing firm managers who take into account all business taxes as well as the costs of adjusting their capital stocks, correctly anticipating the macroeconomic changes that will occur as a result of any change in the tax structure. Firms finance their investments with a mix of equity and debt, choosing an optimal debt-asset ratio that balances the costs and benefits of additional debt, including its tax advantages.

On the consumption side, household supplies of labor and saving for capital investment and demands for all housing and non-housing goods are modeled using an overlapping generations structure. A representative individual in each generation (1) spends a fixed number of years working and in retirement, (2) makes consumption and labor supply choices to maximize lifetime welfare subject to a lifetime budget constraint that includes personal income and other taxes and a fixed number of hours available for work and leisure, and (3) makes a fixed "target" bequest.

The government purchases the composite goods and makes transfer payments, which it finances with the corporate income tax, a progressive tax on labor income after deductions and exemptions, and constant individual-level average marginal tax rates applied to capital income in the form of interest receipts, dividends, and capital gains. The modeling of corporate income tax revenues includes explicit consideration of deductions for depreciation or immediate expensing for both new and old assets (which are treated separately), other production and investment incentives, and state and local sales, income, and property taxes.

The DZ model also includes a simplified foreign or "rest-of-the-world" (RW) sector, with international trade and capital movements between the U.S. and RW. The model includes U.S. and foreign multinational enterprises (MNEs), both parents and subsidiaries, which determine the allocation across the U.S. and RW of relatively mobile firm-specific capital (*FSK*) that earns above-normal returns as well as the allocation of less mobile ordinary capital that earns normal returns.[4] *FSK* captures a wide variety of intangibles, including patents, copyrights, designs, or other proprietary technology, R&D spending, new software, unique data bases, brand names and trademarks, and good will and reputation, which are coupled with unique managerial or organizational skills or knowledge of production

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[4] The assumption of differential international mobility of capital follows Becker and Fuest (2011); see also Zodrow (2010).

processes and distribution networks to create a factor that is assumed to be fixed in total supply and grows at the exogenously specified growth rate (and is thus independent of any tax changes), is unique to the firm, and allows it to permanently earn above-normal returns.[5] The model also allows for income shifting by MNEs in response to tax differentials across countries,[6] the use of intermediate goods that are traded between the affiliates of the MNEs,[7] and international trade in the goods produced by the MNEs in the U.S. and RW. To simplify the analysis, RW is modeled as consisting entirely of the MNE sector (both U.S.-MNE subsidiaries and RW-MNE parents); we thus effectively assume that the remainder of RW is unaffected by the tax reforms in the United States that we analyze. We assume that the tax system in RW is fixed and thus does not respond to changes in the U.S. tax structure. In particular, the U.S. tax reforms considered in this paper include an increase and expansion of the existing U.S. minimum tax regime on foreign source income (global intangible low-taxed income or GILTI). We do not consider the possibility, currently being discussed, of the enactment of similar minimum taxes in the Organisation for Economic Co-operation and Development (OECD), perhaps coordinated with the United States; if enacted, these taxes would have the effect of dampening to some extent the tax-induced outflows of firm-specific capital that occur in our model.

Note that the model includes several fundamental assumptions that are typical of such dynamic computable general equilibrium (CGE) models, including those used by the Joint Committee on Taxation (see Diamond and Moomau, 2003 and Auerbach and Grinberg, 2017 for general discussions) and the Congressional Budget Office (Nelson and Phillips, 2019), as well as the models cited above. Specifically, all markets are assumed to be in equilibrium in all periods, and the economy must always begin and end in a steady-state equilibrium, with all of the key macroeconomic variables growing at an exogenous growth rate that equals the sum of the population and productivity growth rates. Note that this implies that tax changes do not affect the long-term growth rate in the economy; for example, a tax reform might increase the levels of GDP relative to the steady state levels in the absence of reform for many years after the enactment of reform, but eventually GDP will grow at the fixed steady-state growth rate of the economy.

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[5] The modeling of firm-specific capital generally follows Bettendorf, Devereux, van der Horst, Loretz, and de Mooij (2009), de Mooij and Devereux (2011), Auerbach and Devereux (2018), and McKeehan and Zodrow (2017). Numerous recent analyses have stressed the increasing importance of the combination of intellectual capital and organizational and managerial skill, including an OECD study by Demmou et al., (2019) as well as Hassett and Shapiro (2011), Peters and Taylor (2017), and Ewens et al. (2020). These studies suggest that such firm-specific capital may be 40% or more of total capital.

