Why Tax Cuts Don't Boost Capital as Much as We Predict: The Maintenance Margin

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I show that standard models overstate how much business tax cuts boost capital accumulation because they treat the demand for capital maintenance as exogenously zero. Firms adjust the capital stock through investment in new assets and maintenance of old ones, but tax law treats these margins differently. Accounting for maintenance attenuates the effects of tax cuts through two channels. First is a tax shield effect: tax cuts reduce the tax savings from maintenance deductions, so the effective cost of capital falls by less than standard models predict. Second is an input substitution effect: tax cuts make new investment relatively cheaper, causing firms to substitute away from maintenance, which makes capital depreciate more quickly. Both channels depend on the level and elasticity of maintenance demand, which I estimate using digitized Class I railroad filings and IRS industry data. In general equilibrium, I find that accounting for maintenance implies the effects of the 2017 Tax Cuts and Jobs Act on capital, output, and wages are about one-third smaller than standard estimates—approximately $240 billion less corporate capital after ten years than an equivalent model without maintenance would predict.

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1 Introduction

Firms adjust their capital stock on two margins: they invest in new assets and maintain old ones. For many types of capital, maintenance expenditures are nearly as large as those for investment. Yet, workhorse models of business tax reform typically overlook this margin, treating maintenance spending as exogenously zero. This seemingly innocuous simplification creates a large quantitative error: it leads to a systematic overstatement of how much tax cuts boost capital accumulation. For the 2017 Tax Cuts and Jobs Act (TCJA), this omission accounts for a roughly $240 billion overestimation of the ten-year effect on corporate capital. The attenuated effect on capital spills over into similarly smaller effects on wages, output, and tax revenue.

The overstatement arises because the tax code treats the investment and maintenance margins differently. Spending on upkeep for existing capital is an immediately deductible expense, while spending on new capital is usually depreciated over many years, creating a relative price wedge where maintenance is treated more favorably than investment (McGrattan and Schmitz Jr. 1999). As a result, two forces attenuate the effectiveness of business tax policy. First, a tax shield effect blunts the impact of tax cuts, as only the non-maintenance share of the user cost of capital moves with tax parameters. Second, an input substitution effect makes new investment relatively cheaper, causing firms to shift dollars out of maintenance. That, in turn, raises the rate of economic depreciation and slows net capital accumulation.

The quantitative importance of both the tax shield and input substitution channels hinges on the properties of the capital maintenance demand function. The size of the tax shield is determined by the baseline level of maintenance intensity, while the strength of the input substitution effect is governed by the demand elasticity. To assess the macroeconomic consequences of tax reform, we must therefore have credible estimates for these parameters. A central contribution of this paper is to provide them.

I use two distinct sources of data to provide the first empirical estimates of an aggregate maintenance demand function for the United States.

The first pillar of my argument rests on a newly constructed dataset from digitized financial filings for Class I freight railroads, covering the universe of their maintenance behavior for locomotives and freight cars from 1999 to 2023. These regulatory filings provide an unparalleled window into firms' capital decisions, offering a firm-by-asset panel with granular detail on the composition of maintenance costs, including the breakdown between labor, materials, and externally purchased services. To identify the causal effect of relative price changes on maintenance behavior, I construct a Bartik-style instrument that leverages variation in the geographic distribution and labor composition of maintenance costs by firm. By interacting pre-determined, firm-specific labor cost shares with plausibly exogenous state-level shocks to maintenance wages, this strategy isolates cost-driven shifts in the relative price of maintenance from unobserved firm-level demand shocks. This analysis yields a maintenance demand elasticity of approximately four. Crucially, this response is driven entirely by adjustments to in-house maintenance, while outsourced maintenance services do not respond. This divergence provides evidence for causality, as it confirms the instrument is isolating a supply-side cost shock rather than a confounding demand shock, which would likely cause both maintenance margins to move in tandem.

To address concerns about the external validity of the railroad-specific findings and to capture important general equilibrium effects, such as the reallocation of used capital between firms, the second pillar of my argument exploits industry-level corporate tax returns from the Internal Revenue Service's Statistics of Income (SOI). While these data have been used to analyze investment, this is the first time they have been used to analyze maintenance. Following the empirical *investment* literature (Zwick and Mahon 2017; Curtis et al. 2021), I use quasi-experimental variation in industries' exposure to major investment incentives—namely bonus depreciation and the 2017 Tax Cuts and Jobs Act—to recover the demand elasticity. Because industries differ in their capital composition, these national tax policies create differential, plausibly exogenous shocks to the after-tax price wedge between new investment and maintenance. This aggregate-level approach, which implicitly nets out capital reallocation within broad industries, produces an estimated demand elasticity of approximately three. The fact that this general equilibrium elasticity is remarkably close to the micro-level freight rail estimate strengthens the credibility of the finding that maintenance demand is both positive and highly elastic.

With a credible maintenance demand function in hand, we can make statements about the microeconomic and macroeconomic impacts of positive and elastic maintenance demand.

At the microeconomic level, a long and influential body of research estimates the tax elasticity of investment and interprets it as the elasticity of the capital stock (Hall and Jorgenson 1967; Cummins, Hassett, and Hubbard 1994; Hassett and Hubbard 2002; Chodorow-Reich et al. 2025; Hartley, Hassett, and Rauh 2025). However, the existence of an elastic maintenance margin breaks the standard one-to-one mapping between the two. A tax cut that cheapens new investment also makes maintenance relatively more expensive, causing firms to substitute away from upkeep and accelerate the economic depreciation of their existing assets. Consequently, a portion of the observed surge in gross investment is simply replacing capital that now depreciates faster; the net impulse driving capital accumulation is therefore smaller than the gross investment response suggests. This implies that standard regression frameworks, which do not account for endogenous depreciation, suffer from an omitted variable bias that misstates the causal effect of tax policy on the capital stock.[1] I provide a closed-form correction for this bias as a function of the maintenance

1. This bias is related to but conceptually distinct from Goolsbee (1998a) and Chodorow-Reich (2025). Goolsbee (1998a) argues that endogeneity of investment goods prices, which are typically omitted in such regressions, means

demand parameters, showing that the long-run tax elasticity of capital is approximately half as large as the elasticity of investment.

At the macroeconomic level, maintenance implies a smaller steady state change in capital, wages, and output resulting from the tax shield effect, as well as a slower convergence to that smaller steady state. Because the substitution effect diverts some investment to simply replacing capital that now depreciates faster, the net impulse driving capital accumulation is smaller than the gross investment response suggests. Reconciling observed investment responses with the smaller net impulse requires higher adjustment costs, which slows the economy's transition to its new, smaller steady state. This has first-order implications for policy, as the growth effects inside the ten-year budget window—which is the relevant one for tax scores—are even smaller than the frictionless steady-state haircut would imply. In the context of TCJA, accounting for maintenance would push dynamic scores from JCT (2017), Barro and Furman (2018), and Tax Foundation (2017), among others, close to the static score.

Having established the theoretical consequences of positive and elastic maintenance demand, I quantify their aggregate empirical relevance. I embed the estimated maintenance demand function into a general equilibrium model calibrated to the U.S. economy. The 2017 Tax Cuts and Jobs Act is our laboratory, which we use to compare the dynamic paths of capital, output, and wages in our framework to those from an otherwise identical neoclassical benchmark from Chodorow-Reich et al. (2025). This allows us to isolate the precise magnitude of the haircut that accounting for maintenance imposes on the projected gains from tax reform. The results confirm the first-order importance of the maintenance margin. Across a variety of model closures, including those that account for general equilibrium effects through wages, interest rates, and maintenance prices, the ten-year responses macroeconomic aggregates are about 50-70% as large as the standard framework.

Related Literature. This paper relates to four main strands of literature.

First, this paper refines the literature on multiple margins of capital adjustment by showing that the tax distortion between maintenance and investment is a first-order concern. The closest paper is McGrattan and Schmitz Jr. (1999). To my knowledge, theirs is the only other paper that explicitly studies the maintenance-investment distortion in the tax code. While their foundational work focused on the input substitution, I show that the tax shield effect is the first-order channel, with larger and more direct consequences for the user cost of capital. Importantly, I also

that investment elasticities are underestimated. I similarly argue that accounting for an omitted channel means that investment elasticities are underestimated, but my argument implies a disconnect between capital and investment, whereas Goolsbee's does not. Chodorow-Reich (2025) argues that standard techniques overestimate the responsiveness of investment to tax reform, and so then capital must not move as much as such estimates imply. I agree that capital does not move as much as standard estimates imply, but my channel is maintenance.

illustrate how to map theory into empirics to interpret maintenance data, show how maintenance matters for tax scoring, and discuss how it changes the interpretation of standard investment regressions in the public finance literature. Other papers, including Kabir, Tan, and Vardishvili (2024), Boucekkine, Fabbri, and Gozzi (2010), and Albonico, Kalyvitis, and Pappa (2014) study maintenance and capital utilization in non-tax settings. I abstract from utilization because reallocation between investment and maintenance is itself second-order for capital accumulation, and accounting for utilization would require modeling indirect effects of indirect effects.[2] Finally, Feldstein and Rothschild (1974) and Cooley, Greenwood, and Yorukoglu (1997) study how tax policy influences capital replacement decisions in vintage capital settings. Although their models are substantially different, their points are broadly similar: tax cuts may reduce the value of existing capital relative to newer vintages and therefore leads to faster replacement.

Second, my paper relates to a literature documenting the empirical relevance of maintenance for capital. There is a large literature documenting the determinants and effects of maintenance decisions for residential housing (Knight and Sirmans 1996; Harding, Rosenthal, and Sirmans 2007; Hernandez and Trupkin 2021).[3] On the firm side, there is some evidence of tax cuts inducing firms replacing old, high-maintenance capital with younger capital, lower-maintenance capital. For example, Goolsbee (1998b) shows that airlines retire their airplanes more quickly when tax policy makes it favorable to buy new ones. Similarly, Goolsbee (2004) shows that firms buy capital with lower maintenance requirements following tax cuts. Some studies—which abstract from tax distortions—rely on maintenance data from India (Kabir, Tan, and Vardishvili 2024; Kabir and Tan 2024) or Canada (Albonico, Kalyvitis, and Pappa 2014; Angelopoulou and Kalyvitis 2012), but none, to my knowledge, estimate a maintenance demand function at all or using data from the United States. This lack of direct evidence has forced prior models to rely on assumption. My work provides the first empirical estimate of the U.S. maintenance demand function, offering a necessary parameter to correctly model capital dynamics.

Third, the results provide a universal adjustment factor for the quantitative tax reform literature. The user cost of capital is the primary transmission channel for business tax policy in virtually all modern frameworks, whether they incorporate a variety of complications such as explicit demographics (PWBM 2019), heterogeneous capital (Barro and Furman 2018), heterogeneous firms (Sedlacek and Sterk 2019; Zeida 2022), lumpy adjustment (Winberry 2021), finan-

2. My analysis focuses on maintenance of private capital. Kalaitzidakis and Kalyvitis (2004), Kalaitzidakis and Kalyvitis (2005), and Dioikitopoulos and Kalyvitis (2008) study the empirical and theoretical characteristics of public capital capital maintenance.

3. The investment-maintenance distortion goes the other way in the housing tax code. Whereas improvements are deductible from the capital gains tax basis, maintenance is not, which creates a distortion in favor of the former. There is no direct evidence of the importance of that margin, but Cunningham and Engelhardt (2008) and Shan (2011) show that the 1997 Taxpayer Relief Act, which lowered the capital gains tax, increased housing mobility, which is akin to increasing the renewal rate of housing.

cial frictions (Occhino 2023), or global tax considerations (Chodorow-Reich et al. 2025). Because our key mechanisms directly alter this user cost, the haircut we identify in a neoclassical model should apply similarly in these richer settings. Fundamentally, maintenance acts as a powerful dampening force on the central channel of capital taxation, regardless of other model features.

Finally, my paper connects to an extensive literature in public finance on tax incentives and investment. Since Hall and Jorgenson (1967) and Summers (1981), a large literature has used theoretical models to guide investment regressions. The result, from Hassett and Hubbard (2002), is a consensus estimate of the tax elasticity of investment around -0.5 to -1. That estimate has been confirmed in recent years by Zwick and Mahon (2017), Kennedy et al. (2023), and Chodorow-Reich et al. (2025). My theoretical results imply that accounting for maintenance magnifies the coefficients on these regressions for two reasons. First, if there is an additional margin of adjustment for capital, then investment in new capital necessarily becomes more elastic. Second, if the cost of capital moves by less because part of it is tax-deductible, then the coefficient on the cost of capital must be larger. Combining the theoretical closed form omitted variable bias I derive with the empirical demand function suggests that standard investment elasticities are underestimated by one-third.

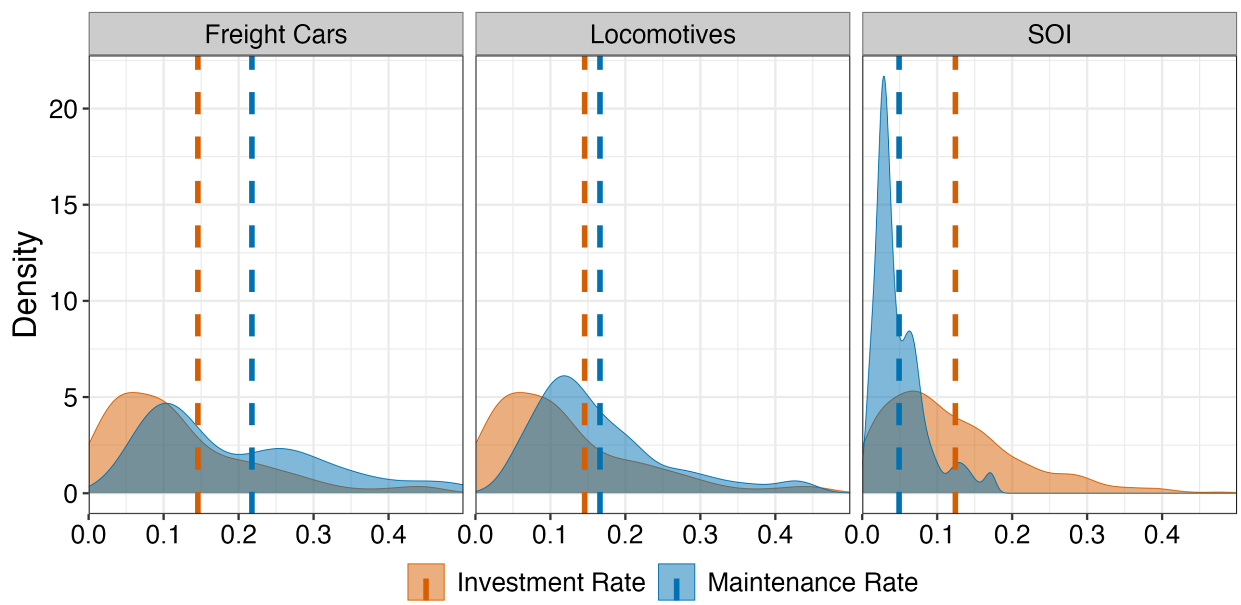
Roadmap. Section 2 presents brief institutional background on the maintenance-investment distinction. Section 3 gives a simple neoclassical model of maintenance, which I then take to the data in Sections 4–5. I return to the theory in Section 6, where I discuss and derive results on the aggregate and empirical implications of positive and elastic maintenance demand. Section 7 shows the importance of the theory by embedding the estimated maintenance demand function into a quantitative model of the Tax Cuts and Jobs Act. Section 8 concludes.

2 Maintenance vs. Investment

Firms engage in a wide range of activities to change the capital stock, from routine maintenance of existing capital to full replacement. Those activities are distinguished by maintenance, which preserves or restores capital services without improving quality, and investment, which creates or upgrades capital. For example, a ground shipping company may make its vehicle fleet live longer through diligent attention to routine maintenance like oil changes or proactively changing the tires early to avoid worse damage through a highway tire blowout. By contrast, investment would be purchasing an entirely new fleet of vehicles or replacing the engine in an existing vehicle. Thus, the key distinction between investment and maintenance is that the former adds new capital to the stock, while the latter simply keeps old capital around for longer in its existing quality. This distinction is not merely semantic. It maps directly to firm expenditures and how the tax code treats them.

Before turning to tax rules, it is useful to establish magnitudes. How large is maintenance, relative to investment? Figure 1 plots the distribution of maintenance and investment rates—measured as shares of beginning-of-period book capital—across two major railroad asset types and across all major industries from the Statistics of Income (SOI). I describe the underlying data in detail in Section 4, but include this preview here to illustrate the economic importance of maintenance expenditures. In each case, maintenance rates are substantial, suggesting that firms allocate considerable resources toward preserving existing capital.

Figure 1: Density plots for maintenance and investment rates



Note: Each density plot is constructed with beginning of period book capital in the denominator. The dashed lines are mean maintenance and investment rates. The rolling stock data span from 1999-2023, with 172 observations per asset type. There are 1116 observations in the SOI data, covering 49 major industries from 1999-2021.

The tax code reinforces the distinction between maintenance and investment through differential treatment under Sections 162 and 263 of the Internal Revenue Code. In general, maintenance is immediately deductible as an operating expense, while investment must be capitalized and depreciated over time. That matters for a firm deciding whether to invest an extra dollar in new capital or spend the dollar on maintaining existing capital. Letting τ denote the firm's tax rate, the after-tax cost of maintenance is $1 - \tau$ because it is deductible. On the other hand, a new capital expenditure must be depreciated over time.[4] Let z denote the net present value of the

4. Firms cannot easily game this distinction because routine maintenance expenditures typically fall below a *de minimis* safe-harbor threshold, while capital improvements do not, and established case law enforces consistent

depreciation deductions. The after-tax cost of investment is $1 - \tau z$. This implies a wedge in the maintenance-investment decision given by

$$\text{Wedge} = \frac{\text{After-tax Cost of \$1 of Maintenance}}{\text{After-tax Cost of \$1 of Investment}} = \frac{1-\tau}{1-\tau z}. \tag{1}$$

Appendix Figure A.1 discusses in detail how the wedge varies by asset and over time. In Section 3, I discuss the economics of the wedge, while Section 5 shows how it empirically maps into substitution between maintenance and investment.

3 A Simple Model of Capital Maintenance

This section augments the standard Hall and Jorgenson (1967) user cost framework á la McGrattan and Schmitz Jr. (1999) by adding a fully deductible maintenance choice alongside new investment. The key extension in this section is showing how to map map theory into empirics, which I carry out in Section 5. In Section 6, I discuss and derive new aggregate implications of positive and elastic maintenance demand.

Time is discrete and there is no uncertainty. A representative firm produces output $Y_t = F(K_t)$ as a weakly concave function of capital. It purchases new capital at price p_t^I and maintenance at price p_t^M. For now, I assume that both are elastically supplied. The firm pays for maintenance because maintenance reduces the depreciation rate of existing capital through a decreasing and convex technology $\delta(m_t)$, where $m_t = M_t/K_t$ is the maintenance rate. Capital then evolves according to

$$K_{t+1} = (1 - \delta(m_t))\, K_t + I_t. \tag{2}$$

I assume that the depreciation technology is given by

$$\delta(m_t) = \delta_0 - \frac{\gamma^{1/\omega}}{1-1/\omega} m_t^{1-1/\omega}, \tag{3}$$

where $\delta_0 > 0$ is a baseline level of depreciation, $\omega > 1$ ensures diminishing returns to maintenance, and $\gamma > 0$ shifts the effectiveness of the marginal unit of maintenance. This specification is decreasing and convex in m_t, so additional maintenance lowers depreciation with diminishing marginal payoffs; intuitively, firms first address the highest-return upkeep tasks, and each extra dollar averts progressively less wear. I also use it because, as I show momentarily, it will deliver an isoelastic maintenance demand function which is both parsimonious and tractable.

application of the rules. For example, in the 2003 court case *FedEx Corp. v. United States*, FedEx disputed whether \$66M worth of expenditures on maintaining existing aircraft engines in 1993 should be considered maintenance or investment. The question decided ten percent of their tax bill for that year.