[6] For recent discussions on the controversial issue of the extent of income shifting by U.S. multinationals, see Dharmapala (2014, 2018), Clausing (2020a, b), and Blouin and Robinson (2020).

[7] The inclusion of intermediate goods in the production functions of MNE parent firms and subsidiaries follows Desai, Foley, and Hines (2009).

Our model also assumes a full employment equilibrium in the labor market in each period and thus is not well-suited to analyzing fiscal policies designed to stimulate an economy with high unemployment. Any simulated changes in hours worked necessarily reflect changes in labor supply and demand in response to tax-induced changes in prices and incomes within the context of a full-employment economy. These include the effects of any increases in government transfers, which reduce labor supply as individuals choose to "consume" more leisure because their income level has increased.

B. Extensions of the Basic Model

Modeling Government Public Investment Expenditures

As noted above, in this analysis we extend our model to include explicitly the effects of government public investment expenditures, including their effects on private sector productivity. To simplify the analysis and because the existing data mostly estimate the average productivity of aggregate government investment, we follow CBO (2016) and Ramey (2020) in assuming a single type of government public or "infrastructure" investment and a single homogeneous stock of public capital. As noted previously, government investment can only affect the levels of GDP in our model, which is characterized by an exogenously specified growth rate.[8] Our modeling of government infrastructure investment proceeds as follows.

First, we add a government or "public" capital stock, K^G, to the model, which reflects the national (combined federal and state/local) stock of nondefense public capital.[9] Government public investment augments the public capital stock and consists of government purchases of the investment good in the economy, which is produced by the corporate sector. We also model the production of government consumption goods and services explicitly, which are assumed to be produced with public capital and government labor using a Cobb-Douglas formulation, similar to those that we use for the other production functions in the model.

Government spending is thus composed of government nondefense infrastructure investment that augments the national stock of public capital and covers replacement investment, the payment of compensation to government employees, the payment of income transfers, interest payments on the national debt (the debt-GDP ratio is held constant), and the purchase of exogenously-specified defense goods. Any government budget imbalances are offset by changes in income transfers.

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8 See Glomm and Ravikumar (1997) and Angelopoulos, Malley, and Philippopoulos (2008) for analyses of models in which public investment can affect an endogenous growth rate. Annabi (2017), discussed further below, shows large productivity effects for education spending in a model with human capital accumulation and endogenous growth.

9 We assume that defense expenditures (both investment and consumption) are exogenous and increase at the fixed growth rate of the economy.

The stock of public capital, which may be augmented by government investment, is assumed to enter into the production functions in each sector and to enhance the productivity of private sector inputs. Specifically, following Ramey (2020), we assume that the total national stock of public capital K^G, including federal public capital K^{GF}, and state and local K^{GSL} public capital, enters the production function multiplicatively, with production characterized by constant returns to scale in private inputs that reflect Cobb-Douglas technology. For example, in the corporate (C) sector, the production function is

$$X^C(t) = A^C[K^C(t)]^{\gamma C}\,[(EL^C(t)]^{1-\gamma C}\,[K^G(t)]^{\theta G},$$

where output $X^C(t)$ and labor $EL^C(t)$ are measured at the end of the current period (t), the stocks of private capital $K^C(t)$ and government capital $K^G(t)$ are measured at the beginning of period (t), reflecting investment that occurred at the end of period (t-1), and θ_G is the constant elasticity of corporate sector output with respect to an increase in the stock of public capital (discussed further below). The other five production sectors in the model (the multinational sector, the noncorporate pass-through sector, the owner-occupied and rental housing sector, and the government consumption goods and services sector) are treated analogously.

The public capital stock is assumed to depreciate exponentially at rate δ^G, and to be augmented by new public investment. We consider only increases in federal government investment expenditures I^{GF}. Moreover, we follow CBO (2016) in assuming that a fraction ϕ^{GSL} of federal government public investment expenditures is offset by reductions in state and local government public investment expenditures. This substitution allows reductions in state sales taxes that total $\phi^{GSL}\,I^{GF}$.