There are two components to the tax system. First, there is a tax on output τ_t^c net of the maintenance bill. Second, the firm receives tax depreciation $z_t \tau_t^c$. Subject to a discount rate r^k, the firm chooses sequences of investment, maintenance, and capital to maximize the net present value of dividends:

$$\begin{aligned} \max_{I_t, M_t, K_{t+1}} \sum_{t=0}^{\infty} \left(\frac{1}{1+r^k}\right)^t \left\{ \left(1-\tau_t^c\right) \left[F\left(K_t\right) - p_t^M M_t\right] - \left(1 - z_t \tau_t\right) p_t^I I_t \right\} \quad \text{s.t.} \\ K_{t+1} = \left(1 - \delta(m_t)\right) K_t + I_t. \end{aligned} \tag{4}$$

Section 6 goes through the first-order conditions for capital and labor; here I focus exclusively on the maintenance FOC to illustrate its implications for empirical estimation.

Optimal Maintenance Policy The marginal benefit to capital maintenance is the reduction in depreciation, $-\delta'(m)$. Its marginal cost is a unit of foregone investment, which is determined by the after-tax relative price of maintenance to investment. The firm equates marginal benefit with marginal cost exactly when

$$-\delta'(m) = \frac{p_t^M}{p_t^I} \frac{1-\tau_t^c}{1-\tau_t^c z_t} = \frac{p_t^M}{p_t^I}(1-\tau_t), \qquad 1-\tau \equiv \frac{1-\tau^c}{1-\tau^c z}. \tag{5}$$

The after-tax relative price is precisely the wedge introduced in Section 2. Because $-\delta'(m) > 0$, the decision to maintain is truly economic rather than merely technical, and shifts in the after-tax relative price will shift maintenance demand and, through $\delta(m)$, the effective depreciation rate of the existing capital stock.

With isoelastic demand, we get the following relationship.

Proposition 1 (Maintenance Demand)**.** *With isoelastic technology, the maintenance demand curve is*

$$m_t = \gamma \left(\frac{p_t^M}{p_t^I} \frac{1-\tau_t^c}{1-c_t-\tau_t^c z_t} \right)^{-\omega}. \tag{6}$$

A higher elasticity ω makes maintenance more price-elastic, while the implied elasticity of depreciation is decreasing in ω. Intuitively, when maintenance is highly "efficient" (ω small), the firm can achieve a given depreciation cut with only a modest spending change, so demand is inelastic; the opposite holds when ω is large. The parameter γ simply shifts the demand function up and down. Proposition 1 yields a method for estimating maintenance demand in practice.

Empirical Maintenance Demand. Suppose we have cross-sectional data on maintenance intensity and relative prices and all units exhibit constant-elasticity demand:

$$m_{i,t} = \gamma \left[\frac{p^M_{i,t}(1-\tau_{i,t})}{p^I_{i,t}} \right]^{-\omega} \times \exp(u_{i,t}), \tag{7}$$

where $u_{i,t}$ captures shocks to maintenance beyond the wedge, for example unanticipated breakdowns or weather events, productivity shifts in upkeep methods, or measurement error. I interpret ω as a behavioral elasticity that reflects both tax and non-tax motives for maintenance. The term $u_{i,t}$ absorbs changes in other determinants of maintenance, including regulatory compliance, reliability concerns, utilization smoothing, and firm-specific operating conditions. The theory requires only that maintenance reduces depreciation with diminishing returns; the empirical design asks how relative after-tax prices shift this schedule. With two-way fixed effects, a log transformation yields

$$\log m_{i,t} = \underbrace{\alpha_i + \lambda_t}_{=\log\gamma} - \omega \, \log\left[\frac{p^M_{i,t}(1-\tau_{i,t})}{p^I_{i,t}} \right] + u_{i,t}. \tag{8}$$

If $u_{i,t}$ is mean zero and orthogonal to the relative price (conditional on fixed effects and controls), we can identify the common elasticity ω from within-unit, over-time variation in the after-tax wedge and then recover γ. Section 5 relies on this approach to estimate the demand elasticity.

4 Data

Whether our traditional investment theories about the transmission of tax policy need to be augmented with a theory of maintenance depends on if maintenance demand is large and elastic enough to matter. Up to now, the central challenge for evaluating that is a paucity of data on maintenance in the United States. This section brings to light two new sources of direct evidence on maintenance. First, I construct a novel dataset by digitizing the universe of maintenance behavior of locomotives and freight cars by Class I freight railroads from 1999-2023. To my knowledge, this is an entirely new dataset in modern economics and the first usage of R-1 data since Bitros (1976). Second, I construct a complementary dataset from industry-level corporate tax returns using the Statistics of Income (SOI) published by the Internal Revenue Service. While these data are not new and have been used to analyze investment (*e.g.*, Zwick and Mahon (2017)), it is the first time the SOI has been used to analyze maintenance. Across both datasets, we require a maintenance rate and some measure of the relative price of maintenance to investment.

4.1 R-1 Data from the Surface Transportation Board

Class I freight railroads—defined as having revenue greater than $1B—carry about 40% of all freight in the United States, with the rest largely taken by trucks. Although the industry used to be highly fragmented, it has consolidated considerably since deregulation in the early 1980s and has been in a stable competitive equilibrium of around seven large firms since the late 1990s, which is when my data begin. Seven companies carry most of the freight traffic: CSX Industries, Burlington Northern & Santa Fe, Union Pacific, Norfolk Southern, Kansas City Southern, Soo Line, and Grand Trunk, which is operated by the Canadian National Railway. The railroads are geographically dispersed but have one or two large local competitors along with smaller Class II and Class III competitors. Burlington Northern and Union Pacific dominate the western United States, CSX and Norfolk Southern the eastern seaboard, while the Soo, Kansas City Southern, and Grand Trunk operate more in the Midwest. All of these railroads own their tracks and equipment and have faced relatively little financial trouble over the past 25 years. Canadian Pacific Railway formally took control of the Soo Line and Kansas City Southern by 2024 and so I end my data in 2023.

By regulation, any freight railroad with sufficiently high revenue must file an annual R-1 report with the Surface Transportation Board (STB). The R-1 report can be thought of as a much more granular version of a 10-K filed by a publicly traded corporation. However, the accounting standards meaningfully differ from GAAP standards in important ways. For example, railroads often depreciate assets using composite rates, which must be approved *ex ante* by the STB. All reports are independently audited by firms like KPMG and PwC and then once more by the government.[5] All R-1 reports detail the size and composition of firms' capital in value and quantities, its trackage by state, taxes paid, capital expenditures, and detailed data on maintenance expenditures by capital type. Importantly, R-1 reports also detail whether maintenance costs come from materials, labor, or purchased services. This level of granularity and precision is a unique and unparalleled window into the physical capital structure of the firm. The data run from 1999-2023.

For this paper, I maintain a narrow focus on freight cars and locomotives because the maintenance activities and associated prices can be straightforwardly identified in the data, whereas maintenance and the price thereof is not for other types of capital.[6]

5. The main reason for the R-1 reporting requirement is that the predecessor to the STB, the Interstate Commerce Commission, extensively used the R-1 report to regulate rate setting prior to the 1990s. To some extent, the STB still plays that regulatory role, but rate setting disputes are far less common now.

6. Additionally, track maintenance is strictly regulated by the Federal Railroad Administration, while regulation of locomotives and freight cars is considerably less intense. That allows firms some leeway in how intensely they maintain their equipment subject to inspection and safety protocols. Of course, that decision is intertwined with how intensely the firms invest in new capital, which is unregulated and determines how much they need to spend on maintaining and repairing existing capital.

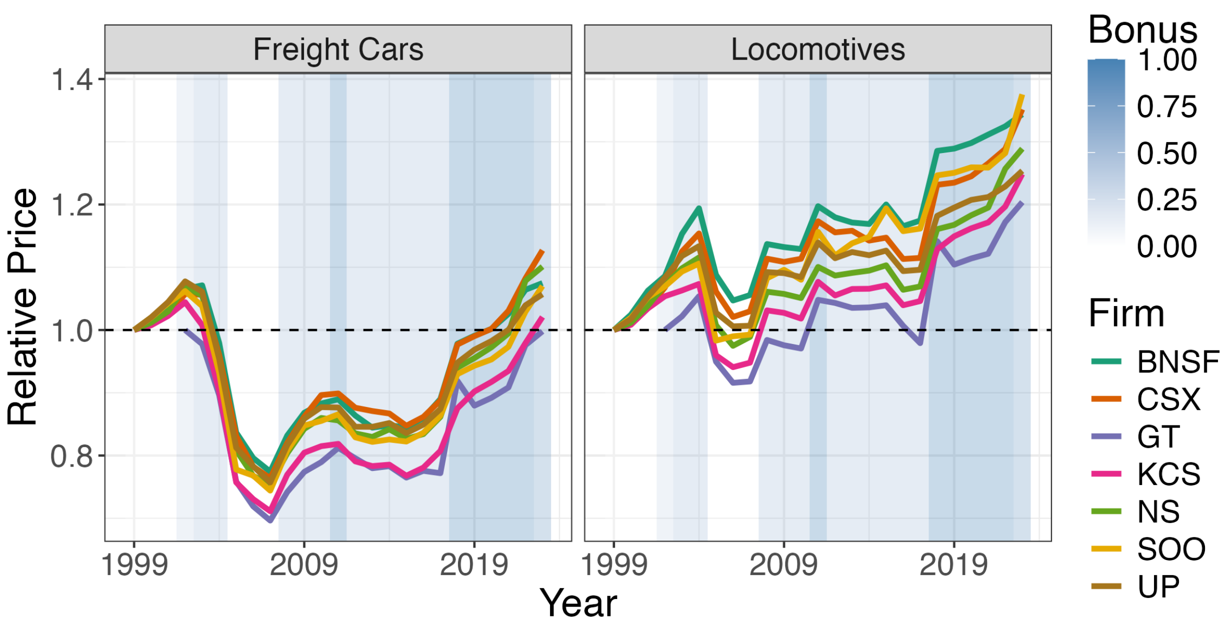
The main measure of the maintenance rate is the ratio of maintenance expenditures to lagged book capital. I also rely on two other metrics. First, because I construct a measure of the physical maintenance rate, which is the ratio of maintenance expenditures on each capital type to either horsepower (locomotives) or freight ton capacity (freight cars). Second, I break down the total maintenance rate into either internal or external maintenance rates. The distribution of the main metric for both capital types is in Figure 1.

Next, I construct firm- and asset-specific relative prices as

$$P_{i,j,t} = \frac{p^M_{i,j,t}}{p^I_{j,t}} \frac{1-\tau_{i,t}}{1-\tau_{i,t} z_t},$$

where $p^M_{i,j,t}$ is the pre-tax maintenance price of capital good j for firm i at time t, and $p^I_{j,t}$ is the investment price of asset j, and $\tau_{i,t}$ is the firm-specific tax rate. Because of restrictions on data availability, only the pre-tax price of maintenance varies by firm and capital type, whereas tax rates vary by firm and investment prices by capital type. Tax rates do not vary between assets because the IRS places locomotives and freight cars in the same depreciation category. Further details on data construction and summary statistics are in Appendix B.1. Figure 2 plots the after-tax relative price of maintenance to investment for all of the Class I railroads since 1999. Whereas the price of maintaining locomotives has persistently increased since 2000, the pattern is more u-shaped for freight cars.

Figure 2: After-tax relative price of maintenance to investment



Notes: I construct the after-tax relative price of maintenance to investment as described in the main text. Background shading is for bonus depreciation.

4.2 Industry Data from the Statistics of Income and the Bureau of Economic Analysis

Corporations report a large number of operating expenses and balance sheet items as line items on their tax forms to the IRS, including maintenance expenditures and book capital. The Statistics of Income (SOI) aggregates the returns into a stratified industry-level sample at a roughly three-digit NAICS level. This is the only economy-wide collection of maintenance data at an annual frequency in the United States. I take maintenance, investment, and book capital stock data from the SOI corporate reports from 1999-2019. This excludes filings made with Forms 1120S, 1120-REIT, and 1120-RIC. Economists have used the underlying microdata to estimate tax elasticities of investment (Zwick and Mahon 2017; Kennedy et al. 2023). I do not have access to the administrative data and so I rely on the industry-level sample, which I aggregate to fifty industries to correspond with data from the Bureau of Economic Analysis (BEA).[7] For some analyses, I break down the aggregate sample into taxable and untaxable samples. The latter is composed of returns with positive net income and the latter do not have positive net income. Some of the returns in the "taxable" category may not actually be taxable because they have a stock of positive net operating losses which they can use to offset taxable income, but the mapping is roughly accurate.

In the SOI, the maintenance rate is the ratio of maintenance expenditures to lagged book capital. However, the SOI measure is considerably noisier than the R-1 maintenance rate for two reasons. First, because labor expenditures are a different line item, SOI maintenance largely reflect spending on materials and external maintenance purchases. Relatedly, some materials costs may end up in costs of goods sold rather than the maintenance line item. Second, the denominator uses tax depreciation to build the stock of capital, so it is not as accurate. I discuss in more detail how these problems affect regression estimates in Section 5. Despite these two issues, the resulting maintenance rates are similar to those observed in aggregate Canadian data.[8] Figure 1 plots the distribution of SOI maintenance rates.

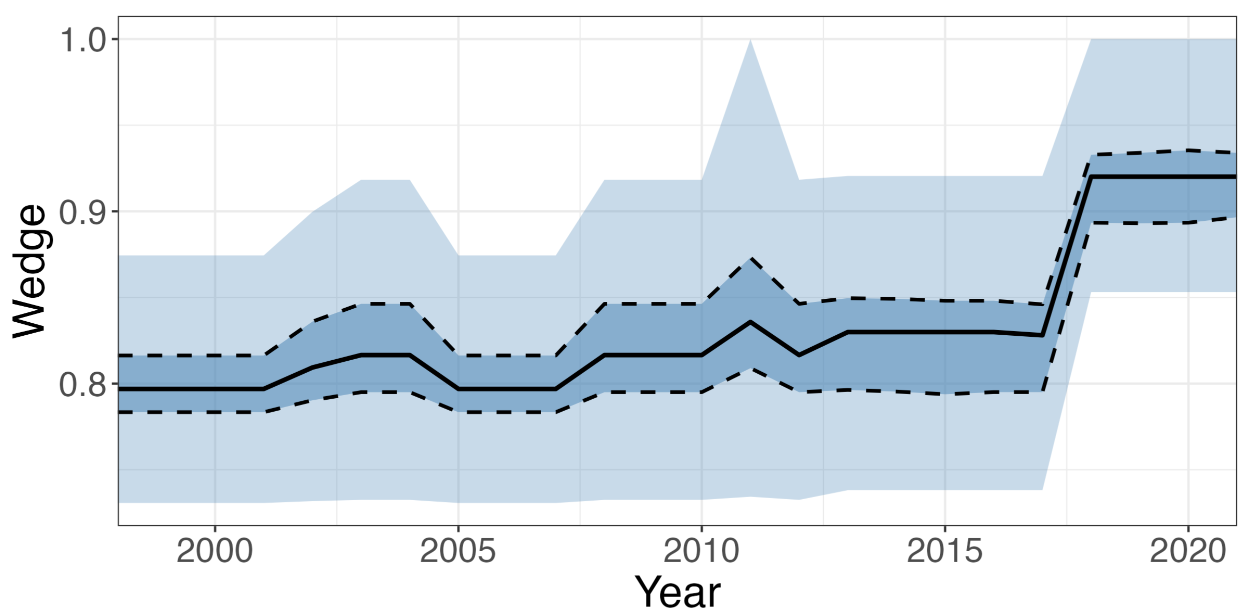
7. Because I rely on BEA data to construct tax rates and other variables and the number of SOI industries fluctuates over time but is always weakly larger than the number of BEA industries, I map the SOI industries into BEA industries for consistency and use the latter as a unit of observation. There are 49 such industries after excluding the financial sector. I use the BEA industry definition for two reasons. First, I mix the BEA and SOI data in some robustness checks. Second, the BEA industry definition is more aggregated across SOI samples than the SOI data, which helps maintain definitional consistency and also supports the GE interpretation of the data I prefer.

8. See Appendix Figure G.7 for a comparison between the aggregate Canadian maintenance rate and the aggregate SOI maintenance rate. One possible correction for the numerator would be adjusting for internal missing labor with outside evidence. For example, the labor cost share for rolling stock and for the equipment maintenance and repair sector (NAICS 811) are both around 30-45% (see Appendix Figure G.2). Using that, we could divide the SOI maintenance rates by 0.65 for certain figures and estimates. Figure G.4 shows the resulting "corrected" distribution of maintenance rates.

There is no easily identifiable measure of relative prices. Because my eventual identification strategy relies solely on the policy wedge, I focus on the maintenance-investment policy wedge defined in equation (1). Given the definition of the wedge in (1), I construct an asset-specific wedge for every BEA asset using a mapping from assets to the tax code from House and Shapiro (2008). I aggregate the asset-specific wedges into a capital-weighted industry-specific wedge. I discuss why I focus on the capital-weighted wedge in the identification strategy subsection. Further details on data construction and summary statistics are in Appendix B.2.

Figure 3 plots the distribution of industry-specific wedges over time for industries in the SOI. Reforms throughout the 2000s tended to proportionally reduce the distortion by more for equipment-intensive industries, while structures-intensive industries saw little change until the TCJA. Altogether, there is significant variation in the incentive to maintain over time; that variation is exactly what we require to figure out if the large demand for maintenance is also elastic.

Figure 3: Distribution of industry-specific wedges over time



Notes: Every line is a quartile of the industry-specific wedge defined in the main text.

5 The Maintenance Demand Function

The theoretical framework of Section 3 showed that an estimate of maintenance demand is essential for counterfactual analysis of business tax reform. This section brings the model to the data by estimating the maintenance demand curve of Proposition 1.

5.1 Evidence from Freight Railroads

I focus on locomotives and freight cars owned by seven different firms from 1999-2023. Denote $P_{i,j,t}$ as the firm i by asset j by year t after-tax relative price of maintenance to investment defined in Section 4. The basic regression specification estimates the maintenance elasticity of demand ω with

$$\log m_{i,j,t} = \alpha_{ij} + \lambda_t - \omega \log P_{i,j,t} + \text{Controls} + u_{i,j,t}, \tag{9}$$

where α_{ij} is a firm-by-capital type fixed effect, λ_t is a time fixed effect, and $P_{i,j,t}$ is the relative price. The coefficient ω is identified by leveraging variation in relative prices within each firm-capital type over time, with firm-by-capital type and time fixed effects controlling for all unobserved, time-invariant characteristics and common temporal shocks. In all regressions, I cluster standard errors by firm and year. This approach guards against the likely outcome that maintenance decisions are correlated between capital types within firms.

Identification Strategy. The relative price $P_{i,j,t}$ is likely endogenous. If firms experiencing higher maintenance demand also have systematically higher input costs or choose different factor mixes, then (9) is biased. There could be several confounding factors. For instance, unobserved firm-level supply shocks could simultaneously affect both the intensity of maintenance and the relative price of that maintenance. Similarly, unobserved local demand conditions or region-specific economic expansions might simultaneously affect input prices and maintenance activity.