Thus, the evolution of the national public capital stock is captured by

$$K^{GF}(t) = (1-\delta^G)\,K^{GF}(t-1) + I^{GF}(t),$$

and the evolution of the state and local public capital stock is

$$K^{GSL}(t) = (1-\delta^G)\,K^{GSL}(t-1) + I^{SL}(t) - \phi^{GSL}\,I^{GF}(t).$$

The time path of the total public capital stock is thus

$$K^G(t) = K^{GF}(t) + K^{GSL}(t) = (1-\delta^G)\,[K^{GF}(t-1) + K^{GSL}(t-1)] + (1 - \phi^{GSL})\,I^{GF}(t) + I^{SL}(t).$$

A separate issue is whether the productivity effects of government public investment expenditures should be phased in to reflect delays in their installation and effectiveness. Ramey (2020) phases the productivity effects of government investment expenditures over six quarters. By comparison, CBO (2016) assumes the full effect of public investment takes place over a 20-year period, with 80% of the effect occurring within 10 years, and Penn-Wharton Budget Model (PWBM, 2019, 2020) assumes the productivity effects of public investment occur at twice the rate assumed by CBO. We incorporate such delays in our simulations to a limited extent by specifying that government infrastructure investment expenditures phase in slowly over the 10-year budget period.[10]

Key Parameter Values

The key parameter value in modeling the effect of government investment expenditures is clearly θ_G, the constant elasticity of private sector output with respect to an increase in the stock of public capital. Ramey (2020) provides a recent overview of these estimates. She notes that several early studies generated relatively high estimates, such as the work of Aschauer (1988, 1989), who estimated $\theta_G = 0.39$, and Munnell (1990), whose estimates ranged between 0.31 and 0.39. Ramey observes, however, that these studies had numerous econometric problems, including not correcting adequately for the endogeneity of output and public capital (wealthier countries with larger output would typically also have more public capital). She notes that Bom and Ligthart (2014) provide a frequently cited meta-analysis of 578 estimates from 68 empirical studies between 1983 and 2008, and report a short-run estimate of $\theta_G = 0.08$ for federal public investment, and a long-run estimate of $\theta_G = 0.12$. Bom and Ligthart also report that the average long-run output elasticity for regional/state/local public investment in core infrastructure (roads, railway, airports, and utilities) is considerably higher at $\theta_G = 0.19$.

CBO (2016) notes that Bom and Ligthart observe that studies examining more recent sample periods tend to have lower estimated elasticities, suggesting that public capital output elasticities have declined over time; accordingly, CBO uses a long-run value of $\theta_G = 0.06$ in their analysis, noting also that recent estimates of the output elasticity of highway spending range from 0.04 to 0.09. However, Bom and Ligthart also note that more recent studies tend to find higher elasticities (e.g., the average of the mean elasticities reported in studies over the last 10 years of their 25-year sample, 1999–2008, is $\theta_G = 0.18$), a result they attribute to either improved econometric techniques or publication bias favoring papers that report positive results.

Ramey includes studies through 2020 in her analysis and concludes that her survey suggests a long-run aggregate output elasticity of public capital between $\theta_G = 0.065$ and $\theta_G = 0.12$, which she notes is quite similar to the range found by Bom and Ligthart (2014). To be consistent with the earlier analyses of Baxter and King (1993) and Leeper et al. (2010), she uses $\theta_G = 0.05$ as her central estimate of the output elasticity of aggregate public investment expenditures; note that a smaller value is also appropriate because her analysis is relatively short-run (four years). However, drawing on Bom and Ligthart and her own review of the literature, she also considers $\theta_G = 0.10$ in most of her analyses, which falls in between the Bom and Ligthart short-run estimate of $\theta_G = 0.08$ and their long-run estimate

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[10] Specifically, we assume that the $3.3 trillion of public investment is distributed over the 10-year period according to the following weighting scheme: [0.005, 0.025, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.17, 0.2].

of θ_G = 0.12. We follow a similar approach in our simulations, using the value of θ_G = 0.05 used by Ramey (and PWBM) as her central estimate, and the value of θ_G = 0.12, which is at the top of her range of long-run estimates from the literature.

Given the critical nature of the choice of θ_G, numerous caveats are in order. CBO notes that most estimates of θ_G are based on analyses of public investment in physical capital or traditional infrastructure, rather than public investments in R&D and education; in particular, CBO argues that estimates of θ_G could be much higher for successful public investments in R&D.[11] Similarly, public investments in education may also have higher returns than investments in traditional infrastructure, especially if they generate important externalities or result in a permanent increase in the growth rate. For example, Annabi (2017) constructs a simulation model that examines the productivity effects of education expenditures. With an exogenous growth rate, his results imply a government investment output elasticity of 0.066, very close to the value assumed by CBO. However, in an endogenous growth model with human capital externalities, an increase of 1% of GDP in education investment increases the growth rate by 0.05, which is enough to quadruple the long-run gain in GDP relative to the case with exogenous growth. Our results are analogous to the first set of results, as we do not model human capital accumulation and assume an exogenous growth rate. In addition, as noted above, our model assumes full employment and thus does not capture any reductions in unemployment that might arise due to increased government spending in an economy characterized by unemployment. In particular, Auerbach and Gorodnichenko (2012) note that the elasticity of output with respect to government investment is much higher during recessionary periods, with their estimates suggesting values of θ_G between 1.0 and 1.5 during recessions. Finally, the productivity of public investment is more likely to be relatively large if the current public stock of capital is smaller than optimal. For example, Ramey (2020) estimates that the current level of public investment (3.5% of GDP) is larger than optimal level (2.5% of GDP) if the output elasticity of the public stock of capital is θ_G = 0.05, but smaller than the optimal level (5.0% of GDP) if the output elasticity is θ_G = 0.10.

On the other hand, there are several reasons why the output elasticity of public capital may be smaller than we assume. Public investments that are allocated inefficiently, awarded to inefficient high-cost producers, or subject to excessive regulations or other factors that inflate costs, could be less productive than implied by the smaller output elasticity we use in our analysis (for example, see Brooks and Liscow [2019] for a recent analysis of increasing real costs over time in the construction of interstate highways). Indeed, in the studies reviewed by Bom and Ligthart (2014), roughly 20% of the estimates indicate a negative effect of public investment on output, and five of the 24 studies published in the last 10 years of their sample have a mean elasticity estimate less than θ_G = 0.05, with a minimum estimate of θ_G = 0.027. In addition, it is important to note that government spending that represents purchases or production of government consumption goods and

[11] See also Szarowskà (2017) and Goel, Payne, and Ram (2008).

services rather than public investment will not have the positive effects on private factor productivity associated with public infrastructure spending.

Finally, our analysis follows CBO in assuming that one-third of national public investment expenditures are offset by reductions in state and local public expenditures ($\phi^{GSL} = 0.33$), which allows a reduction of $\phi^{GSL} I^{GF}$ in state and local tax revenues that we assume takes the form of reduced sales taxes. CBO notes considerable uncertainty regarding this parameter as well, citing studies with state and local offsets that range from nearly full offset (Knight, 2002) to a recent case in which state and local spending increased (Leduc and Wilson, 2015).[12] Note that the design of a federal infrastructure program can affect the degree of state and local offset—for example, federal grants to state and local government can reduce the extent of offset by including restrictions on the uses of funds or matching requirements. In our analysis, we follow CBO in assuming $\phi^{GSL} = 0.33$.

Government Expenditure Levels

We use Bureau of Economic Analysis (BEA) data on government expenditures for 2019 to calibrate the initial equilibrium in the model.[13] Total federal, state, and local government expenditures (before deducting depreciation) are $7.88 trillion or 36.8% of GDP, including $3.15 trillion of transfer payments, $0.88 trillion of interest payments, and $0.75 trillion of gross government nondefense investment expenditure. All remaining expenditures, including all defense expenditures, are treated as fixed government consumption of $3.10 trillion.

Federal government expenditures (before deducting depreciation) equal $5.16 trillion or 24.1% of GDP. This includes $3.01 trillion of transfer payments (including $1.03 trillion for Social Security, $0.78 trillion for Medicare and $0.66 trillion for grants to state and local governments), $0.58 trillion of interest payments, and $0.15 trillion of gross government nondefense investment expenditure. All remaining expenditures, including all defense expenditures, are treated as fixed government consumption of $1.43 trillion. Total government nondefense gross investment expenditures of $0.58 trillion are composed of $0.15 trillion of federal expenditures and $0.43 trillion of state and local expenditures.

Total federal, state, and local nondefense fixed assets equal $13.86 trillion.[14] Of this amount, $1.78 trillion reflects federal government assets, including $0.98 trillion in structures and equipment and $0.80 trillion in software and R&D. The remaining $12.1 trillion reflects

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12 See also Leff Yaffe (2020), who finds that construction of the interstate highway system led to additional state and local spending on roads to connect to the newly constructed interstate highways.

13 See Bureau of Economic Analysis, National Income and Product Account (NIPA) Tables 3.1, 3.2, and 3.3, https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=2 - reqid=19&step=2&isuri=1&1921=survey.

14 See NIPA Table 7.1, https://apps.bea.gov/iTable/iTable.cfm?ReqID=10&step=2.

state and local fixed assets, including $11.93 trillion of structures and equipment and $0.15 in software and R&D.