To get exogeneity, we essentially want variation in maintenance input costs that is plausibly unrelated to firm-level or capital-type-specific unobserved factors. To motivate this approach, imagine a hypothetical experiment in which a central planner randomly assigns a series of "shifts" in national labor markets. For example, imagine national-level negotiations or policies that randomly alter the prevailing wage index for certain maintenance occupations across states. In such an idealized setting, these cost changes would be as good as randomly assigned from the perspective of individual firms, ensuring that any resulting changes in maintenance input prices are not driven by firm-level or region-specific unobserved conditions. Toward approximating that idealized experiment, I construct the instrument

$$Z_{i,j,t} = \frac{\text{Labor}_{i,j,t-2}}{\text{Internal Maintenance}_{i,j,t-3}} \sum_{s=1}^{S} \frac{\text{Rail Miles}_{i,t,s}}{\text{Rail Miles}_{i,t}} W_{s,t}. \tag{10}$$

Let us break $Z_{i,j,t}$ down. It is essentially the exposure of firm i and capital type j to labor cost shocks. The first component is the the ratio of labor cost to internal maintenance costs lagged by three years. These are the shares. I focus on *internal* costs because external maintenance contracts are generally contractually fixed and so are inflexible, which means that any variation in maintenance is driven by the internal component. Later, I show this empirically. I multiply that ratio by a weighted average of state-level maintenance costs $W_{s,t}$ (the shifts). State weights are the ratio of rail miles in a particular state to total rail miles owned by firm i. The maintenance cost is the wage index for occupation code 49-0000, which is a broad category of maintenance workers. Within railroads, maintenance centers are geographically dispersed and not determined *ex ante* by local labor costs.[9]

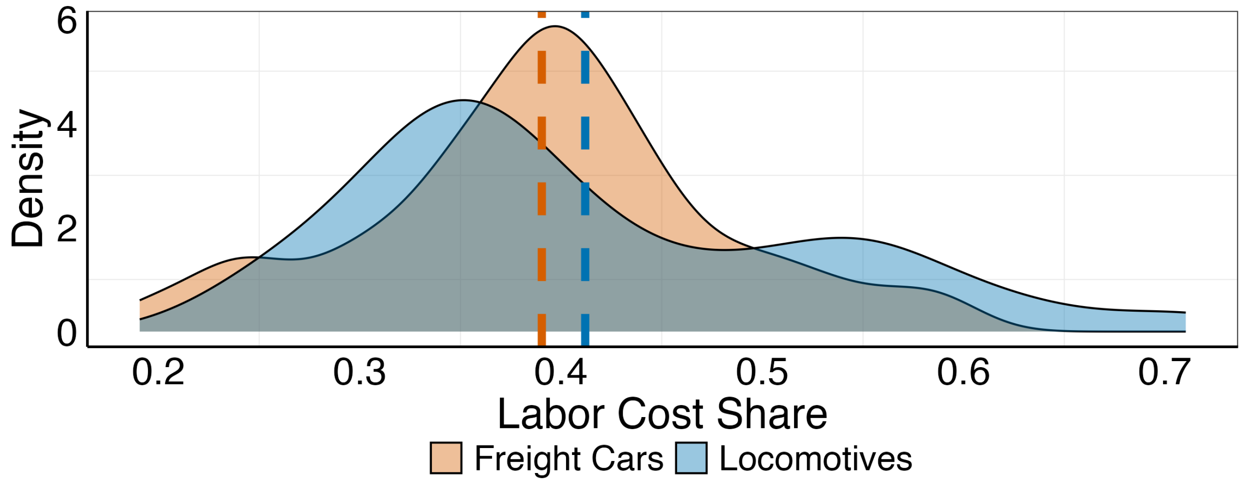
In practice, the instrument approximates the ideal experiment by using state-level input cost indices as "shifts" and employing firm- and capital-type-specific cost shares as "weights." In the language of Borusyak, Hull, and Jaravel (2024), I leverage the "many exogenous shifts" approach rather than the exogenous shares approach. The instrument thus leverages exogenous variation in labor input costs that arises from broad economic conditions outside the firm's control. Provided that these shifts are not systematically related to unobserved local confounders—such as persistent differences in asset age that also correlate with labor input cost shares or local booms that simultaneously raise wages and maintenance—this approach recovers a causal elasticity. Put differently, we anchor our instrument in truly pre-determined cost-structure weights and as-good-as-random aggregate wage swings. In combination, these two pieces deliver a source of variation in relative maintenance prices that is plausibly orthogonal to unobserved demand- or supply-side shocks at the firm-asset level.

Figure 4 plots the labor cost share by firm and asset type. There is substantial variation with and between firms and asset types over time, indicating that the shares in $Z_{i,j,t}$ have enough variation. Table C.1 shows that the first stage of the instrument is directionally correct and statistically significant. In both the baseline and the specification with controls for firm trends, age, and local demand shocks, the coefficient on $Z_{i,j,t}$ is positive. I show that this remains true with two other instruments: using cost shares lagged by three years as well as a national maintenance wage index. Across all instrument specifications, the effective F-statistic from Montiel-Olea and Pflueger (2013) is around ten. Consequently, I use weak instrument robust inference for the results. Additionally, I show in Figure C.6 that lags of the log maintenance rate are not predicted by $Z_{i,j,t}$, so there do not appear to be anticipation effects and thus the exclusion restriction is satisfied on pre-trends. Finally, Figure C.7 shows that the labor cost share is orthogonal to lagged maintenance, relative prices, and asset age. Therefore, the potentially endogeneous component of the instrument—the labor share—is not correlated with observable, pre-period predictors of

9. Recall that the numerator of the relative price is a weighted average of materials and labor costs, while the denominator is investment prices. I choose to ignore the materials component of the relative price in the numerator because it is heavily correlated with movements in the denominator. For example, the parts used as inputs for new engines are the same as those used to repair existing engines. Thus, I focus on isolating exogenous variation in the labor component using a shift-share instrument.

maintenance.

Figure 4: Internal Labor Cost Share for Rolling Stock



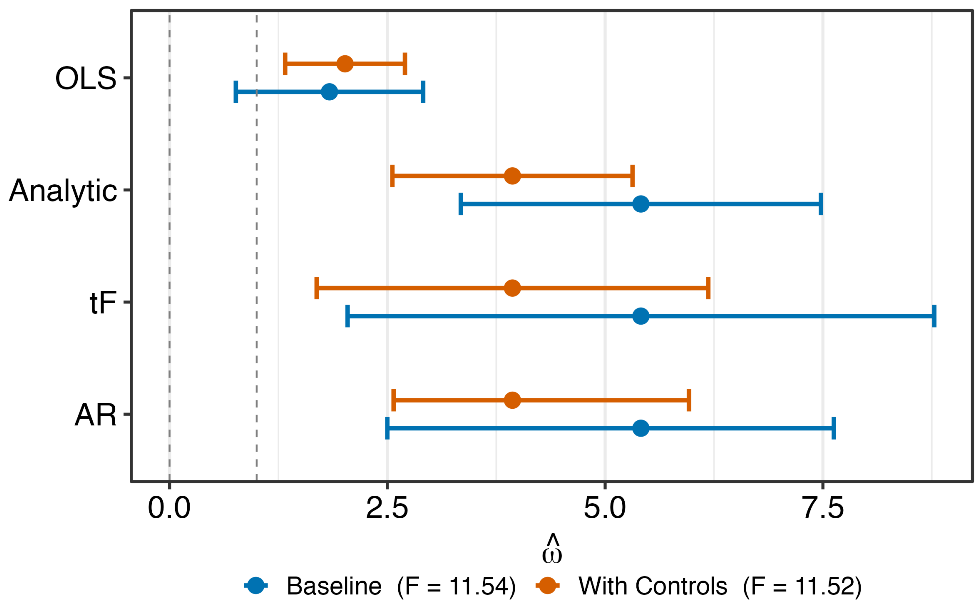
Note: The figure plots the winsorized density of labor cost shares for locomotives and freight cars from R-1 reports.

To address potential confounding at both the unit level and the shift level, I include a number of controls. First, at the shift level, changes in local demand could lead to changes in demand for freight rail services, which may affect input costs and maintenance demand simultaneously. Consequently, I construct each firm's demand exposure as a weighted average of state-level GDP growth rates, with weights determined by freight miles in every state. Second, while the time fixed effect helps address confounding at the national level, I also include firm-specific time trends. The firm-trends help address confounding by capturing unobserved, time-varying factors that are unique to each firm and may influence maintenance demand independently of the instrument. For example, the firm-specific trend effectively controls for dynamic changes such as firm-specific technological advancements, management strategies, or responses to national economic shocks that are not fully accounted for by time fixed effects alone. At the unit level, I control for the age of capital because older capital may require more maintenance. I proxy for age with the inverse ratio of net to gross book capital.

Results. I present results for estimates of (9) in Figure 5, where standard errors are clustered by firm. The baseline OLS estimate without controls cannot reject $\omega = 1$, which is the case in which the input substitution effect does not exist. However, adding controls and instrumenting for the relative price leads to a consistent rejection of the null. Indeed, the TSLS point estimate of the price elasticity of maintenance demand is around 3.5. For comparison, the tax elasticity of the investment rate is generally between 0.5 and 1 (Hassett and Hubbard 2002), while other studies have found values about twice as large (Zwick and Mahon 2017). Consequently, the estimated partial equilibrium maintenance elasticities are about twice as large as prevailing investment elasticity estimates.

My approach to inference follows Lee et al. (2022) and Lal et al. (2024). Because the instrument is bordering on weak, I show 95% confidence intervals computed by inverting the Anderson-Rubin and tF statistics, respectively. While both are wider than analytic standard errors, they both easily reject the null hypotheses of (i) no input substitution effect and (ii) perfectly inelastic maintenance demand.

Figure 5: R-1 maintenance demand elasticity with 95% confidence interval



Note: This figure plots the point estimates and result for estimating (9). The blue lines contain no controls, while the orange lines control for local GDP exposure, firm-year trends, and the age of the capital stock. All standard errors are clustered by firm. The top estimate is for OLS only, while the bottom three all correspond to the instrument specified in (10). Analytic confidence intervals are from traditional Wald estimates, while the tF and AR confidence intervals result from inverting the tF (Lee et al. 2022) and Anderson and Rubin (1949) tests, respectively. The F-statistic reported in the legend is the effective F-statistic from Montiel-Olea and Pflueger (2013).

I present several checks of the results in the appendix. Using two alternative instruments, I show that the results hold up regardless of whether I use a national wage index rather than the weighted state-level indices (Figure C.9) or a different lag length for the labor share (Figure C.10). Next, I construct a measure of the capital stock which is purely physical rather than in dollar value. This is consistent with a one-hoss shay depreciation profile for capital and hence is an extreme assumption. However, it is a useful assumption because it provides a bound on the degree of measurement error in the capital stock. I measure the stock of locomotive capital in units of horsepower and the stock of freight cars in tons of capacity. Both figures come from Schedule 710 of the R-1 report. These measures have a high correlation (0.9) with the book value of the capital stock. As such, they yield essentially practically the same estimates for both the reduced form and instrumental variables regressions in Appendix Figure C.8. Finally, I report results which also control for lagged maintenance in Figure C.11. This diminishes the short-run price elasticity in both magnitude and significance, but the long-run elasticity is unchanged. Since the theoretical motivation comes from steady-state reasoning, that leaves our main results unchanged.

The main results aggregate external and internal maintenance into a single homogeneous input. That is probably not the case in practice. While both internal and external maintenance rely on contracts which are presumably sticky, there are reasons to think that the latter would be stickier. With internal maintenance, firms can respond to price changes by reallocating labor within the firm to other tasks or simply choosing not to maintain if input prices rise too much. In contrast, external maintenance contracts are typically specified in advance and usually result from the original purchase. That suggests some degree of heterogeneity in the maintenance demand elasticity, something I explore theoretically in Appendix F.2. Figures C.5 and C.4 offer a more precise window into what drives the change in demand for maintenance. Splitting into internal and external maintenance and re-running (9) yields that the estimated elasticity nearly doubles the main elasticity for internal maintenance and is zero for external maintenance. Thus, the main result—that maintenance is price-elastic—is driven by internal maintenance.

One interpretation of the internal–external divergence is as a test of the exclusion restriction for the instrument. The shifter moves the cost of in-house maintenance, not demand for effective services, so a valid supply-side shock predicts (i) large quantity adjustment for internal maintenance, (ii) little quantity movement for external maintenance where contracts and vendor capacity are sticky, and (iii) a shift in the sourcing mix toward external when internal wages rise relative to vendor rates. The estimates and Figures C.5–C.4 align with these predictions: internal quantities absorb the shock, external quantities do not, and the mix tilts outward. If the instrument were instead proxying for demand, we would expect internal and external quantities to move in tandem and the sourcing share to remain stable. The observed asymmetry is therefore difficult to reconcile with a demand confound and is exactly what the exclusion restriction implies under a cost-side shock.

5.2 Maintenance in the SOI

In general equilibrium, firms may sell used capital to each other, resulting in a smaller reduction in maintenance than we would predict from simply observing the decline in maintenance expenditures from an individual firm in partial equilibrium. An extension of the baseline model to include reallocation in Appendix F.1 shows how this channel would depress the aggregate maintenance elasticity. Thus, the R-1 data is an incomplete description of the aggregate maintenance demand elasticity because there is no reallocation force. Consequently, I rely on the SOI data to estimate something closer to the aggregate elasticity. In contrast to the R-1 data, which uses the asset-firm as the observational unit, we can broadly interpret an industry-level demand elasticity from the SOI as reflecting an aggregate elasticity which nets out any reallocation. That relies on the assumption that the SOI industries are sufficiently broad and capital use sufficiently specific that any capital sales following a tax cut would remain within the corresponding industry. While that assumption is reasonable for some industries, it is more difficult to make that argument for others. For example, an oil rig is essentially useless outside the oil industry, while a used rental car from Hertz can be used in essentially any industry.

Identification Strategy. I rely on cross-sectional variation in exposure to the tax policy changes to identify the demand elasticity. Because some industries rely more on capital exposed to tax reform than others, this leads to exogenous variation in tax policy across industries. Indeed, a large battery of studies from House and Shapiro (2008), Kitchen and Knittel (2011), Zwick and Mahon (2017), Garrett, Ohrn, and Suárez Serrato (2020) show that such policies had large effects on firm-level investment and employment outcomes. Second, the 2017 Tax Cuts and Jobs Act increased bonus from 50% to 100% for eligible capital and also slashed the corporate rate from 35% to 21%. Although this made the marginal rate zero for bonus-eligible capital, the absolute change in tax rates was larger for ineligible capital. This, once more, led to variation across industries in exposure to tax policy, which Kennedy et al. (2023) and Chodorow-Reich et al. 2025 show substantially boosted investment.

I rely on bonus and TCJA to deliver the identifying variation in the wedge $\frac{1-\tau_t^c}{1-\tau_t^c z_{i,t}}$ over time and between industries to yield the coefficient ω in

$$\log m_{i,t} = \alpha_i + \lambda_t - \omega \log\left(\frac{1-\tau_t^c}{1-\tau_t^c z_{i,t}}\right) + \text{Controls} + \varepsilon_{i,t}, \tag{11}$$

where α_i is an industry fixed effect and λ_t is a time fixed effect. I describe how to construct the wedge in Section 4. Since τ_t^c is common across capital types and industries, the key modeling choice is how to construct the weights over capital types in $z_{i,t}$ to build an industry average wedge. Broadly, one can average investment flows or capital stocks over the past L years prior to a reform.

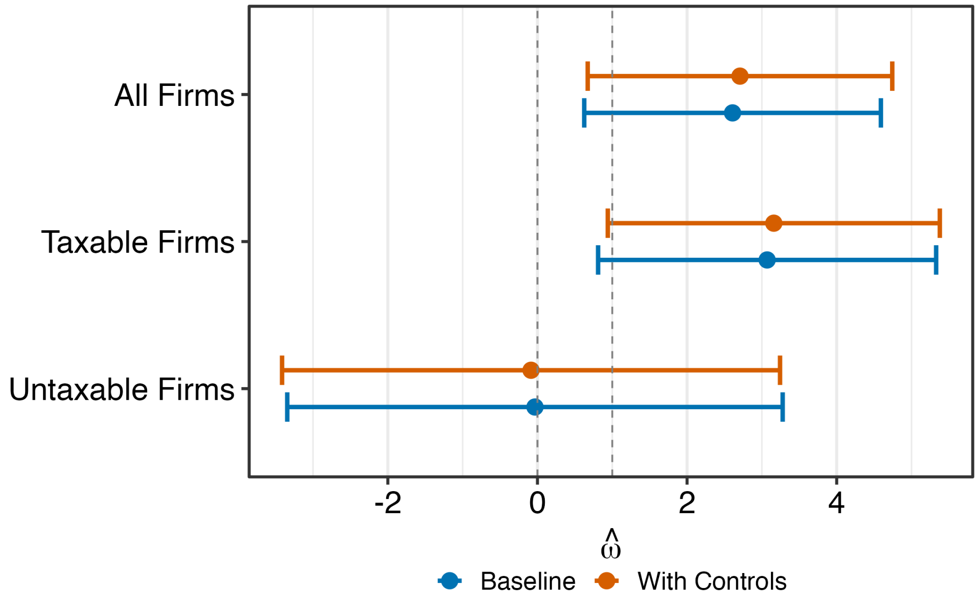
In an investment-weighted scheme, which is typically used to study the investment elasticity following bonus (Zwick and Mahon 2017), each asset class is weighted by investment weights.

Under this approach, ω captures the elasticity of maintenance per unit of capital with respect to a user cost change for recently acquired assets. However, this specification is conceptually misaligned with maintenance behavior, which applies to the entire installed capital base, not just to recent investment. By contrast, a capital-weighted scheme weights each asset class by its average capital stock over L pre-reform years. Because depreciation allowances affect the user cost of assets already on the books, this weighting scheme is more appropriate for studying maintenance, which is by definition spending on *existing* capital. In this case, ω reflects the elasticity of maintenance per unit of capital with respect to a user cost change for the installed base. This is the economically relevant margin for firms deciding how much to invest in repairs or upkeep given the cost of replacing old assets.

The primary assumption is that the industry-by-year level policy variations are independent of other industry-by-year shocks that could simultaneously affect maintenance rates. These shocks might simultaneously influence both the implementation of tax policies and maintenance behaviors within industries, violating the assumption that policy variations are independent of other industry-year level factors. For example, policy around Covid-19 would plausibly not meet this criteria. Without adequately controlling for these time-varying confounders, the estimated relationship between tax policy and maintenance rates could be confounded by these unobserved influences. Toward mitigating that, I include broad linear and quadratic industry trends at the two-digit NAICS level.

Results. Figure 6 shows estimates of (11) for three groups: all firms, taxable firms, and untaxable firms. The top row of each group is a simple regression of the log maintenance rate on the log tax term, while the second column includes a control for the age of capital proxied by the ratio of gross to net book capital, and both include linear and quadratic trends for two-digit NAICS industries. Controlling for age accounts for the fact that older capital may require more maintenance. Compared to the partial equilibrium R-1 coefficient, the SOI general equilibrium coefficient is only about 60% as large. Although we reject the null hypothesis of perfectly inelastic maintenance demand, we fail to reject the null of unit elasticity. The gap between the SOI and freight rail estimates suggests some reallocation between firms following tax cuts, resulting in a smaller decline in aggregate maintenance than we observe at the micro level. However, that conclusion must be tempered by the fact that there is some omitted variable bias introduced by the omission of a pre-tax price of maintenance in the SOI regression.