IV. Simulation Results

In this section we report two sets of simulation results. In both cases, we assume the tax changes described above are permanent and finance 10 years of public investment followed by permanent increases in transfer payments other than Social Security benefits. The increase in federal public sector investment of $3.3 trillion over 10 years results in a permanent increase in the size of the public capital stock.[15] Federal public investment is offset by one-third due to reductions in state and local public investment, and is phased in over the 10-year period. Any government revenue shortfalls are offset with reductions in transfer payments. We consider two cases:

(1) The elasticity of output with respect to public investment is $\theta_G = 0.05$, the central value used by Ramey (2020), which is just under the central value of $\theta_G = 0.06$ used by CBO (2016).

(2) The elasticity of output with respect to public investment is $\theta_G = 0.12$, the top of the range of output elasticities reported by Ramey (2020), and the average long-run elasticity reported by Bom and Ligthart (2014).

A. Output Elasticity of Public Capital = 0.05

We first consider the case in which the elasticity of private sector output with respect to the stock of public capital is $\theta_G = 0.05$. In this case, the public capital stock increases by 0.5% two years after enactment, by 2.1% five years after enactment, by 10.1% 10 years after enactment, and by 16.0% for all years outside the 10-year budget window.[16] With an output elasticity of $\theta_G = 0.05$, the level of private production once the additional public investment is complete is 1.1% larger due to the increase in productivity attributable to the larger public capital stock.

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[15] Note that we assume that federal government investment increases permanently to cover depreciation on the increase in the public capital stock attributable to the 10-year increase in federal government net investment. If instead there were no additional replacement investment and the public capital stock were allowed to depreciate to its original level and thus eliminate the reform-induced increase in productivity over time (for example, if maintenance investment were permanently deferred on incremental infrastructure investment), the macroeconomic effects of the fiscal plan would be significantly worse. Government spending on public investment, including replacement investment, which increases the productivity of private capital and labor, has much more positive macroeconomic effects than spending on transfers, which improves recipient household welfare and may improve social equity but in terms of labor force participation has only an income effect that reduces labor supply.

[16] Recall that public investment is phased in over the 10-year period.

The macroeconomic effects of the tax and expenditure plan in this case are shown in Table IV.1. The larger public sector capital stock increases labor productivity and real wages rise by 0.4% five years after enactment, by 0.3% 10 years after enactment, and by 0.5% in the long run. This broad-based increase in real wages offsets the increased taxation of labor income for high income households (those with incomes in excess of $400,000) due to the increases they experience in personal income taxes and payroll taxes. The net result is an increase in hours worked, initially of 0.8%, 1.0% 10 years after enactment, and 0.7% in the long run. Gross labor compensation increases initially by 0.8% and by 1.3% 10 years after enactment and in the long run, reflecting the combined effect of the increases in real wages and labor supply.

The larger public capital stock also increases the productivity of private capital, which acts to encourage domestic investment and saving. However, this effect is more than offset by the increase in the corporate income tax rate to 28%, the new corporate minimum tax on book income, the changes in the GILTI tax provisions (which increase the taxation of capital income but encourage a reallocation of capital back to the United States and reduce income shifting), and the changes in the taxation of capital income under the personal income tax, which act to increase the cost of capital and reduce the return to saving. In addition, the increase in public investment crowds out private investment. As a result, private investment in ordinary capital declines initially by 1.2%, by 5.3% 10 years after enactment, and by 2.5% in the long run. This decline is partially offset by increases in imports of ordinary capital, and the net result is a decline in the stock of ordinary capital, which declines by 1.3% 10 years after enactment and by 1.4% in the long run. Since the allocation of firm-specific capital *FSK* is determined primarily by differences is statutory tax rates, the increase in the U.S. statutory corporate income tax rate to 28% results in a reallocation of capital out of the United States, with the stock of domestic *FSK* declining by 1.6% two years after enactment, by 2.9% 10 years after enactment, and by 1.5% in the long run; these results are, however, dampened by the changes in the GILTI provisions.

These input changes, including the increase in government investment over the first 10 years after enactment, roughly cancel in terms of their effects on GDP, which increases by 0.2% two years after enactment, but falls by 0.2% 10 years after enactment and in the long run. Aggregate private consumption declines, especially over the 10-year budget window when more production is devoted to government investment (by 1.3% five years after enactment and by 1.2% 10 years after enactment), but declines by only 0.3% in the long run.

Table IV.1. Macroeconomic Effects of 10-Year Tax-Financed Public Investment Plan — $\theta_G = 0.05$

Variable **% Change in Year:**	**2**	**5**	**10**	**20**	**50**	**LR**
GDP	0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Private consumption	-0.4	-1.3	-1.2	-0.4	-0.4	-0.3
Private investment in ordinary *K* in U.S.	-1.2	-4.8	-5.3	-2.5	-2.5	-2.5
Stock of ordinary *K* in U.S.	0.0	-0.6	-1.3	-2.0	-1.5	-1.4
Stock of *FSK* in U.S.	-1.6	-3.5	-2.9	-2.0	-1.7	-1.5
Employment (hours worked)	0.8	1.0	1.0	0.8	0.8	0.7
Labor compensation	0.8	1.4	1.3	0.9	1.2	1.3
Real wage	-0.1	0.4	0.3	0.1	0.5	0.5
Total public capital stock	0.5	2.1	10.1	16.0	16.0	16.0

Note: Percentage changes in aggregate variables, relative to steady state with no reform.

B. Output Elasticity of Public Capital = 0.12

We next consider a case in which public investment is more productive, as we assume the output elasticity of public capital is $\theta_G = 0.12$, the top of the range suggested by Ramey (2020) in her review of the literature. The pattern of public sector investment is the same, with the public capital stock increasing by 0.5% two years after enactment, by 2.1% five years after enactment, by 10.1% 10 years after enactment, and by 16.0% for all years outside the 10-year budget window. With an output elasticity of $\theta_G = 0.12$, the level of private production once the additional public investment is complete is 2.6% larger due to the increase in productivity attributable to the larger public capital stock.

Because public investment is more productive in this case, the macroeconomic effects of the public investment expenditure and tax plan are more favorable than when $\theta_G = 0.05$; they are shown in Table IV.2. The larger public sector capital stock increases labor productivity and real wages rise by 0.6% five years after enactment, by 1.0% 10 years after enactment, and by 2.3% in the long run; by comparison, the long-run increase in real wages when $\theta_G = 0.05$ is 0.5%. Hours worked again increase, initially by 0.8% and by 0.7% in the long run, as does gross compensation, initially by 0.6%, by 1.9% 10 years after enactment, and by 3.1% in the long run.

For investment and saving, the increase in the productivity of private capital due to a larger public capital stock is again more than offset by the increase in the corporate income tax rate to 28% and the other changes in the taxation of business and capital income. Private investment in ordinary capital declines initially by 1.9%, by 5.2% 10 years after enactment, and by 1.3% in the long run (by comparison, the long-run decline when $\theta_G = 0.05$ so that capital is less productive is 2.5%). This decline is partially offset by increases in imports of ordinary capital, but the net result is a reduction in the stock of ordinary capital, which declines by 1.4%

10 years after enactment and by 0.3% in the long run (by comparison, the long-run decline when θ_G = 0.05 is 1.4%). The increase in the U.S. statutory corporate income tax rate to 28% again results in a reallocation of firm-specific capital out of the United States, with the stock of domestic *FSK* declining by 1.6% two years after enactment, by 3.7% 10 years after enactment, and by 2.4% in the long run.

With greater productivity of government investment, the net effect of the tax and expenditure plan is increases in GDP, with GDP increasing by 0.3% two years after enactment, by 0.4% 10 years after enactment, and by 1.1% in the long run. Aggregate private consumption again declines over the first 10 years after enactment as resources are diverted to public investment (by 0.8% five years after enactment and by 0.5% 10 years after enactment), but then increases, rising to 0.9% in the long run.[17]

Table IV.2. Macroeconomic Effects of 10-Year Tax-Financed Public Investment Plan — θ_G = 0.12

Variable **% Change in Year:**	**2**	**5**	**10**	**20**	**50**	**LR**
GDP	0.3	0.2	0.4	0.9	1.0	1.1
Private consumption	-0.1	-0.8	-0.5	0.7	0.8	0.9
Private investment in ordinary *K* in U.S.	-1.9	-5.1	-5.2	-1.5	-1.3	-1.3
Stock of ordinary *K* in U.S.	-0.1	-0.7	-1.4	-1.6	-0.6	-0.3
Stock of *FSK* in U.S.	-1.6	-4.0	-3.7	-3.0	-2.7	-2.4
Employment (hours worked)	0.8	0.9	0.9	0.8	0.7	0.7
Labor compensation	0.6	1.6	1.9	2.3	3.0	3.1
Real wage	-0.2	0.6	1.0	1.5	2.2	2.3
Total public capital stock	0.5	2.1	10.1	16.0	16.0	16.0

Note: Percentage changes in aggregate variables, relative to steady state with no reform.