Figure 6: Maintenance demand elasticity with 95% confidence interval



Note: This figure plots the point estimates and result for estimating (11). All estimates have two-way fixed effects together with linear and quadratic trends in two-digit NAICS codes. Orange lines control for the age of the capital stock. All standard errors are clustered by industry. The top estimate is for the All Firm sample, while the bottom two groups of estimates split the SOI into a taxable and an untaxable sample and re-runs (11) individually for each.

In the aggregate, some reallocation seems to be taking place and resulting in maintenance dampening. Since we do not actually observe capital sales, we can partially test for that by splitting the sample into firms with positive net income ("taxable") and untaxable firms. The mapping is rough because some of the firms in the taxable sample have positive net operating losses, so they are not actually taxable. In principle, maintenance should rise for untaxable firms and decline for taxable firms following a tax cut if the reallocation model is qualitatively correct. Even if no reallocation takes place, the demand elasticity should be significantly larger for taxable than untaxable firms. The middle two rows and bottom two rows of Figure 6 show demand elasticity estimates together with 95% confidence intervals. The maintenance demand elasticity doubles to around three and becomes more statistically significant, which is quite similar to the partial equilibrium estimate in Figure 5. On the other hand, the untaxable elasticities are centered at zero. Thus, interpreted as either a placebo test for the theory or more broadly as reflecting reallocation, the sample split provides sound evidence in favor of the hypotheses advanced in Section 3.

There are two potential sources of measurement error with the maintenance rate, both of which may plague the estimates. The first comes from the denominator, which is the lagged capital stock. Because that measure of capital is tax book capital and is inherently determined by tax policy, there is industry-specific and time varying measurement error by construction. The set of controls largely deal with this. The industry fixed effects account for time-invariant characteristics and baseline differences across industries that would otherwise systematically distort capital measurements. Since the time fixed effects isolate industry-specific variation in exposure to tax policy changes, including linear and quadratic industry trends captures time-varying unobserved factors within industries. Finally, by construction, the tax wedge itself explicitly models the varying degrees of tax policy exposure across industries and therefore directly addresses the primary source of measurement error related to tax policy differences.

Appendix Figure C.14 presents separate estimates of the maintenance elasticity using a BEA measure of capital instead. These data come from the detailed fixed asset tables by industry and come with the corresponding issue that the capital stock is a mix of corporate and non-corporate capital. Nevertheless, it is encouraging that the estimates are similar across specifications, albeit with less statistical significance. Another source of error, which is only relevant for the taxable and untaxable samples, is that lagged capital is for a different set of firms in the current than the previous period. I correct for this by using contemporaneous rather than lagged capital.

An additional issue comes from the SOI's sampling methodology. In 2013, the SOI changed the number of industries sampled. Because some of the sampled industries are too small in that period, the IRS censored their reporting meant that some industries did not report maintenance expenditures, resulting in the possibility of some aggregation error. Figure C.14 shows that the results are unaltered by re-running the regression through 2013 rather than 2021.

As a second placebo test, I conduct the exact same regression using an investment-weighted $z_{i,t}$ in Figure C.13. The magnitude of ω diminishes considerably and no regression can reject the null of perfectly inelastic maintenance demand. This, again, accords with theory. A null result indicates that firms are not adjusting their maintenance on recently acquired investment goods, which is what we would expect.

Selection Effects. One concern is that industries more exposed to bonus are also precisely those industries with inherently more price-elastic capital maintenance. This is an important concern about the *investment* elasticities estimated using bonus (Koby and Wolf 2020). The steady-state tax elasticity of long-lived capital is higher than short-lived capital, so bonus to exposure is correlated with a pre-existing elasticity distribution, which biases elasticity estimates. If that channel operated here, the maintenance demand elasticity would be overestimated because of selection effects.

To investigate selection, I re-run the baseline regression and add an interaction between the equipment-capital ratio and the wedge term. If the marginal effect varies by the equipment-capital ratio, then capital elasticities are heterogeneous and we would have cause to worry about selection. Appendix Figure G.6 shows that the marginal effect is essentially invariant across the equipment-capital ratio. Although the elasticity seems to grow slightly larger as industries become more equipment-intensive, the effect is statistically insignificant and quantitatively small. Thus, the selection channel does not appear to be present here because it is difficult to reject the null hypothesis of homogeneity across capital types.

5.3 Omitted Variable Bias from Endogenous Wages

The preceding analysis implicitly treats p^M and p^I as policy invariant. Although a classic result from Goolsbee (1998a) shows that investment supply is upward sloping, newer evidence (House and Shapiro 2008; House, Mocanu, and Shapiro 2017; Basu, Kim, and Singh 2021) indicates that investment-good prices did not respond to tax policy changes during the 2000s, largely due to increased foreign competition. That invariance is less plausible for maintenance. Because labor is a key maintenance input and wages rise after tax cuts (Fuest, Peichl, and Siegloch 2018; Kennedy et al. 2023), p^M is plausibly endogenous to policy. If maintenance prices rise while investment-good prices are invariant, the pre-tax relative price p^M/p^I increases.

Let $\varepsilon_s > 0$ denote the elasticity of maintenance supply. With upward-sloping supply, shocks to the wedge partly move p^M, so estimating (8) recovers the *equilibrium* elasticity

$$\omega_{\text{eq}} = \frac{\omega}{1 + \omega/\varepsilon_s},$$

which satisfies $|\omega_{\text{eq}}| < |\omega|$ for any finite ε_s.[10] In absolute value, the regression coefficient understates the structural demand elasticity. How do we interpret the regression elasticities in each case?

R-1 railroads. In the railroad panel, the concern is that local wage movements may co-move with unobserved maintenance needs (utilization spikes, backlog clearance), rendering p^M partly endogenous. I mitigate this in three ways. First, I use a wage shift-share (Bartik) that interacts lagged, pre-policy maintenance labor shares with external wage shocks to shift the cost side of p^M rather than demand. Second, the specifications include firm-asset fixed effects, firm-specific trends, and year fixed effects, along with local activity and asset-age controls, which absorb slow-moving co-trends between wages and maintenance intensity. Third, I separate internal and external maintenance. Internal maintenance (a margin where firms can flex quantities) exhibits a large elasticity, whereas external maintenance (supplied by vendors with comparatively inelastic capacity) responds weakly. This internal–external divergence is what a cost-shift design predicts and serves as a diagnostic that remaining wage endogeneity primarily attenuates the elasticity. I

10. Let demand be $m = a(Qp_M)^{-\omega}$ with $Q \equiv (1-\tau)/p^I$, and inverse supply $p_M = b\, m^{1/\varepsilon_s}$ with $\varepsilon_s > 0$. Substituting gives $m^{1+\omega/\varepsilon_s} = a(Qb)^{-\omega}$. Taking logs and differentiating w.r.t. $\ln Q$ yields $\frac{d \ln m}{d \ln Q} = -\frac{\omega}{1+\omega/\varepsilon_s} \equiv -\omega_{\text{eq}}$, hence $\omega_{\text{eq}} = \omega/(1+\omega/\varepsilon_s) < \omega$ for finite ε_s.

therefore read the internal estimate as closes to the structural demand slope and interpret pooled estimates as conservative lower bounds.

SOI industries. In the industry panel, identification comes from demand shifters (tax exposure), so wage pass-through works against the wedge: after a tax cut, wages rise while the after-tax price of investment falls, pushing the estimated coefficient toward zero in absolute value. I address this by absorbing common wage movements with two-way fixed effects and flexible trends, so identification relies on differential policy exposure across industries rather than aggregate comovement. I also use a taxable versus nontaxable split: wage shocks should affect both groups, but only taxable industries face the wedge and they are the ones that adjust maintenance, which is the pattern I find. Because I do not separately price p^M in this setting, I label the SOI coefficient an equilibrium elasticity, acknowledging that wage movements plausibly dampen the response and make the estimate a lower bound on the structural elasticity.

Interpretation. Across both designs, any residual wage-related endogeneity that survives instruments, fixed effects, and trends operates in the same direction: it reduces the magnitude of the estimated elasticity. Reading the R-1 internal estimate as close to structural and the SOI estimate as an equilibrium lower bound yields a coherent and conservative interpretation for any quantitative estimates.

5.4 Combining Estimates

Having clarified how wage endogeneity affects $\widehat{\omega}$ in each dataset, I now combine the estimates into a single maintenance demand schedule for counterfactuals. The maintenance demand function is of the form

$$m = \gamma \left(\frac{p^M}{p^I} \frac{1-\tau^c}{1-\tau^c z} \right)^{-\omega}.$$

We need the demand function to construct policy counterfactuals, but there are two issues which make it difficult to do that. First, cross-sectional estimation yields a missing intercept problem for obtaining and doing inference on γ. Second, we have a battery of different estimates for ω, but it is not easy to come up with a consensus estimate for the demand function given variation in the estimation procedure. Ideally, we would simply rely on the industry estimates from the SOI, but they are far less precise than those from the R-1 reports and reflect considerable measurement error.

To address the first issue, my approach to recover $\hat{\gamma}$ is to solve for $\hat{\gamma} = \bar{m}\, \bar{P}^{-\hat{\omega}}$, where bars denote sample averages. I obtained standard errors for $\hat{\gamma}$ using a wild cluster bootstrap for the R-1 sample and the delta method for SOI samples. Given those estimates, I used the delta method to get the covariance between $\hat{\omega}$ and $\hat{\gamma}$.[11]

I rely on modern meta-analytic methods to combine the R-1 and SOI estimates into a single maintenance demand schedule. From the R-1 estimates, I take our baseline IV regressions along with all alternative instrument estimates excluding the physical capital regressions. I take all SOI regressions except those from untaxable firms. I then proceed in two steps. First, I pool the SOI estimates of γ and estimate a single-parameter random-effects meta-analysis using restricted maximum likelihood (REML). I rely only on the SOI because we are primarily interested in an aggregate demand function, so using the R-1 would cause us to overestimate the level of demand. However, I do rely on estimates from both datasets to recover the demand elasticity. Once more, I estimate REML while allowing for unstructured between-study covariance. That automatically gives more weight to the tighter estimates while allowing for heterogeneity across datasets and clustering standard errors within samples. Finally, to fill the off-diagonals in the covariance matrix, I take a precision-weighted average of the SOI estimates' empirical $\mathrm{Cov}(\hat{\gamma}, \hat{\omega})$.[12]

Figure 7 plots the resulting demand curve together with a 95% confidence interval. I also plot an estimated demand curve for the SOI and the R-1. The aggregate demand curve is nearly on top of the SOI curve but is more elastic. That indicates our estimates will tend toward conservatism. The line in green together with the corresponding confidence interval is precisely what we need to estimate the counterfactual effects of business tax reform, something I turn to subsequently in the context of the 2017 Tax Cuts and Jobs Act.

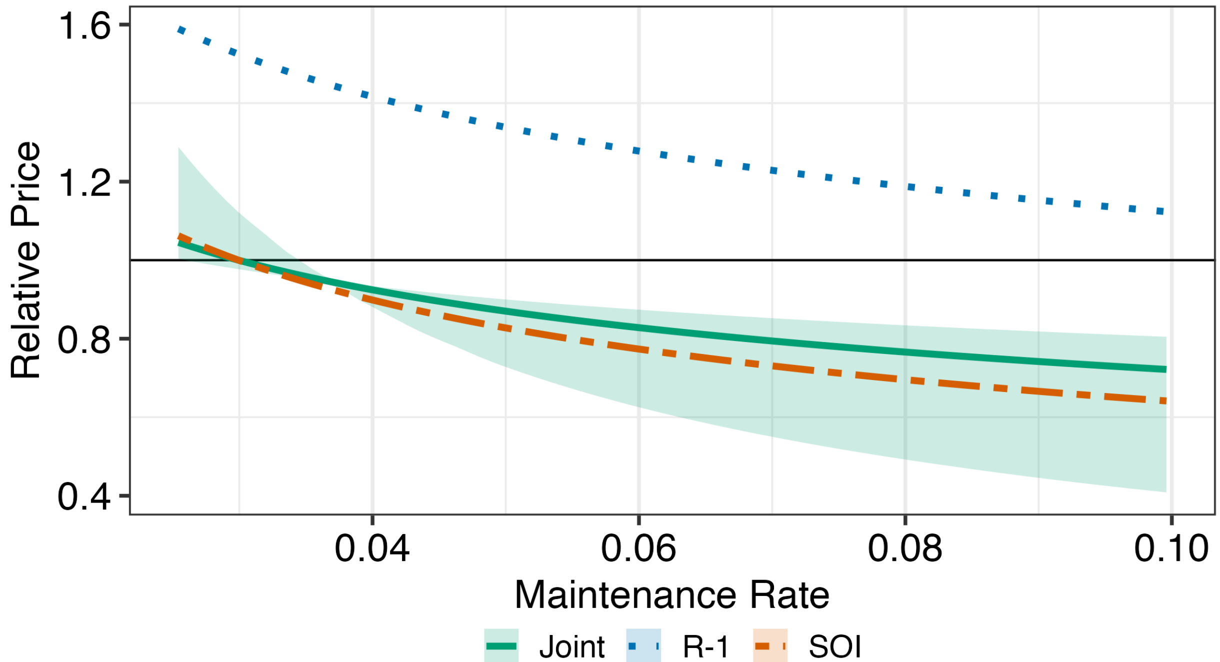
11. In particular, for every regression i, I obtain the covariance from

$$\mathbb{C}\big(\gamma_i^*,\, \omega_i\big) \;\approx\; \frac{\partial \gamma_i^*}{\partial \omega_i}\, \mathbb{V}(\omega_i) \;=\; \Big[-\bar{m}_i\, \bar{w}_i^{-\omega_i}\, \ln \bar{w}_i\Big]\, \mathbb{V}(\omega_i) \;=\; -\gamma_i^*\, \ln\big(\bar{w}_i\big)\, \mathbb{V}(\omega_i).$$

Note that for the R-1 data, I use the Anderson-Rubin confidence intervals for standard errors on $\hat{\omega}$. Due to several approximation steps, the variance-covariance matrix is occasionally not positive-definite, so I perturb the covariance entries using the nearest-positive-definite method until the matrix becomes positive-definite.

12. That value exceeds the positive-definite bound $\sqrt{\mathbb{V}(\hat{\gamma})\mathbb{V}(\hat{\omega})}$, so I truncate it to $\rho = 0.99$ of the bound to ensure a positive-definite covariance matrix, then use that as our parameter covariance estimate. We end up with a non-PD covariance matrix initially because our estimates do not all come from the same samples.

Figure 7: Estimated Maintenance Demand Curve with 95% CI



Notes: The green curve is the pooled inverse-demand schedule from eight regressions each from the SOI and the R-1 data for the elasticity and the eight SOI estimates for the level parameter. The shaded band is the 95% Monte-Carlo confidence interval around the pooled curve.

5.5 Dynamics

One of the key theoretical results depends implicitly on the assumption that maintenance adjustment costs are negligible. If that is not true, then the tax elasticity of depreciation must be low along the transition path. I test that empirically with local projections for both the R-1 and SOI datasets. That amounts to taking our baseline regressions and estimating the dynamic response of maintenance to shocks.

Figures C.2 and C.1 plot the local projections for the SOI and R-1 specifications, respectively. In the railroad data, where identification comes from Bartik-style shocks to maintenance input costs, the response of maintenance is immediate but also displays persistence. Firms reduce upkeep on impact, and the effect deepens for two to three years before attenuating. This pattern is consistent with some adjustment frictions, such as planning lags or a stock-of-disrepair channel, that make the full reallocation of resources away from maintenance gradual rather than instantaneous. In contrast, in the SOI industry-level data, where identification comes from discrete policy shocks, the response of maintenance is essentially contemporaneous. Industries cut upkeep in the same year the wedge falls, and conditional on lagged maintenance intensity, there is little evidence of further propagation in subsequent years. This difference is intuitive: federal policy reforms generate sharp, one-time shifts in the after-tax wedge that can be acted upon immediately, while cost shocks in the railroad setting are more drawn out and may require staggered operational adjustments. Taken together, the evidence suggests that maintenance responds rapidly to tax-policy-driven wedges but that persistence and adjustment costs can matter in environments where shocks to relative prices are themselves more gradual or sustained. Since the SOI results are more policy-relevant, I focus on the implied dynamics from them in subsequent quantitative exercises.

6 Aggregate Implications of Maintenance Demand

Having established that maintenance demand is positive and elastic, we now turn to incorporating that into the theory. This section derives new theoretical results on the aggregate implications of positive and elastic maintenance demand.

6.1 The User Cost of Capital

As a framing device, consider the standard neoclassical model. In the model, the usual expression for the user cost of capital is

$$\Psi^{NGM} = \frac{r+\delta}{1-\tau}.$$

With Cobb-Douglas production, there are clear linkages from a permanent shock to tax policy to the responses of macro aggregates. After rewriting in intensive form, changes in user cost propagate through to capital, wages, and output via

$$\varepsilon_K = -\frac{1}{1-\alpha}\varepsilon_{\Psi}^{NGM} \quad \text{and} \quad \varepsilon_w = -\frac{\alpha}{1-\alpha}\varepsilon_{\Psi}^{NGM} \quad \text{and} \quad \varepsilon_Y = -\frac{\alpha}{1-\alpha}\varepsilon_{\Psi}^{NGM}, \tag{12}$$

where the tax elasticity of user cost is

$$\varepsilon_{\Psi}^{NGM} = \frac{\tau}{1-\tau}. \tag{13}$$

Perturbing the cost of capital by changing the tax rate τ therefore propagates to other cariables exactly as in (12). How does that change when we add maintenance? Because every unit of new capital must be maintained at cost $p^M m$, the steady-state user cost is

$$\Psi^{NGMM} = \underbrace{\frac{p^I(1-c-\tau z)}{1-\tau}}_{p^I(1-\tau)}\Big(r^k + \delta(m)\Big) + p^M m, \tag{14}$$

where r^k is the discount rate and m is the optimal maintenance rate given from Proposition 1. If maintenance demand were zero and depreciation constant, then we would recover the benchmark user cost of capital derived by Hall and Jorgenson (1967) and regularly employed in both theoretical (Chodorow-Reich et al. 2025) and empirical work (Hartley, Hassett, and Rauh 2025).

Now, consider a small reform $\Delta\tau$, where τ is the marginal tax on the return to a unit of new investment. To focus on the tax wedge and save on notation, let $p^I = p^M$. With maintenance, the generalized tax elasticity of user cost is

$$\boxed{\varepsilon_{\Psi}^{NGMM} = \underbrace{\frac{\tau}{1-\tau}}_{\substack{\text{NGM} \\ \text{Benchmark}}} \times \underbrace{\left(1 - \frac{m}{\Psi}\right)}_{\substack{\text{Tax Shield Effect} \\ \text{(First-Order)}}} - \underbrace{\frac{\tau}{1-\tau}\left(\frac{\varepsilon_m}{\Psi}\left[\frac{\delta(m)\varepsilon_\delta}{1-\tau} + m\right]\right)}_{\substack{\text{Input Substitution Effect} \\ \text{(Second-Order)}}}.} \tag{15}$$

Equation (15) shows how much the user cost of capital changes when taxes change. That matters because the aggregate effects of any capital tax change is mediated by the tax elasticity of the user cost of capital. There are three components to (15), which I discuss in turn.

Benchmark Elasticity. The first component of the first term in (15) is the benchmark tax elasticity of the user cost of capital from (13).

Tax Shield Effect. The benchmark elasticity ε_{Ψ}^{NGM} is given a haircut by the maintenance share of user cost. Since the lifetime cost of a unit of capital includes its upkeep costs and that upkeep is tax-deductible, only the remaining share is exposed to tax cuts. If maintenance dominated user cost, the user-cost elasticity would collapse to zero, and capital would not respond to taxes at all. Thus long-lived assets that also require heavy upkeep can be less tax-elastic than short-lived ones, reversing the standard "long-lived assets are more price-elastic" result in House (2014) and McKay and Wolf (2022).

Input Substitution Effect. Cutting taxes effectively makes new capital cheaper relative to maintaining old capital. Firms therefore reallocate dollars from maintenance toward investment, which mechanically raises depreciation. This effect is emphasized by McGrattan and Schmitz Jr. (1999). If maintenance demand were unit-elastic, the drop in m would exactly offset the rise in $\delta(m)$, leaving net user-cost sensitivity unchanged. With more elastic maintenance demand, depreciation moves a bit further against the shield (or with it), but this effect is generally small compared to the main tax-shield haircut.[13]

Proposition 2 (Attenuated Tax Elasticity)**.** *To first order, the sensitivity of the user cost of capital to a tax change is strictly smaller than in the benchmark neoclassical model.*

This immediately follows from equation (15) following the conclusion that input substitution is second-order. The result highlights the central role of the maintenance share of user cost in quantifying this attenuation.

6.2 Implications for Macro Variables and Dynamic Scoring

Because the transmission of tax policy into aggregate variables is directly mediated by the cost of capital, incorporating maintenance has first-order consequences for macro outcomes.

Capital, Output, and Wages

Tax reformers are typically interested in tax cuts because of their transmission through capital deepening into higher output and wages (Romer and Romer 2010). Given the tax shield effect, it immediately follows that, to first-order, the tax elasticities of the relevant macro aggregates are strictly smaller. Let s_m denote the maintenance share of user cost.

Corollary 1. *The tax elasticities of capital, output, and wages are strictly smaller in the maintenance model than in the benchmark model. In fact, the tax elasticities are marked down exactly by the maintenance share of user cost to first order. For any variable X, the tax elasticity is marked down by*

$$\varepsilon_X^{NGMM} = (1 - s_m)\varepsilon_X^{NGM}.$$

In the Cobb-Douglas case, there is a simple way to illustrate the distinction in macro propagation between the NGM and the NGMM. The tax elasticity of wages and output are governed by the factor $\alpha/(1-\alpha)$. In typical applications, that factor is around 0.6, which requires $\alpha = 0.375$ (Barro and Furman 2018). If, for example, the maintenance share of user cost $s_m = 0.5$, that would be observationally equivalent to cutting α from 0.375 to 0.23.

13. To see why, note that the total derivative of user cost with respect to τ is

$$\frac{\mathrm{d}}{\mathrm{d}\tau}\Psi\big(\tau, m^*(\tau)\big) = \underbrace{\frac{\partial\Psi}{\partial\tau}\big(\tau, m^*(\tau)\big)}_{\text{tax shield effect}} + \underbrace{\frac{\partial\Psi}{\partial m}\big(\tau, m^*(\tau)\big) \cdot \frac{\partial m^*(\tau)}{\partial\tau}}_{\text{input substitution effect}}.$$

But by the first-order condition at the optimum $m^*(\tau)$, we have $\frac{\partial\Psi}{\partial m}\big(\tau, m^*(\tau)\big) = 0$.

Remark (Clarifying the Roles of γ and ω for Macroeconomic Outcomes). Proposition 1 establishes that the maintenance share of user cost is a sufficient statistic for the attenuation of the tax elasticities of capital, output, and wages. Suppose demand for maintenance is constant-elasticity and parameterized by ω and γ. Since these parameters determine the maintenance and depreciation elasticities, but that channel is second-order, γ and ω are irrelevant for the tax elasticities of capital, output and wages. Any combination of γ and ω will suffice as long as they produce the observed maintenance rate at the prevailing relative price. Therefore, we do not need to know maintenance demand to precisely predict what happens to output, capital, and wages given a tax reform—we just need to observe the maintenance rate *and* trust our observations on the discount and depreciation rates.

Investment

The effect of maintenance on the tax elasticity of investment depends entirely on the maintenance demand elasticity. If demand is perfectly inelastic, then $\varepsilon_I = \varepsilon_K$ just as in the benchmark case. However, positive demand strictly attenuates the tax elasticity of investment. The story becomes more nuanced when we have curvature in the depreciation technology, which makes depreciation respond to tax changes through maintenance.

Corollary 2 (Investment–Capital Elasticity Gap)**.** *We can explicitly define steady-state investment in terms of tax rates as*

$$I(\tau) = \delta\left(m(\tau)\right) \times K\left(\tau, \delta(m(\tau)), m(\tau)\right),$$

from which it follows that

$$\varepsilon_I \approx \varepsilon_\delta + \varepsilon_K. \tag{16}$$

With isolastic maintenance demand, there are two ways to recover the canonical Hall-Jorgenson benchmark in which $\varepsilon_I = \varepsilon_K$. First, if maintenance demand is zero, then we get (14). This is both obviously not true in practice and assuming it is, as we have seen, theoretically dangerous for the conclusions one might reach about capital elasticities. The other way is if the knife-edge case $\omega = 1$ prevails.

Remark (Permanent Lift in the Investment Rate). In steady state $I/K = \delta(m)$. Since m falls when the after-tax price of new capital declines ($\partial m/\partial(1-\tau) < 0$), a tax cut raises $\delta(m)$. The result is a permanently higher gross investment rate and hence a younger average capital stock. Benchmark models with fixed depreciation cannot capture this vintage-age effect.[14]

14. Firms typically have an additional scrappage margin for adjustment, which we know is empirically important in the context of tax reform (Goolsbee 1998b). That is implicitly accounted for here by the fact that tax cuts stimulate firms to invest at a higher rate and shed old capital more quickly through higher depreciation. A vintage model

Consider the neoclassical model as a contrast. There, the tax elasticity of investment is a sufficient statistic for partial equilibrium changes in capital and output because in steady state, $I = \delta K$. Hence the tax elasticities of investment and capital coincide, $\varepsilon_I = \varepsilon_K$. This one-for-one mapping is what allows the empirical literature—from the classic Hall–Jorgenson regressions to recent quasi-experiments such as from Zwick and Mahon (2017)—to translate an estimated "investment elasticity" directly into partial equilibrium predictions for capital deepening and output. The maintenance margin introduced next breaks that identity, enlarging the investment response but dampening the capital response, and therefore compels a re-examination of those standard empirical inferences.

Implications for Measurement. Elastic and positive maintenance demand induces a divergence between the elasticities of capital and investment. That presents an issue for evaluating tax reforms both statically and dynamically. Typically, researchers estimate the response of investment to variation in user cost and read it as the response of capital (Cummins, Hassett, and Hubbard 1994; Hartley, Hassett, and Rauh 2025; Zwick and Mahon 2017; Chodorow-Reich et al. 2025). Unless we are in the knife-edge unit-elastic or perfectly inelastic cases, that is not permissible. Since maintenance data are sparse and significantly noisier than investment data when available, it is also generally not an option to jointly evaluate maintenance and investment. However, as long as there is a credible estimate of the maintenance demand function, then we can map standard investment regressions to the responses of macro aggregates.

Corollary 3 (Omitted-Variable Bias in Standard Investment Regressions)**.** *Suppose the econometrician regresses investment on the user cost of capital but excludes maintenance. If maintenance demand is positive and elastic maintenance, the coefficient on user cost is biased downward. With constant-elasticity depreciation, a closed form exists.*

Proof: Appendix D.3.

Corollary 3 shows that, whenever maintenance demand is positive, standard regressions of investment on the textbook cost of capital understate the true gross investment response to tax changes. Thus, using observed investment responses to back out the aggregate effects of tax reforms is fundamentally misleading unless one also models maintenance behavior. But we can continue to estimate the standard investment regressions as long as we apply the maintenance demand correction. Since capital is generally unobserved directly, we can back out its implied

would show this more explicitly, but the scrappage channel is captured by endogenous depreciation through elastic maintenance demand. In some sense, then, the demand elasticity for maintenance may be interpreted as a reduced form tax elasticity for the age distribution of capital. This would speak directly to the indirect evidence in Goolsbee (2004) that lower taxes induce firms to buy capital with lower maintenance costs.

empirical response from $\varepsilon_K = \varepsilon_I - \varepsilon_\delta$, where ε_I is a direct empirical estimate of the investment elasticity and ε_δ is implied by the parameters γ and ω.

Convergence and Scoring in the NGMM. So far, we identified two key distinctions between investment in the NGM and in the NGMM. First, the tax elasticities of investment and capital generally diverge. Second, the model-consistent regression estimate of the tax elasticity of investment is strictly larger in the NGMM. Together, those two facts imply a new dimension to the dynamics of investment in the NGMM: adjustment costs must be higher to rationalize the same investment response to tax policy. The intuition follows from both the tax shield and input substitution effects. First, because maintenance outlays are fully deductible, only the non-maintenance share of user cost that finances new capital actually falls, so the initial price incentive behind any investment spike is already muted. Second, via the input substitution effect, a slice of the observed investment surge is therefore just replacing machines that now wear out faster. The regression elasticity $\hat{\varepsilon}_I$ captures this large gross-investment jump, but the net impulse pushing the capital stock equals $|\hat{\varepsilon}_I| - |\hat{\varepsilon}_\delta|$, after the depreciation drag is peeled away. Reconciling such a shrunken net impulse with the same gross swing forces the model to assume steeper installation frictions.

Consider this with a capital adjustment costs. Although investment adjustment costs (Christiano, Eichenbaum, and Evans 2005) are popular in macroeconomics, it is far more common in the tax literature to use convex—and usually quadratic—capital adjustment costs (Summers 1981; Koby and Wolf 2020; Chodorow-Reich et al. 2025). Suppose we have an estimated tax elasticity of investment $\hat{\beta} = \hat{\varepsilon}_I$. When parameterized by an adjustment cost parameter ϕ, NGM adjustment costs are

$$\phi_{NGM} = \frac{1}{\delta} \frac{1}{|\hat{\varepsilon}_I|}.$$

By contrast, it follows from our discussion above that capital adjustment costs in the model with maintenance are

$$\phi_{NGMM} \approx \frac{1}{\delta(m)} \frac{1}{|\hat{\varepsilon}_I| - |\hat{\varepsilon}_\delta|}. \tag{17}$$

See Appendix D.4 for the full derivation with quadratic capital adjustment costs. By contrast, the NGM adjustment cost parameter entirely neglects the depreciation margin and so is strictly smaller, i.e., $\phi_{NGM} < \phi_{NGMM}$. It therefore follows that convergence to steady state is slower in the NGMM.

Slower convergence to a smaller steady state has direct implications for scoring tax reform. By statute and convention, the cost of a tax reform is scored over a ten-year window by the Congressional Budget Office (CBO). The CBO computes a static score, which is the cost of the bill assuming no behavioral changes. More recently, the CBO, along with the Senate Joint Committee on Taxation, has prepared dynamic scores, which account for the additional revenue that the reform may yield from growth effects. Dynamic scores are also done for ten-year horizons. Since it typically takes far longer than ten years for models to converge to steady state, the transition path is important for scoring. When we put together our theoretical results, there is a clear implication for scoring.

Corollary 4 (Dynamic Scoring in the NGMM)**.** *Since convergence is slower in the NGMM and the steady state is smaller than the NGM, a dynamically scored NGMM is strictly closer to the NGM.*

Although economists emphasize the importance of dynamic scoring (Barro and Furman 2018; Elmendorf, Hubbard, and Williams 2024), simply allowing for one more channel to at least partially offset investment pushes us back toward a framework with macro and fiscal outcomes similar to as if we allowed no responses to the reform at all.

Our theoretical findings motivate an illustrative quantification of a tax reform, which I turn to subsequently.

7 Capital Maintenance and the 2017 Tax Cuts and Jobs Act

Theory has two key implications for the economics of capital maintenance, along with an an implication for dynamic scoring of tax reform. First, when maintenance demand is positive, the resulting steady state capital, output, and wages are strictly smaller than predicted by an otherwise identical model without maintenance. Second the convergence rate is strictly smaller. Together, these imply that dynamic scores of tax reforms are closer to the conventional score than commonly understood. In this section, I illustrate the quantitative importance of each implication using the 2017 Tax Cuts and Jobs Act.

7.1 Model and Calibration

At its heart, the model is the same as in Section 3. Time is discrete and infinite. There are three sectors which produce output: corporate, non-corporate, and the government. The representative firm in each sector $i = c, nc$ produces a final output good $Y_{i,t}$ with identical Cobb-Douglas technology and discounts the future at rate r^k. The capital and labor inputs have respective shares α_K and α_L with $\alpha_K + \alpha_L \leq 1$. Aggregate output is given by

$$Y_t = \sum_{i \in \{c,nc,g\}} Y_{i,t}.$$

I normalize corporate productivity to one and discuss the calibration of non-corporate productivity below. To facilitate comparison with Chodorow-Reich et al. (2025), I use their calibrations of the discount rate, the capital share, and the labor share. To capture general equilibrium effects, one unit of inelastically supplied labor is allocated across sectors such that wages are equal between them.

Toward showing the distinction between the neoclassical growth model with maintenance (NGMM) and the standard neoclassical model (NGM), I set up two different laws of motion for capital and set the corresponding parameters such that both models start from the same steady state capital-labor ratio within each sector and the same initial divison of capital between sectors. Capital evolves according to (2) in the NGMM, while it has constant depreciation δ in the NGM. Initially, I assume there is no curvature in the supply curves of either maintenance or investment, which I relax later on. As a result, the maintenance intensity in the NGMM is driven solely by the tax wedge. To capture dynamics, both the NGM and the NGMM variants have capital adjustment costs paid in tax-deductible units of labor

$$\Phi(M_t, I_t, K_t) = \frac{\phi}{2}\left(\frac{I_t}{K_t} - \delta(m_t)\right)^2 K_t. \tag{18}$$

In the NGM variant, $\delta(m_t) = \delta$ since $m_t = 0$.[15] To get a fair comparison between the two models, some of the parameters—like ϕ—differ. I describe how subsequently.

NGMM Calibration. I calibrate (18) using the formula in (17) and use a constant-elasticity depreciation technology. The maintenance demand function estimate from Section 5.4 along with the initial tax rates pin down a point estimate for $\hat{m}$. To account for uncertainty, I use the demand function's variance-covariance matrix to take 5000 draws for ω and γ jointly. Next, for each draw, I set δ_0 and non-corporate productivity A_{nc} to jointly match the ratio of corporate to total capital of $K_c/K = 0.7$ and such that the NGMM's initial ratio of gross investment to private output equals 0.109, which is the pre-TCJA average physical investment rate in the National Income and Product Accounts.[16] The ratio of corporate to total capital comes from Chodorow-Reich et al. (2025). With those parameters, I apply first-order approximation to the tax elasticity of depreciation derived in Appendix D.2 to get $\hat{\varepsilon}_\delta$. Finally, to get $\hat{\varepsilon}_I$, I take the investment elasticity from Table 3, Column 3, Row 1 of Chodorow-Reich et al. (2025). I assume no covariance between the maintenance demand and investment demand elasticities and therefore propagate uncertainty about the elasticity estimate using the standard error estimates from Chodorow-Reich et al. (2025) by again taking 5000 draws. For every draw, I adjust the elasticity upward using Corollary 3. Putting those three ingredients together yields ϕ_{NGMM}.

15. Note that this version of adjustment costs implies that maintenance instantaneously adjusts. I rely on capital adjustment costs because it allows for an easier comparison with Chodorow-Reich et al. (2025), which uses the same specification.

16. In particular, I divide the sum of non-residential investment in equipment and structures by gross domestic product less government expenditures in NIPA Table 1.1.5.

NGM Calibration. As a benchmark, I calibrate an otherwise identical model except that maintenance demand is inelastically zero. This entails two calibration changes. First, I set the constant depreciation rate δ such that the NGMM and the NGM have the same initial steady state capital-labor ratio in both sectors and the divison of capital between them is the same. Second, given that depreciation rate, I calculate ϕ_{NGM} using the unadjusted tax elasticity of investment from Chodorow-Reich et al. (2025). The idea is to calibrate adjustment costs as if we believe the NGM is true, rather than adjust upwards as if the NGMM is correct. This yields a conservative difference in convergence rates.

Policy Reform. I set pre- and post-TCJA tax rates for both sectors following Chodorow-Reich et al. (2025). Following their approach, I assume that bonus depreciation is permanent and that the non-corporate sector did not see a change in marginal tax rates.[17] Given the reform, I compute aggregate output growth by calculating

$$\frac{\Delta Y_{0,t}}{Y_0} = \sum_{i\in\{c,nc,g\}} c_i \frac{\Delta Y_{i,0,t}}{Y_{i,0}},$$

where c_i is the sectoral weight for corporates (c), noncorporates (nc), and government, respectively, and $\Delta Y_{i,0,t}/Y_{i,0}$ is the cumulative growth from year zero to t.

7.2 Aggregate Effects of TCJA

The Tax Cuts and Jobs Act cut capital taxes for corporations by around 3.4% on average. Figure 8a plots the post-TCJA path of domestic corporate capital under the NGM and the NGMM. Under our calibration, a proper accounting for maintenance suggests domestic corporate capital increased by 3.8% after ten years. By comparison, the NGM predicts that capital rose by nearly 5.3%. In other words, the NGMM predicts a ten-year response 70% as large as the standard model. Given an initial level of corporate capital of \$17T, that amounts to a difference of around \$250 worth of corporate capital ten years out.[18]

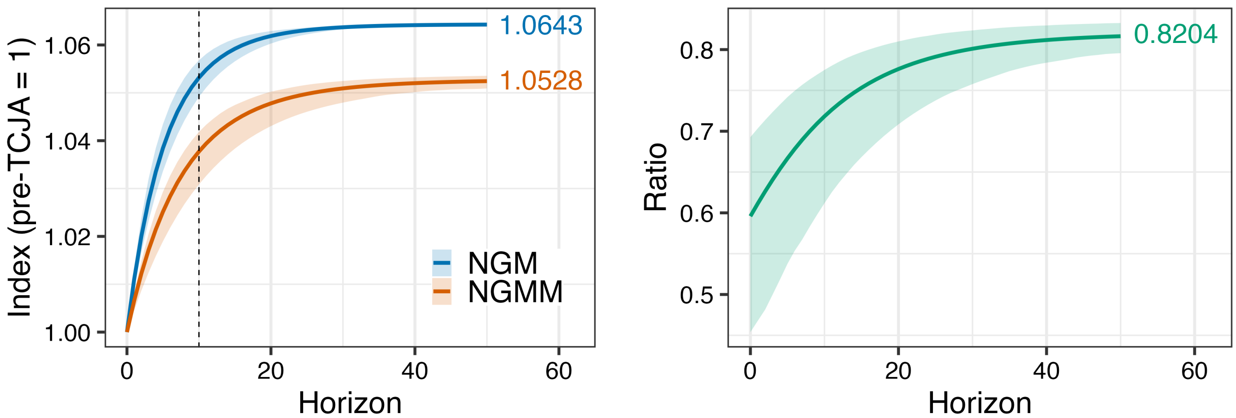
The long-run distinction between the NGMM and the NGM prediction is considerably less dramatic than the short-run. The steady-state increase in NGMM corporate capital is around

17. This is not actually what happened during TCJA because bonus was not permanent and the non-corporate sector saw several large tax reductions. Our goal is to demonstrate the aggregate effects of maintenance accounting rather than give a complete score for TCJA, and Chodorow-Reich et al. (2025) is the seminal aggregate analysis, so one can see the quantitative exercise as a comparison to their work rather than a complete description of TCJA. Given that, the magnitude of the pre- and post-TCJA tax rates for the corporate sector come from a capital-weighted average of the domestic block in Table E.10 of the same paper.