V. Conclusion

In this paper, we use the Diamond-Zodrow computable general equilibrium model of the U.S. economy to simulate the dynamic macroeconomic effects of a fiscal plan that uses revenues from various tax changes proposed by the Biden campaign ($3.3 trillion over 10 years, as estimated by the Tax Foundation [Watson, Li, and LaJoie, 2020]) to finance 10 years of public investment. Public investment leads to an increase in the public capital stock that enhances the productivity of private factors of production. Once the increase in

[17] The effects of the public investment plan would of course be more favorable if one-third of federal public investment spending were not offset by reductions in state and local public investment spending.

public investment ends after 10 years, we assume that the tax changes are permanent and the revenues are used to cover depreciation on the incremental increase in the public capital stock so that the size of the public capital stock is held constant, with all remaining revenues used to finance increases in transfer payments other than Social Security benefits.

The macroeconomic effects of the plan reflect the net impact of (1) the 10-year increase in productivity associated with the increase in the public capital stock as well as the effects of the subsequent increase in government transfers, and (2) the increases in distortionary taxation of business, capital, and labor income used to finance those expenditures. Our simulation results indicate that these net macroeconomic effects depend significantly on the extent to which the increase in the public capital stock increases the productivity of private capital and labor, which depends on the output elasticity of public capital, θ_G.

When this elasticity is set at the central estimate (θ_G = 0.05) used in a recent analysis of infrastructure investment by Ramey (2020) and just under the value of θ_G = 0.06 used by CBO (2016), the increases in output associated with the increase in productivity due to the larger public capital stock are not quite large enough to offset the distortionary costs of the taxes used to finance the increase in public investment as well as the subsequent increase in transfer payments. As a result, GDP declines by 0.2% 10 years after enactment and in the long run, private investment falls by 5.3% 10 years after enactment and by 2.5% in the long run, and the stock of ordinary capital declines by 1.3% 10 years after enactment and by 1.4% in the long run, while labor supply increases by 1.0% 10 years after enactment and by 0.7% in the long run. Relatively mobile firm-specific capital declines by 2.9% 10 years after enactment and by 1.5% in the long run.

By comparison, when the output elasticity of public capital is set at θ_G = 0.12, which is at the higher end of the range of empirical estimates reported by Ramey (2020) and the average long-run elasticity reported by Bom and Ligthart (2014), the increases in output associated with the increase in productivity due to the larger public capital stock more than offset the distortionary costs of the taxes used to finance the increase in public investment and subsequent transfer payments. In this case, GDP increases by 0.4% 10 years after enactment and by 1.1% in the long run, private investment falls by 5.2% 10 years after enactment and by 1.3% in the long run, and the stock of ordinary capital declines by 1.4% 10 years after enactment and by 0.3% in the long run, while labor supply increases by 0.9% 10 years after enactment and by 0.7% in the long run. Relatively mobile firm-specific capital declines by 3.7% 10 years after enactment and by 2.4% in the long run.

We conclude with some caveats. In our view, dynamic, overlapping generations, computable general equilibrium models of the type used in this analysis are one of the best tools available to analyze the real economic effects of tax policy changes such as those analyzed in this study. In particular, such models provide a rich structure based on fundamental economic theory that captures many of the complex and interacting effects of changes in fiscal policy, including their dynamic and intergenerational effects, in a comprehensive general equilibrium framework. Such models, including our version, can also be used to analyze the intragenerational and intergenerational distributional effects of changes in fiscal policy, although we do not do so in this study.

Nevertheless, it is clear that the estimated effects of the policies presented in this report analysis analyze the results of particular simulations within the context of a specific model. The results of any study that attempts to model the effects of corporate and individual income tax changes as well as changes in government expenditures including those that increase the stock of public capital in today's highly complex and internationally integrated economy are subject to uncertainty, and this analysis is no exception. In particular, such results always depend on the details of the policy proposed and how they are modeled, including how the revenues are used, the structural assumptions that characterize the model, and the specific model parameters that are utilized in the simulations.