18. Note that the only sources of uncertainty I account for are in the maintenance demand function and capital adjustment costs. If, like in Chodorow-Reich et al. (2025), there is uncertainty about the full set of parameters, then the resulting predictions would be too noisy to say that TCJA increased capital at all.

5.2%, which is 82% as large as the NGM prediction. The decreasing gap along the transition path is easiest to see by taking the ratio of capital in the NGMM to NGM capital. Figure 8b plots that ratio, which captures differences in convergence rates. The initial response is only 60% as large, and it takes nearly 50 years post-TCJA for the ratio to flatten out.

Figure 8: The Effect of TCJA on Corporate Capital in the NGM and the NGMM



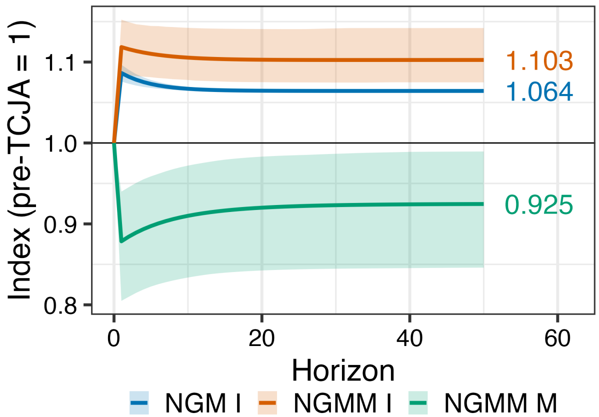
(a) Path of Domestic Corporate Capital

(b) Ratio of IRFs

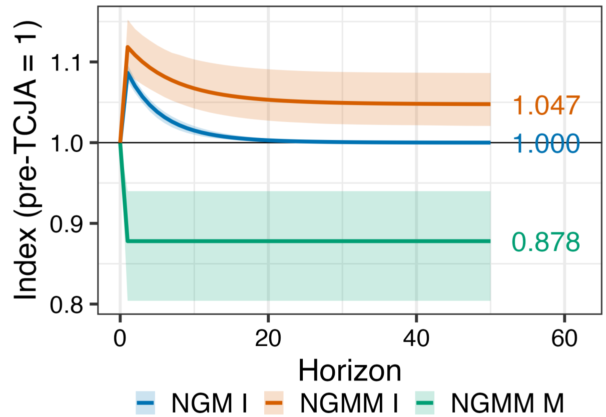
Notes: Panel (a) shows the response of domestic corporate capital to the TCJA in the NGMM (orange line with 95% CI) and the NGM (blue line). Panel (b) plots the ratio of the NGMM to NGM capital IRFs with a bootstrapped 95% CI.

Figure 9 shows how capital changes within the two models. In the NGM, capital rises through permanently higher investment, whereas capital rises in the NGMM through higher investment in new capital more than offsetting lower maintenance of existing capital. Figure 9b shows that the NGMM maintenance and investment rates permanently rise in response to a permanent tax shock. In contrast, the NGM investment rate returns to the initial steady state after the economy converges around twenty years from the shock.

Figure 9: The Effect of TCJA on Capital Inputs in the NGM and the NGMM



(a) Investment and Maintenance Levels

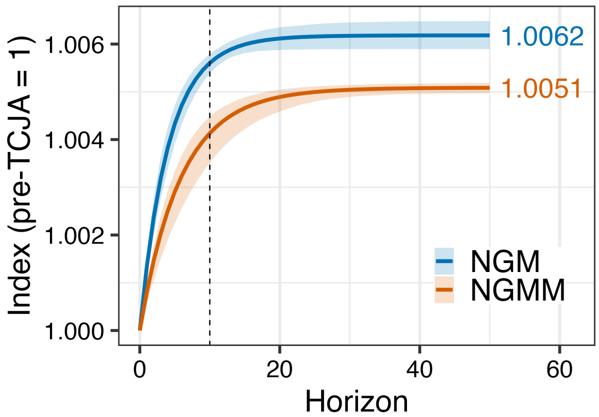


(b) Investment and Maintenance Rates

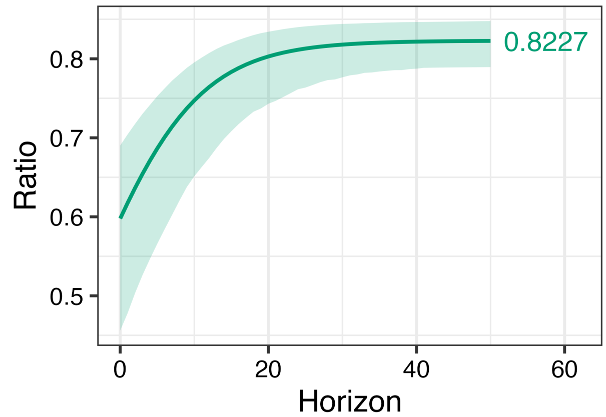
Notes: Panel (a) shows the response of domestic corporate investment to TCJA in the NGMM (orange line with 95% CI) and the NGM (blue line). Panel (b) plots the ratio of the NGMM to NGM IRFs.

Figure 10a shows the path of the growth effects of the reform. Output growth is a weighted average of growth in the corporate sector (positive), the noncorporate sector (negative), and the government sector (zero). The result is that, by 2027, aggregate output is 0.55% higher under the standard model, while it is 0.4% higher in the NGMM. Figure 10b plots the ratio of output growth in the NGMM to output growth in the NGM. Figures 10c and 10d do the same for wages. Across capital, wages, and output, the ten-year ratio of NGMM to NGM variables under this model closure is about 70% as large, while in steady state that gap closes to around 82%.

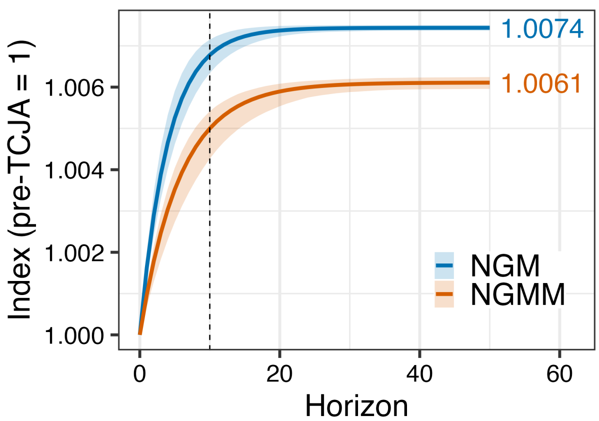
Figure 10: The Effect of TCJA on Aggregate Output and Wages



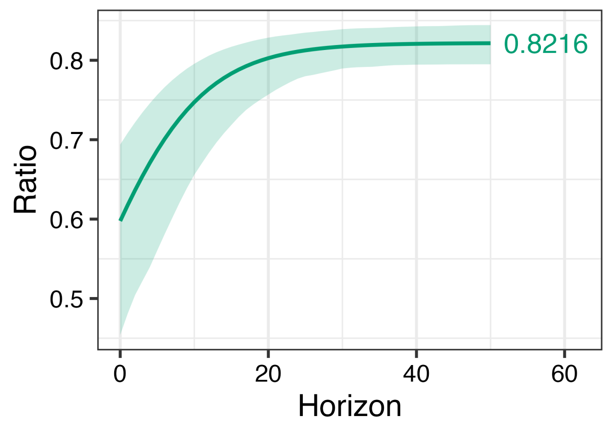
(a) Path of Output



(b) Ratio of Output IRFs



(c) Path of Wages



(d) Ratio of Wage IRFs

Notes: Panel (a) shows the response of output to the TCJA in the NGMM (orange line) and the NGM (blue line) and Panel (b) plots the ratio of output IRFs. Panels (c) and (d) do the same for wages. All lines are bootstrapped with a 95% confidence interval.

7.3 Scoring TCJA

The quantitative difference in convergence rates between the NGMM and the NGM is materially important for the debate over how to score tax reform. Government bodies like the Congressional Budget Office and the Joint Committee on Taxation typically publish the budgetary and macroeconomic effects of tax reform at a ten-year horizon. Such "scores" are often static: they do not account for the changes in behavior engendered by the reform. For example, the static TCJA score would not account for the extra capital—and hence, extra output—resulting from the drop in the marginal effective tax rate on capital. By contrast, a "dynamic" score would account for the extra output resulting from behavioral changes.[19] Like static scores, dynamic scores are given for a ten-year window. As a result, the relevant metric for evaluating a reform is not the steady-state effects—which may take decades to reach—but the ten- or twenty-year marks along the convergence path.

Dynamic scores are only different from static scores to the extent that growth occurs. Since NGMM growth is minimal over the first ten years, the dynamic score is comparatively closer to the static score than in the NGM. To score the reform, I follow Barro and Furman (2018). For both the NGM and the NGMM, I adjust the Congressional Budget Office's (CBO) static output projections by feeding in a model-implid growth path. Taking as given the corporate revenue share of output projected by the CBO, the extra output generates additional tax revenue. I assess the contribution of each model by dividing the ten-year static cost of the bill by the amount of extra revenue generated through accounting for dynamic effects. The resulting figure is the percent of the bill's cost offset by extra revenue through additional output. If, for example, the dynamic offset is 100%, then the bill pays for itself. The results are in Table 1. Evidently, the bill does not pay for itself. In the NGM, about 7.5% of the static cost is offset by higher GDP, whereas the maintenance model offsets 5% of the static cost. Given how little of the static cost is offset by the NGMM, one interpretation of the model is that accounting for maintenance essentially obviates the need to dynamically score the effects of tax reform, although dynamic scoring also appears largely irrelevant under the NGM.[20]

19. See Elmendorf, Hubbard, and Williams (2024) for a discussion of the debate over when and how to dynamically score tax reforms, among other types of legislation.

20. Nevertheless, the scoring exercise is not meant to score the tax reform in its entirety. I only look at the domestic corporate tax and investment provisions, whereas other margins may be important. The static score for permanent bonus comes from Barro and Furman (2018).

Table 1: Ten-Year Corporate Capital, Aggregate Output, and Scores

		$\Delta K_c/K_c$ (%)		$\Delta Y/Y$		Static-Score Offset	
		10Y	Ratio	10Y	Ratio	10Y	Ratio
GE	NGM	5.5	-	0.56	-	7.5	-
	NGMM	3.9	0.71	0.41	0.73	5.0	0.67
	NGMMP	4.1	0.75	0.44	0.79	5.3	0.71
GE w/CO	NGM	4.2	-	0.33	-	4.3	-
	NGMM	2.8	0.67	0.21	0.64	2.4	0.55
	NGMMP	2.9	0.69	0.22	0.67	2.6	0.60
PE	NGM	9.3	-	3.4	-	63.9	-
	NGM	7.0	0.75	2.5	0.74	38.6	0.60
PE w/CO	NGM	7.6	-	2.8	-	46.9	-
	NGM	5.2	0.73	1.9	0.71	26.4	0.56

Notes: Within each panel, the ratio is relative to the corresponding NGM model. The NGMMP denotes the model closure in which labor costs make up half of maintenance costs, so tax cuts induce a rise in the relative price of maintenance beyond that implied by the tax cut.

Table 1 also shows how quantitative conclusions vary with different model closures. For each closure, I show the ten-year growth in the capital stock, aggregate output, and the degree to which the static score gets reduced by growth effects. Broadly, I conduct three different experiments. First, I allow the price of maintenance to rise with wages by assuming that labor makes up half the cost of maintenance. Because there are decreasing returns to maintenance, the marginal reduction in maintenance costs more than offsets the increase in depreciation, but the results are hardly different from the NGMM. In the second panel, I explore crowding out. For each model, I use Barro and Furman (2018) to compute the model-implied 2027 debt-GDP ratio and compare it to the no-TCJA baseline. Then, I use Neveu and Schafer (2024) to compute the resulting increase in crowding out for each model. This exercise exacerbates the difference in aggregate outcomes between NGM and NGMM. Indeed, the resulting score offset is only around half of that in the NGMM. Finally, the last two panels are in partial equilibrium, meaning that labor supply is perfectly elastic. While growth effects are naturally larger in this setting, the ratio of NGMM to NGM responses remains similar. Indeed, the general message remains constant across models: accounting for maintenance shaves off a similar degree of the aggregate effects, and to a larger degree than typically observed by simply accounting for crowding out. That is clear from the resulting IRFs from each model, which I show in Appendix E.

Altogether, the results suggest that the maintenance channel is quantitatively important for analyzing the consequences of capital tax policy for capital accumulation, and hence for wages, productivity, and output. Although the NGM replicate those from Chodorow-Reich et al. (2025)—and therefore the haircuts I obtain apply to their results—the results extend to a broad array of models. In richer settings, the general equilibrium increase in domestic corporate capital accumulation is similarly large to the NGM and the channel is largely the same: capital accumulation via user cost reductions (Sedlacek and Sterk 2019; Zeida 2022). Maintenance may interact with capital in different ways in richer settings with more frictions, but fundamentally, the the lesson for tax models of all kinds is simply that maintenance acts as a powerful dampening force regardless of frictions.

8 Concluding Remarks

In this paper, I discuss the theoretical, empirical, and quantitative implications maintenance demand for the transmission of business tax reform into aggregate outcomes. I provide a parsimonious and flexible framework for evaluating the likely consequences on the short-run and long-run impacts on allocations of maintenance, investment, and capital. Additionally, I put together an entirely new dataset on the maintenance and investment behavior of Class I freight railroads using financial filings from the Surface Transportation Board. Together with maintenance data from corporate tax returns, the evidence indicates that maintenance demand is large and elastic, which has quantitatively large implications for tax reforms. Importantly, this does not require any frictions and in fact relies entirely on combining a neoclassical model with an important but overlooked distortion.

Positive and elastic maintenance demand raises troubling questions for standard approaches to capital theory and measurement. Perhaps the central issue in capital theory is the fact that capital is unobserved. To varying degrees of uncertainty, we observe what are presumably inputs into capital accumulation like investment, but it has historically been a source of controversy how to translate those observations into capital itself (Hayek 1935; Pigou 1941; Feldstein and Rothschild 1974). In recent years, this issue has become particularly salient for many types of intangible capital (Peters and Taylor 2017; Haskel and Westlake 2018; McGrattan 2020). A differentially taxed secondary input for physical capital production implies that measurement issues are perhaps as abundant for physical capital production as they are for intangibles. This finding raises a host of difficult questions far beyond the issues discussed in this paper around tax policy counterfactuals. Indeed, practically any researcher who relies on proper measurement of the capital stock and the cost of capital must consider the extent to which their question is contaminated by maintenance, which extends from growth accounting to the labor share and beyond. Given the groundwork laid here and in prior work by McGrattan and Schmitz Jr. (1999) and Goolsbee (2004), the case for public finance and macroeconomists to undertake these studies is, I think, too big to ignore.

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A Institutional Background

Once classified as an expenditure that must be capitalized, assets are slotted into one of eight lives under rules governed by the Modified Asset Cost Recovery System (MACRS)—three, five, seven, ten, fifteen, twenty, 27.5, or 39 years—which govern how quickly they may be depreciated; shorter class lives yield faster deductions and larger present-value tax benefits. Given a class life of T years and a discount rate r^k, the net present value of a dollar of deductions for a capital investment is

$$z = \sum_{t=0}^{T} \left(\frac{1}{1 + r^k} \right)^t d_t,$$

where d_t is the allowable deduction by the IRS in period t. Table A.1 shows typical assets and associated present value of deductions z for each class category, and Table A.2 works out the year-by-year tax consequences of spending a marginal dollar investing in a new seven-year asset versus maintaining an existing one.

Table A.1: MACRS Asset Lives and NPV of Depreciation Allowances z at a 6% discount rate

MACRS Asset Life (Years)	**Representative Examples**	z
3	Racehorses; special tools	0.9467
5	Automobiles; computers; office machinery	0.9038
7	Furniture; fixtures; general-purpose equipment; locomotives[21]	0.8645
10	Appliances; vessels; barges	0.8108
15	Land improvements; sewage treatment facilities; telephone poles	0.6942
20	Farm buildings; municipal sewers	0.6219
27.5	Residential rental property	0.5001
39	Nonresidential real property (commercial buildings)	0.3958

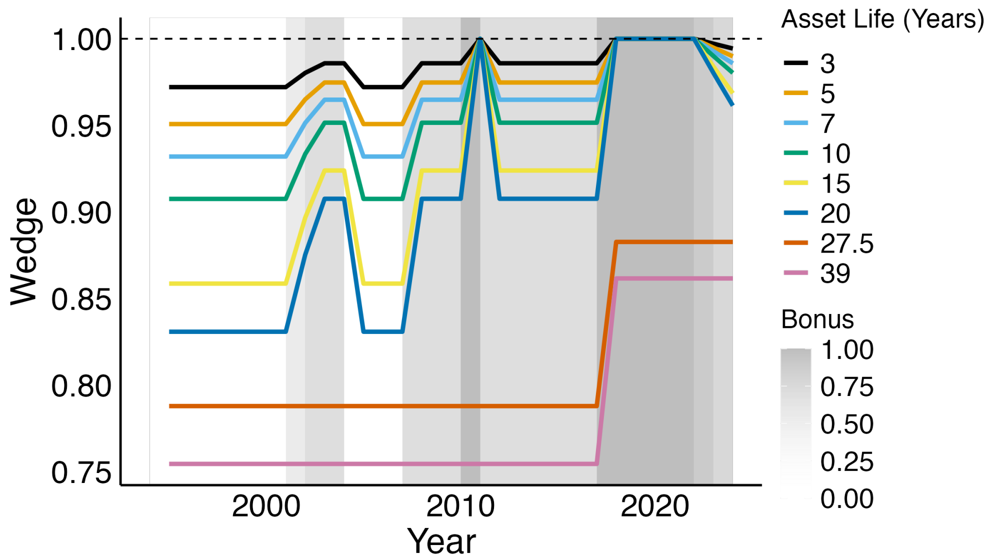
Table A.2: The Tax Treatment of Investment and Maintenance for a Seven-Year Asset

Year:	0	1	2	3	4	5	6	7	Total	z
Investment										
Deductions (000s)	142.9	244.9	174.9	124.9	89.3	89.2	89.3	44.6	1,000	
Tax benefit ($\tau = 35\%$)	50.0	85.7	61.2	43.7	31.3	31.2	31.3	15.6	350	0.86
Tax Benefit (PV)	50.0	80.9	54.5	36.7	24.8	23.3	22.0	10.4	302.6	
Maintenance										
Deductions (000s)	1,000	0	0	0	0	0	0	0	1,000	
Tax benefit ($\tau = 35\%$)	350	0	0	0	0	0	0	0	350	1.00
Tax Benefit (PV)	350	0	0	0	0	0	0	0	350	

Notes: This table adapts Table 1 from Zwick and Mahon (2017) to a seven-year MACRS schedule (8-year life with half-year convention and 200% declining balance until straightline becomes optimal). It includes year-by-year deductions, tax benefits, and present values using a 6% discount rate, and reports z, the PV factor per dollar of tax benefit.

Figure A.1 plots the wedge since 1995 for all MACRS assets. The wedge is largest for long-lived assets and with 100% bonus, the wedge vanishes for qualifying assets. Of course, some firms may elect not to claim bonus if they are not taxable because the deductions are worthless to them (Kitchen and Knittel 2011). Regardless, the wedge has varied considerably between asset types over time.

Figure A.1: The Maintenance-Investment Wedge for MACRS Assets



Notes: The wedge is defined in the main text as the ratio $(1-\tau)/(1-\tau\tilde{z})$, where $\tilde{z}$ is the net present value of depreciation allowances after accounting for bonus depreciation. I set the discount rate as $r = 0.06$.

B Data

B.1 Freight Rail

All variables from the freight rail data come from R-1 filings with the Surface Transportation Board (STB). I used Amazon Textract to extract the relevant data from filings prior to 2012; all data after that date is available on the STB website. Each variable comes from the following part of the R-1 filing:

- All components of **maintenance** come from Schedule 410, Line 202 (Locomotives) and Line 221 (Freight Cars)
- All components of investment and capital come from Schedules 330 and 335 from the lines pertaining to locomotives and equipment
- The miles of rail per state come from Schedule 702
- Data on capital inventories come from Schedule 710

I construct the relative price $P_{i,j,t} = \frac{p^M_{i,j,t}(1-\tau_{i,t})}{p^I_{j,t}}$ as follows:

1. **Price of investment.** The price of investment does not vary by firm, only by capital type.

- Freight Cars: Through 2016, I use item PCU3365103365103Z ("Producer Price Index by Industry: Railroad Rolling Stock Manufacturing: Passenger and Freight Train Cars, New (Excluding Parts)"). I stitched that series together with item WPU14440102, which is the PPI for Passenger and Freight Train Cars, New (Excluding Parts).

- Locomotives: Through 2018, I use BLS item WDU1441, which is the producer price index for locomotives. The BLS discontinued that item in 2019 and did not replace it with a PPI specific to locomotives. Instead, there is only a rolling stock price series (WPU144) including both locomotives and freight cars as well as one which is specific to freight cars (WPU14440102). I disentangled which component of WPU144 is due to locomotives and which to freight cars by using asset-specific investment weights from the R-1 data and then constructing a Tornqvist index. The asset weights come from computing the locomotive share of total rolling stock investment.

2. **Tax term.** The tax term varies by firm but not by capital type because rolling stock are taxed at the same rate. However, there is variation between firms because firms vary in their geographic area and hence their exposure to state tax policy. R-1 Schedule 702 details the mileage of track by state for each firm. I use that information to construct a weighted tax term. I extend the dataset of Suárez Serrato and Zidar (2018) to construct the tax term through 2023 under the assumption that railroads are depreciating rolling stock as seven-year assets. I calculate the net present value of rolling stock tax depreciation allowances with $r^k = 0.0713$, which is the average for NAICS 48 from Gormsen and Huber (2022).

3. **Price of maintenance.** The price of maintenance is a weighted average of internal labor and material costs and external purchased services. Labor costs are firm-specific and come from each firm's Wage Form A&B filed with the Surface Transportation Bureau. I construct a firm-specific wage index based on hourly wage rates for rolling stock maintenance workers. The materials cost index is the "Producer Price Index by Industry: Railroad Rolling Stock Manufacturing: Railway Maintenance of Way Equipment and Parts, Parts for All Railcars, and Other Railway Vehicles (PCU33651033651054)". The external cost component is an industry average of internal maintenance costs. This approach assumes a constant markup over time for maintenance services. I weight each input with the cost share from Schedule 410, which breaks down maintenance expenditures by labor cost and materials for both locomotives and freight cars.

Three additional variables are worth discussing:

1. GDP Exposure $\Delta \log Y_{i,t}$: Using the Bureau of Economic Analysis's GDP by State data, I calculate the log change in output. Then, to get a summary measure of each firm's exposure

to local demand shocks, I compute weighted average of GDP growth using rail miles within each state as weights.

2. Wages $W_{i,t}$: I use data on wages by state in the Installation, Maintenance, and Repair Occupation (SOC Code 49-0000). Then I take a weighted average for each firm using rail miles within each state as weights.

3. Maintenance share of user cost $\frac{m_{i,j,t}}{\Psi_{i,j,t}}$: The depreciation and discount rates are uniform across firms ($r^k = 0.0713$ from NAICS 48). The depreciation rate for locomotives is 4% and for freight cars 3%, both of which are industry standards for freight railroads.

Table B.1: Summary statistics for variables from R-1 financial statements (Locomotives).

Variable	Mean	10th Percentile	Median	90th Percentile	Count
Year	2011.19	2001.10	2011.00	2021.00	172
$m_{i,j,t}$ (Total)	0.17	0.07	0.14	0.30	172
$m_{i,j,t}$ (Internal)	0.11	0.04	0.09	0.19	172
$m_{i,j,t}$ (External)	0.06	0.00	0.05	0.11	172
$m_{i,j,t}$ (Physical)	0.03	0.02	0.02	0.04	172
$\log M_{i,j,t}$	11.99	10.35	12.37	13.41	172
$\log I_{i,j,t}$	11.34	9.19	11.94	13.31	172
$\frac{I_{i,j,t}}{K_{i,j,t}}$	0.15	0.02	0.10	0.28	172
$P_{i,j,t}$	1.11	1.00	1.10	1.25	172
Capital Age	1.48	1.24	1.51	1.69	172
Local GDP Exposure	1.99	-0.21	2.13	4.09	172
$Z_{i,j,t}$	0.56	0.36	0.50	0.83	172
$\ell_{i,t-3}$	0.41	0.29	0.37	0.57	172
W_t	1.33	1.08	1.32	1.64	172
$\tau_{i,t}$	1.04	1.00	1.04	1.09	172
$\frac{m_{i,j,t}}{\Psi_{i,j,t}}$	0.59	0.45	0.59	0.74	172

Table B.2: Summary statistics for variables from R-1 financial statements (Freight Cars).

Variable	Mean	10th Percentile	Median	90th Percentile	Count
Year	2011.19	2001.10	2011.00	2021.00	172
$m_{i,j,t}$ (Total)	0.22	0.08	0.16	0.45	172
$m_{i,j,t}$ (Internal)	0.15	0.05	0.10	0.34	172
$m_{i,j,t}$ (External)	0.07	0.02	0.05	0.12	172
$m_{i,j,t}$ (Physical)	0.03	0.02	0.03	0.06	172
$\log M_{i,j,t}$	11.70	10.35	11.92	13.03	172
$\log I_{i,j,t}$	9.33	6.02	10.56	12.21	172
$\frac{I_{i,j,t}}{K_{i,j,t}}$	0.08	0.00	0.05	0.19	172
$P_{i,j,t}$	0.90	0.77	0.88	1.04	172
Capital Age	1.59	1.18	1.62	1.93	172
Local GDP Exposure	1.99	-0.21	2.13	4.09	172
$Z_{i,j,t}$	0.52	0.36	0.53	0.67	172
$\ell_{i,t-3}$	0.39	0.26	0.39	0.51	172
W_t	1.33	1.08	1.32	1.64	172
$\tau_{i,t}$	1.04	1.00	1.04	1.09	172
$\frac{m_{i,j,t}}{\Psi_{i,j,t}}$	0.60	0.41	0.60	0.78	172

B.2 SOI

The key policy variation in the SOI data comes from aggregating the asset-specific wedges into an industry-specific wedges:

$$\frac{1-\tau_t}{1-\tau_t z_{i,t}},$$

where τ_t is the top corporate tax rate and $z_{i,t}$ is the net present value of depreciation allowances for industry i. There are three steps to aggregation. First, for every asset type j with class life T in the MACRS tax life table, I compute $z_{i,j}$ as

$$z_{i,j} = \sum_{t=0}^{T} \left(\frac{1}{1+r_i^k}\right)^t d_t.$$

I discount the future using the industry average cost of capital estimate from Gormsen and Huber (2022). That comes from mapping their firm-level estimates into the corresponding BEA industries and taking a time series average within industries. Time series variation comes from bonus depreciation. Letting θ_t denote the percent of bonus available,

$$z_{i,j,t} = \theta_t + (1-\theta_t) z_{i,j,t}$$

where θ only applies to eligible assets (no structures). Second, to get the industry $z_{i,t}$, I map the 36 assets in the BEA's detailed fixed asset tables to the corresponding tax depreciation from the IRS. I use House and Shapiro (2008) to do this. Third, I compute asset j's weight by taking capital-weighted shares of capital from 1998-2001. I use those weights for all years up until 2018 and use weights from 2014-2017 for 2018-onward. I do this to balance exogeneity and relevance for the two major reforms (bonus and TCJA). There was no policy variation from 1998-2001 or from 2014-2017. Letting $\alpha_{i,j}$ denote the asset-specific weight, the industry-average $z_{i,t}$ is therefore

$$z_{i,t} = \sum_{j=1}^{36} \alpha_{i,j} z_{i,j,t}.$$

The maintenance rate is defined as the ratio of the maintenance and repairs line item divided by book capital. Similarly, the net investment rate is net investment divided by net book capital, and age is proxied by the ratio of gross to net book capital. The capital age, net investment, and maintenance rates are winsorized at the 2% and 98% level.

Table B.3: Summary statistics for variables from the Statistics of Income.

Variable	Mean	10th Percentile	Median	90th Percentile	Count
All					
Year	2009.95	2001.00	2010.00	2019.00	1116
$m_{i,j,t}$	0.05	0.02	0.04	0.09	1116
$\frac{I_{i,j,t}}{K_{i,j,t}}$	0.06	-0.14	0.06	0.23	1116
$\frac{1-\tau_{i,t}}{1-\tau_{i,t}z_{i,t}}$	0.83	0.76	0.82	0.92	1116
$\frac{m_{i,j,t}}{\Psi_{i,j,t}}$	0.22	0.09	0.19	0.38	1116
$\frac{m_{i,j,t}}{\Psi_{i,j,t}}$ (Adjusted)	0.30	0.13	0.27	0.48	1116
Capital Age	2.21	1.66	2.15	2.80	1116
Taxable					
Year	2009.04	2000.00	2009.00	2019.00	1114
$m_{i,j,t}$	0.05	0.02	0.04	0.10	1114
$\frac{I_{i,j,t}}{K_{i,j,t}}$	0.11	-0.47	0.05	0.61	1114
$\frac{1-\tau_{i,t}}{1-\tau_{i,t}z_{i,t}}$	0.83	0.76	0.82	0.92	1114
$\frac{m_{i,j,t}}{\Psi_{i,j,t}}$	0.23	0.09	0.21	0.42	1114
$\frac{m_{i,j,t}}{\Psi_{i,j,t}}$ (Adjusted)	0.31	0.13	0.29	0.53	1114
Capital Age	2.25	1.69	2.19	2.93	1114
Untaxable					
Year	2009.05	2000.00	2009.00	2019.00	1113
$m_{i,j,t}$	0.05	0.01	0.04	0.09	1113
$\frac{I_{i,j,t}}{K_{i,j,t}}$	0.13	-0.40	0.02	0.83	1113
$\frac{1-\tau_{i,t}}{1-\tau_{i,t}z_{i,t}}$	0.83	0.76	0.82	0.92	1113
$\frac{m_{i,j,t}}{\Psi_{i,j,t}}$	0.23	0.07	0.20	0.43	1113
$\frac{m_{i,j,t}}{\Psi_{i,j,t}}$ (Adjusted)	0.30	0.11	0.28	0.54	1113
Capital Age	2.12	1.52	2.06	2.75	1113

B.3 The Maintenance Share of User Cost

Now, suppose the estimates are not credible, so we are left with the conclusion that the elasticity of maintenance demand is not significantly different from zero. In that case, we would be left with the average maintenance rate as determining the parameter γ. Would maintenance still be important? A useful way to frame it is by considering the maintenance share of the user cost of capital. Define this as

$$s_m \equiv \frac{(1-\tau)\cdot p^M \cdot m}{(1-\tau z)\cdot p^I \cdot \left(r^k+\delta\right) + (1-\tau)\cdot p^M \cdot m}.$$

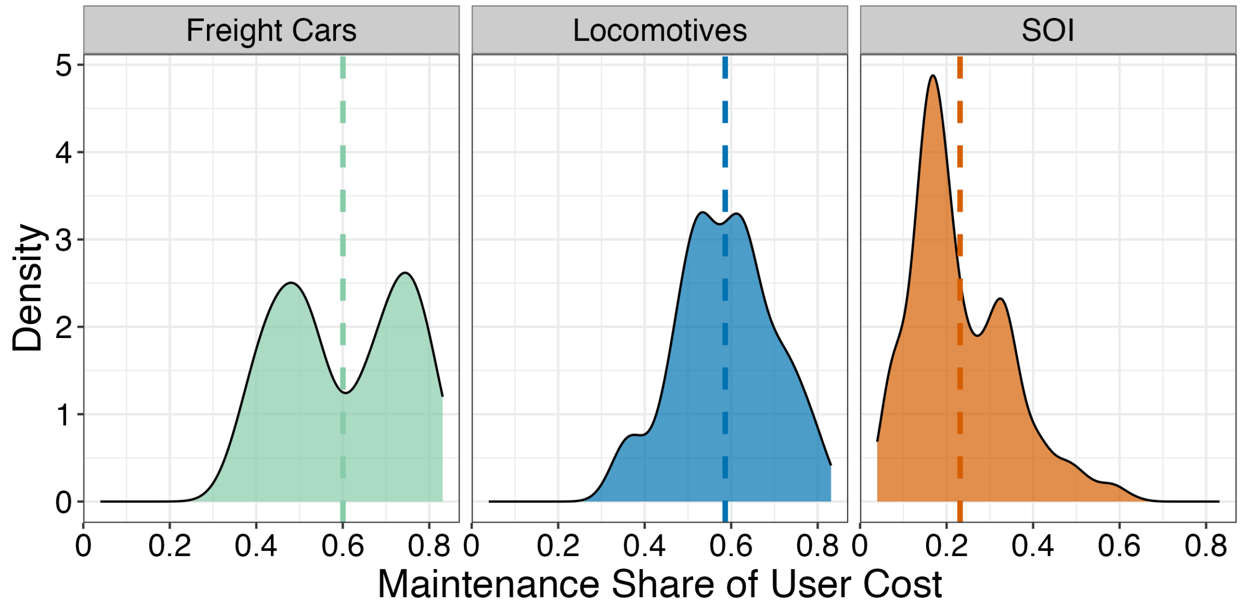
The maintenance share s_m tells us how much the long-run cost of capital is insulated from tax reform. I derive s_m formally in Section 3.

To get an estimate of the maintenance share of user cost in the R-1 data, I apply a 3% depreciation rate to freight cars and a 4% depreciation rate to locomotives. These are common values in the freight rail industry. I use a discount rate of 7.1%. That value is the industry average from Gormsen and Huber (2022) and is close to values cited in R-1 filings. The remainder of user cost is constructed exactly as described above.

In the SOI, I take the average r^k by industry from Gormsen and Huber (2022) and compute a capital-weighted industry average depreciation rate using the Fixed Asset tables from the BEA. The prices of investment and maintenance are common across industries. The former is the implicit price deflator for fixed investment from the BEA, while the latter is the producer price index for the equipment maintenance and repair sector. That data only exists starting in 2007, so I use the auto repair price index for years prior to then.

I plot the distribution of the maintenance share of user cost s_m across industries (left panel) and for rolling stock (right panel) in Figure B.1. In the industry data, maintenance makes up about a quarter of the cost of capital, while it is double that for the rolling stock data. The disparity indicates that longer-lived equipment like rolling stock may have higher maintenance shares. Appendix Figure G.1 indicates that there is an inverse relationship between an industry's maintenance share and the average depreciation rate. In other words, longer-lived assets tend to have a smaller share of user cost exposed to tax reform. That matters because the most exposed assets to typical reforms like bonus depreciation are precisely those goods.

Figure B.1: Density plots for the maintenance share of user cost (unadjusted)

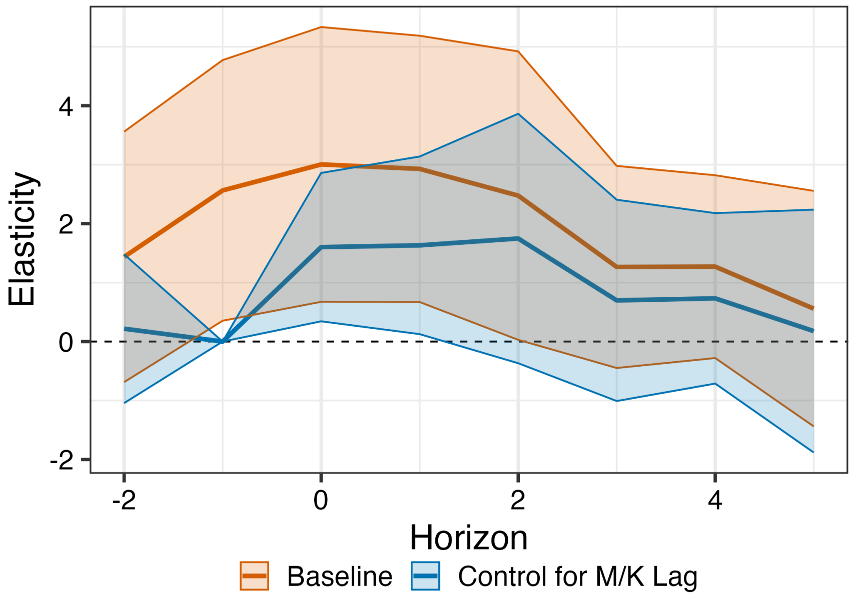


Note: Each density plot is constructed with beginning of period book capital in the denominator. The dashed lines are mean maintenance shares. Across the SOI, freight cars, and locomotives, the mean maintenance shares are 23%, 60%, and 58.6%.

C Estimation Details and Additional Results

C.1 Dynamics

Figure C.1: Local Projection of Relative Price Shocks on the Maintenance Rate (SOI)

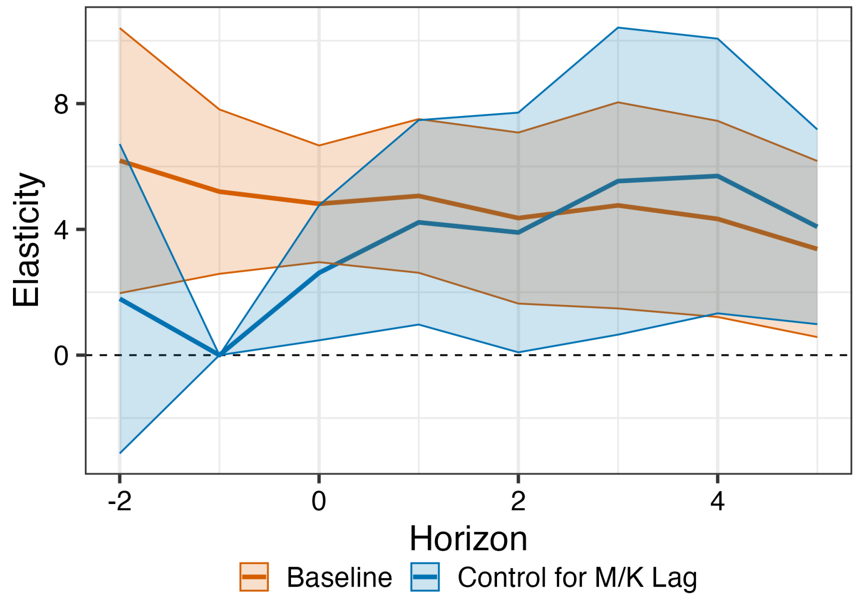


Note: This figure plots the coefficients ω_h from the regression

$$\log m_{i,t+h} = \alpha_i + \lambda_t - \omega_h \log\left(\frac{1-\tau_t^c}{1-\tau_t^c z_{i,t}}\right) + \text{Controls} + \varepsilon_{i,t+h}.$$

The path in blue controls for the lagged maintenance rate. Both specifications control for industry trends and correspond to the SOI sample with all types of firms.