APPENDIX

Table A. Parameter Values Used in the DZ Model

Symbol	Description	Value
Utility Function Parameters		
ρ	Rate of time preference	0.015
σ_U	Intertemporal elasticity of substitution (EOS)	0.50
σ_C	Intratemporal EOS	0.80
σ_H	EOS between composite good, housing	0.30
σ_N	EOS between corporate composite good and noncorporate good	2.00
σ_{NS}	EOS between subsidized and nonsubsidized noncorporate good	2.00
σ_M	EOS between M-sector and C-sector corporate goods	2.00
σ_I	EOS between domestic and foreign produced goods	5.00
σ_R	EOS between rental and owner-occupied housing	1.50
α_C	Utility weight on the composite consumption good	0.73
α_H	Utility weight on non-housing consumption good	0.48
α_{NS}	Utility weight on subsidized noncorporate consumption good	0.50
α_N	Utility weight on composite corporate good	0.62
α_M	Utility weight on M-sector corporate good	0.42
α_R	Utility weight on owner-occupied housing	0.76
α_{LE}	Leisure share parameter of time endowment	0.17

Production Function Parameters

$\varepsilon_C,\ \varepsilon_M$	EOS for C-sector and M-sector corporate goods	1.00
ε_N	EOS for noncorporate good	1.00
$\varepsilon_H,\ \varepsilon_R$	EOS for owner and rental housing	1.00
ε_G	EOS for government-produced goods	1.00
γ_C	Capital shares for C-sector corporate goods	0.27
γ_N	Capital share for noncorporate good	0.30
$\gamma_H,\ \gamma_R$	Capital share for owner and rental housing	0.98
γ_G	Capital share for government-produced good	0.64
$\beta_X,\ \beta_N,\ \beta_H$	Capital stock adjustment cost parameters	5.0, 10
ζ	Dividend payout ratio in corporate sector	0.40
$b_C,\ b_N,\ b_H,\ b_R$	Debt-asset ratios	0.35, 0.40
β_d	Cost of excessive debt parameter	0.30
γ_{KM}	Capital share parameter in M-sector composite KEL factor	0.27
γ_{MK}	KEL share parameter in M-sector production function	0.66
γ_{MI}	Intermediate good share in M-sector production function	0.05

Other Parameters

ε_K	Portfolio elasticity for ordinary capital	1.0
ε_{FSK}	Portfolio elasticity for firm-specific capital	2.0
n	Exogenous growth rate (population plus productivity)	2.0
θ_G	Output elasticity of public capital	0.05, 0.12
$\phi^{GSL.}$	Share of federal investment offset by state/local reductions	0.33

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Authors

John W. Diamond, Ph.D., is the Edward A. and Hermena Hancock Kelly Fellow in Public Finance and director of the Center for Public Finance at the Baker Institute, an adjunct professor of economics at Rice University, and CEO of Tax Policy Advisers, LLC. His research interests are federal tax and expenditure policy, state and local public finance, and the construction and simulation of computable general equilibrium models. His current research focuses on the economic effects of corporate tax reform, the economic and distributional effects of fundamental tax reform, taxation and housing values, public sector pensions, and various other tax and expenditure policy issues. Diamond is co-editor of Pathways to Fiscal Reform in the United States (MIT Press, 2015) and Fundamental Tax Reform: Issues, Choices and Implications" (MIT Press, 2008). He has testified before the U.S. House Ways and Means Committee, the U.S. House Budget Committee, the Senate Finance Committee, the Joint Economic Committee and other federal and state committees on issues related to tax policy and the U.S. economy. Diamond served as forum editor for the National Tax Journal (2009-2017) and on the staff of the Joint Committee on Taxation, U.S. Congress (2000-2004). He has also served as a consultant for the World Bank on the efficacy of structural adjustment programs. He received his Ph.D. in economics from Rice University in 2000.

George R. Zodrow, Ph.D., is Allyn R. and Gladys M. Cline Professor of Economics and Faculty Scholar, Center for Public Finance, Baker Institute for Public Policy, at Rice University. He is also the Chair of the Economics Department at Rice, an International Research Fellow at the Centre on Business Taxation at Oxford University, and the President of Tax Policy Advisers LLC. Zodrow is the recipient of the 2009 Steven D. Gold Award, presented by the National Tax Association to recognize significant contributions to state and local fiscal policy and a capacity to cross the boundaries between academic research and public policy making. His research interests are tax reform in the United States and in developing countries, state and local public finance, and computable general equilibrium models of the effects of tax reforms. His articles have appeared in numerous scholarly publications and collective volumes on taxation, and he is the author or editor of several books on the topic. Zodrow recently served for ten years as editor of the National Tax Journal and has also been an editor of the "Policy Watch" section of International Tax and Public Finance. He was a visiting economist at the U.S. Treasury Office of Tax Analysis in 1984-85 during the preparation of Treasury I, the precursor to the Tax Reform Act of 1986, and has been involved in tax reform projects in numerous countries.