Figure C.2: Local Projection of Relative Price Shocks on the Maintenance Rate (R-1)



Note: This figure plots the coefficients ω_h from the local projection

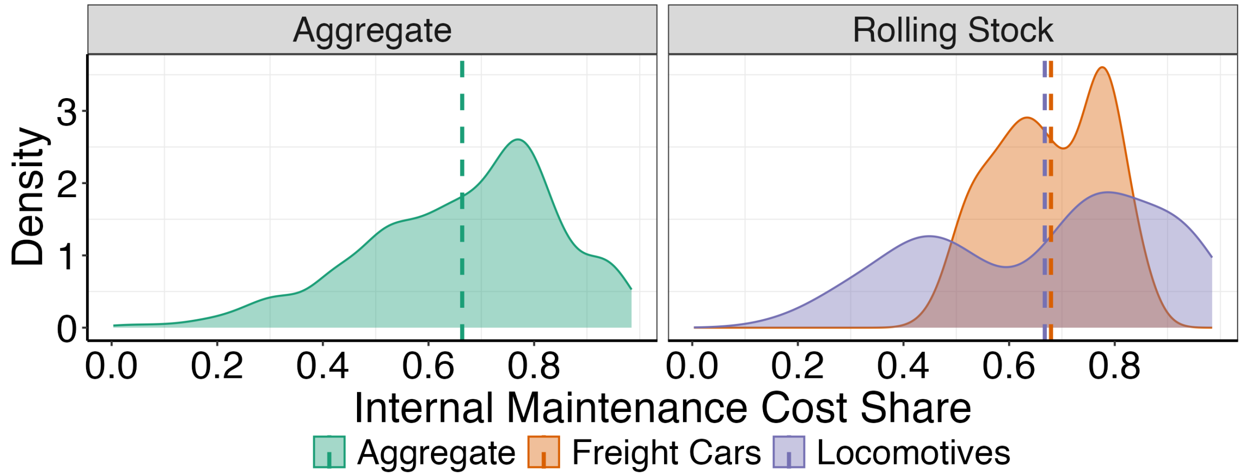
$$\log m_{i,j,t+h} = \alpha_{ij} + \lambda_t - \omega_h \log P_{i,j,t} + \text{Controls} + u_{i,j,t+h}.$$

The line in blue controls for the lagged maintenance rate, while the line in orange does not. Both specifications are the IV variants and control for firm-specific trends.

C.2 Internal vs. External Maintenance

We can think of maintenance as taking two forms. Either firms can outsource their maintenance to other firms or they can do it themselves. By analogy, we can choose to change the oil in our car engines at home in the garage or we can bring it to a mechanic. It is likely that such decisions depend considerably on the complexity of the maintenance required as well as the extent of in-house expertise. As a result, the degree to which firms maintain internally varies considerably across and within industries. For example, many airlines rely on Delta's in-house maintenance arm, Delta TechOps, to carry out routine maintenance and repairs, but even Delta relies on suppliers for more complex repair operations. However, we lack cross-sectional data on how reliant firms are on outside maintenance services.

Figure C.3: Ratio of Internal Maintenance to Total Maintenance



Notes: The distribution of aggregate internal maintenance rates is constructed using Table 1 from the Statistics of Income, which encompasses all firms regardless of legal type, together with input-output tables from the BEA on purchases of equipment repairs from NAICS code 811 except housing services. For 2007, 2012, and 2017, I subtract payments to NAICS 811 from total maintenance expenditures after applying a labor cost correction. The distribution of the share of internal railroad equipment maintenance comes from dividing internal maintenance expenditures by total maintenance expenditures for all Class I freight railroads for locomotives and freight cars.

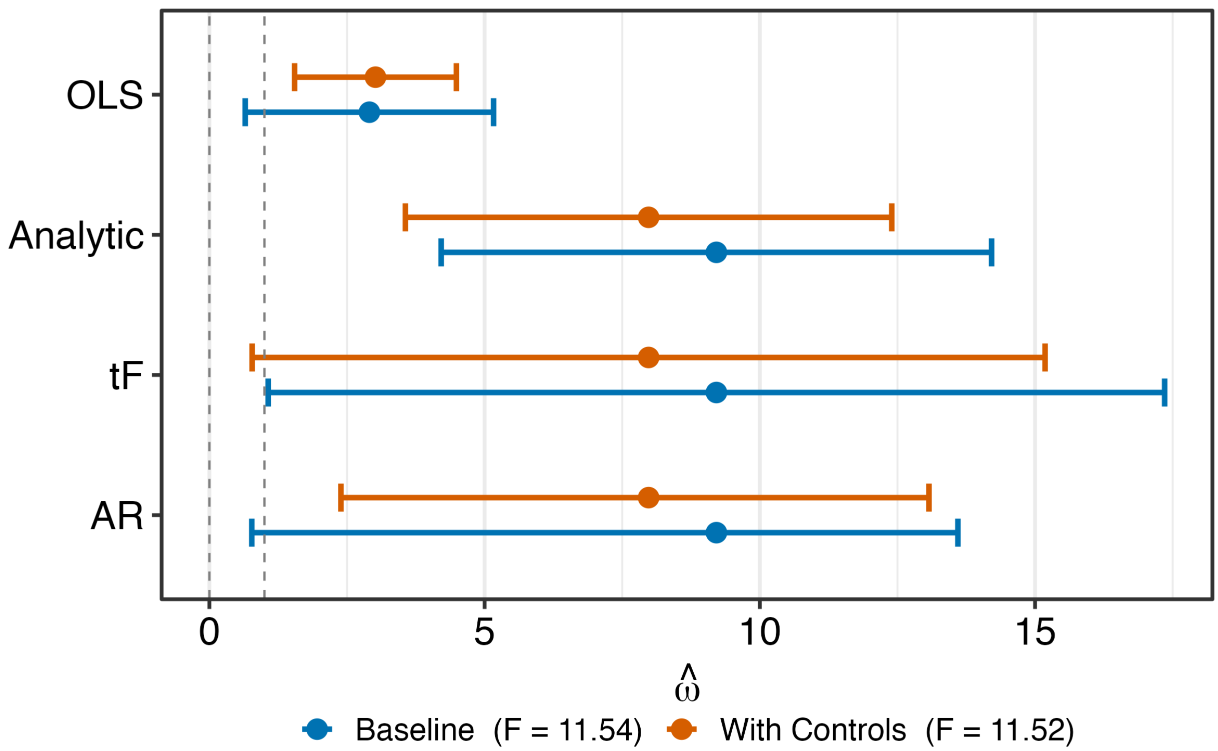
Figure C.3 provides new evidence on this margin. The left panel plots a rough measure of the distribution of industry-level internal maintenance rates constructed using payments to the repair sector from the BEA's input-output table. On average, two-thirds of maintenance is done internally. The average figure is similar for rolling stock, but the distributions are quite different. Internal locomotive maintenance is bimodal, reflecting the fact that firms choose to specialize in or outsource complex locomotive maintenance.

The high internal share of upkeep is critical because internal maintenance is under the firm's direct control, whereas external maintenance is typically locked into predetermined service contracts and therefore less flexible. If maintenance demand is elastic, firms will adjust primarily along this flexible, in-house margin by scaling labor hours or materials usage in response to changing costs rather than renegotiating long-term external agreements. In the next observation, we decompose that internal cost pool into its two key inputs to show exactly how shifts in wages and materials prices drive firms' maintenance decisions.

Moreover, a substantial portion of in-house upkeep spending goes to wages rather than materials or parts. In the R-1 railroad panel, internal labor accounts for about 40 percent of total maintenance expenditures on both freight cars and locomotives (Figure 4). There is not a corresponding aggregate labor cost share, but Appendix Figure G.2 plots the ratio of labor costs to total receipts for the maintenance and repair sector using the Economic Census from 2002-2022.

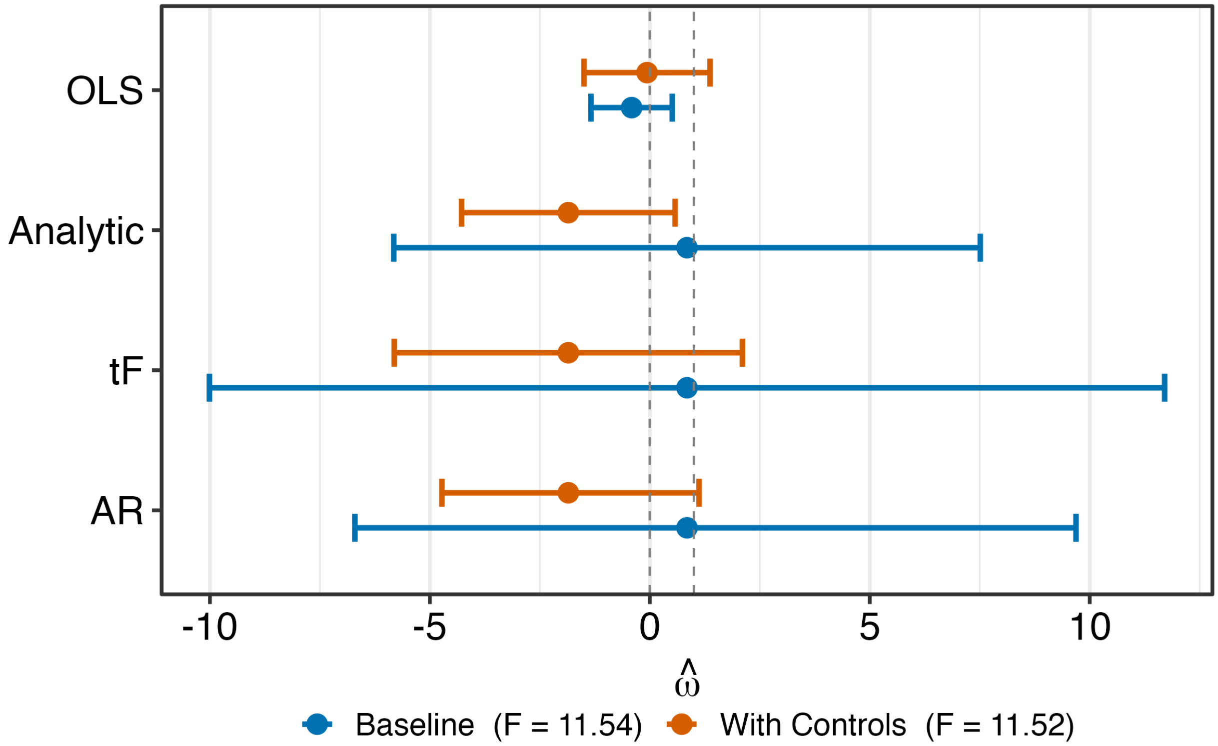
The labor share is consistently 30%. Thus, materials and parts are usually around 60-70% of maintenance expenditures. Given the rough agreement between the railroad data and the equipment repair sector, we could reasonably boost the typical SOI maintenance rate to between 7% and 8%, or about 2/3 as large as the usual investment rate.

Figure C.4: Internal maintenance demand elasticity with 95% confidence interval



Note: This figure plots the point estimates and result for estimating (9), except that I use the internal maintenance rate. The blue lines contain no controls, while the orange lines control for local GDP exposure, firm-year trends, and the age of the capital stock. All standard errors are clustered by firm. The top estimate is for OLS only, while the bottom three all correspond to the instrument specified in (10). Analytic confidence intervals are from traditional Wald estimates, while the tF and AR confidence intervals result from inverting the tF (Lee et al. 2022) and Anderson and Rubin (1949) tests, respectively. The F-statistic reported in the legend is the effective F-statistic from Montiel-Olea and Pflueger (2013).

Figure C.5: External maintenance demand elasticity with 95% confidence interval



Note: This figure plots the point estimates and result for estimating (9), except that I use the external maintenance rate. The blue lines contain no controls, while the orange lines control for local GDP exposure, firm-year trends, and the age of the capital stock. All standard errors are clustered by firm. The top estimate is for OLS only, while the bottom three all correspond to the instrument specified in (10). Analytic confidence intervals are from traditional Wald estimates, while the tF and AR confidence intervals result from inverting the tF (Lee et al. 2022) and Anderson and Rubin (1949) tests, respectively. The F-statistic reported in the legend is the effective F-statistic from Montiel-Olea and Pflueger (2013).

C.3 Instrument Validity

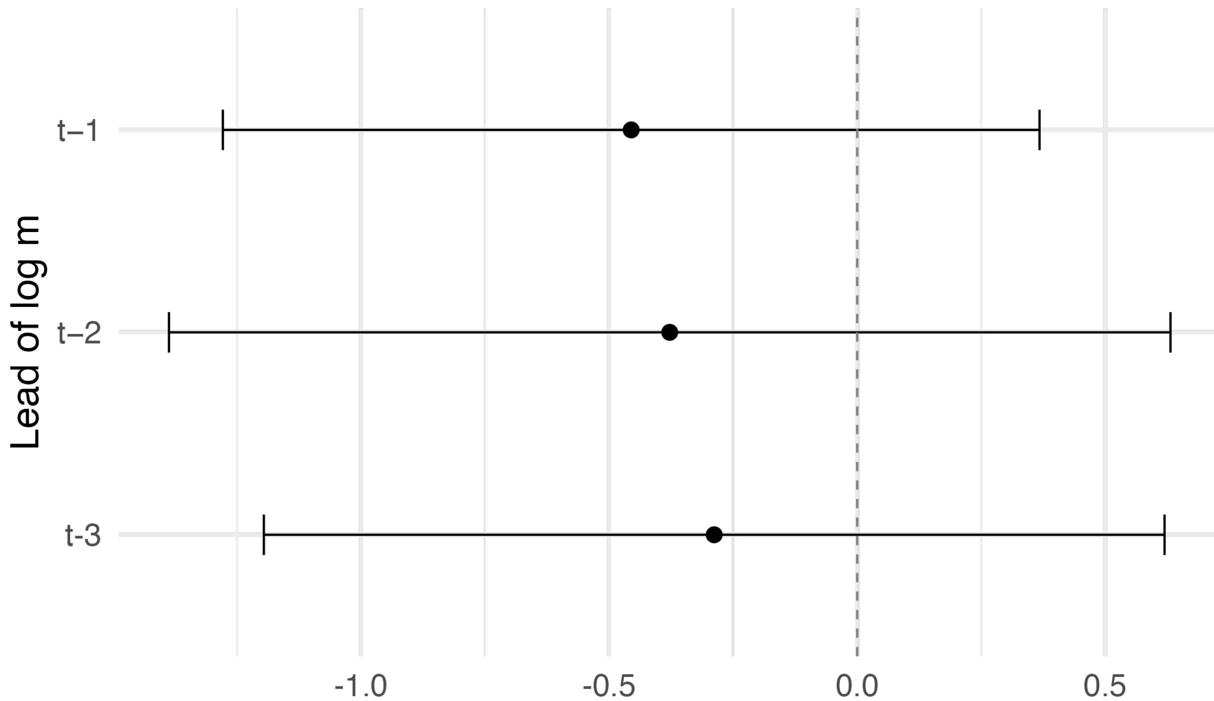
Table C.1: First-Stage Regressions for Varying Instruments

	(1)	(2)	(3)	(4)	(5)	(6)
$Z_{i,j,t}$	0.165**	0.173**	0.002**	0.002**	0.156***	0.164**
	(0.049)	(0.051)	(0.000)	(0.000)	(0.041)	(0.045)
Capital Age		−0.012		−0.026		−0.020
		(0.032)		(0.028)		(0.031)
GDP Exposure		−0.004*		−0.002		−0.003
		(0.002)		(0.003)		(0.002)
Num.Obs.	340	340	314	314	326	326
Effective F-stat	11.54	11.52	14.32	13.27	10.16	9.74
Firm Trends	N	Y	N	Y	N	Y
Instrument Type	Baseline	Baseline	Shares Lagged 3 Years	Shares Lagged 3 Years	National Wage Index	National Wage Index

* p < 0.1, ** p < 0.05, *** p < 0.01

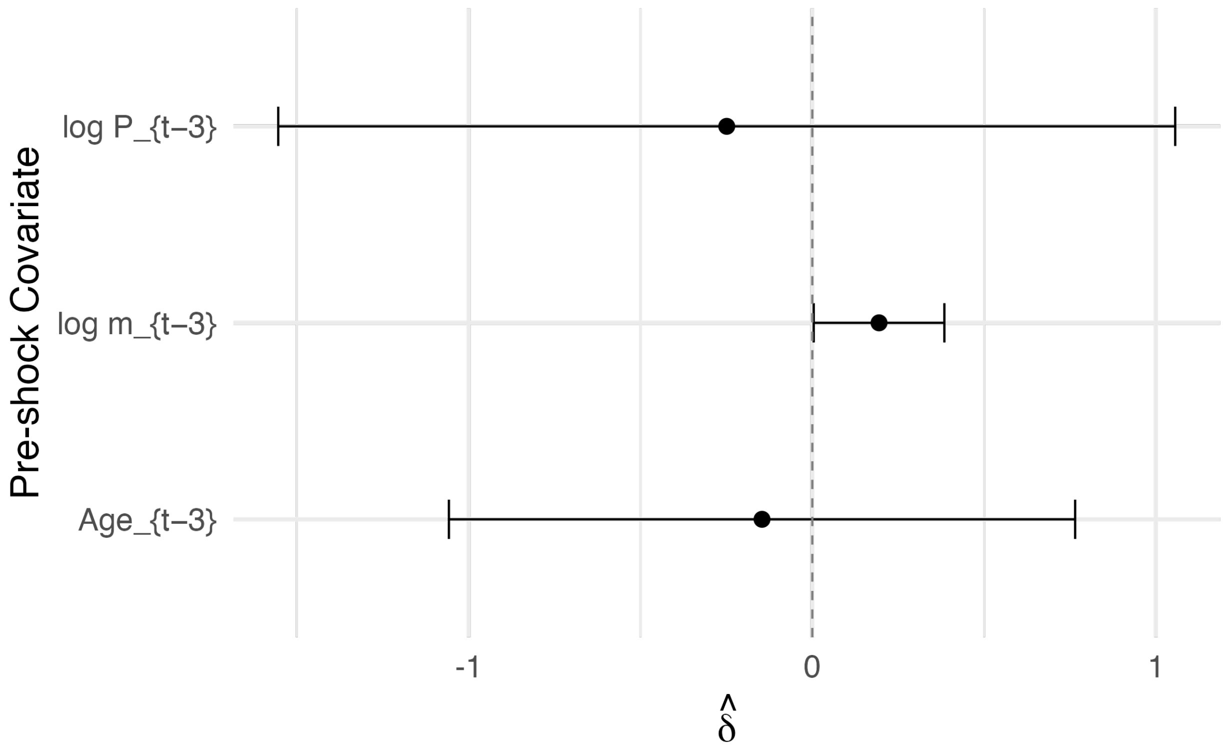
Notes: This table estimates the first stage of regressions for the main freight rail specification in (9). The first two columns use the baseline instrument described in the main text, with second adding firm-specific trends and controls for local demand shocks and capital age. The second columns are the same instrument, but with the labor share lagged three years instead of two. The final two columns use a national wage index, which is the employment cost index for workers in maintenance and repair (FRED item CIU2020000430000I). Standard errors are clustered by firm. The effective F-stat is from Montiel-Olea and Pflueger (2013).

Figure C.6: Lead tests of the log maintenance rate on $Z_{i,j,t}$



Note: This figure plots coefficients from regressing a pre-shock maintenance rate on the instrument $Z_{i,j,t}$ after controlling for firm-year trends, year fixed effects, and firm-asset fixed effects. Standard errors are clustered by industry.

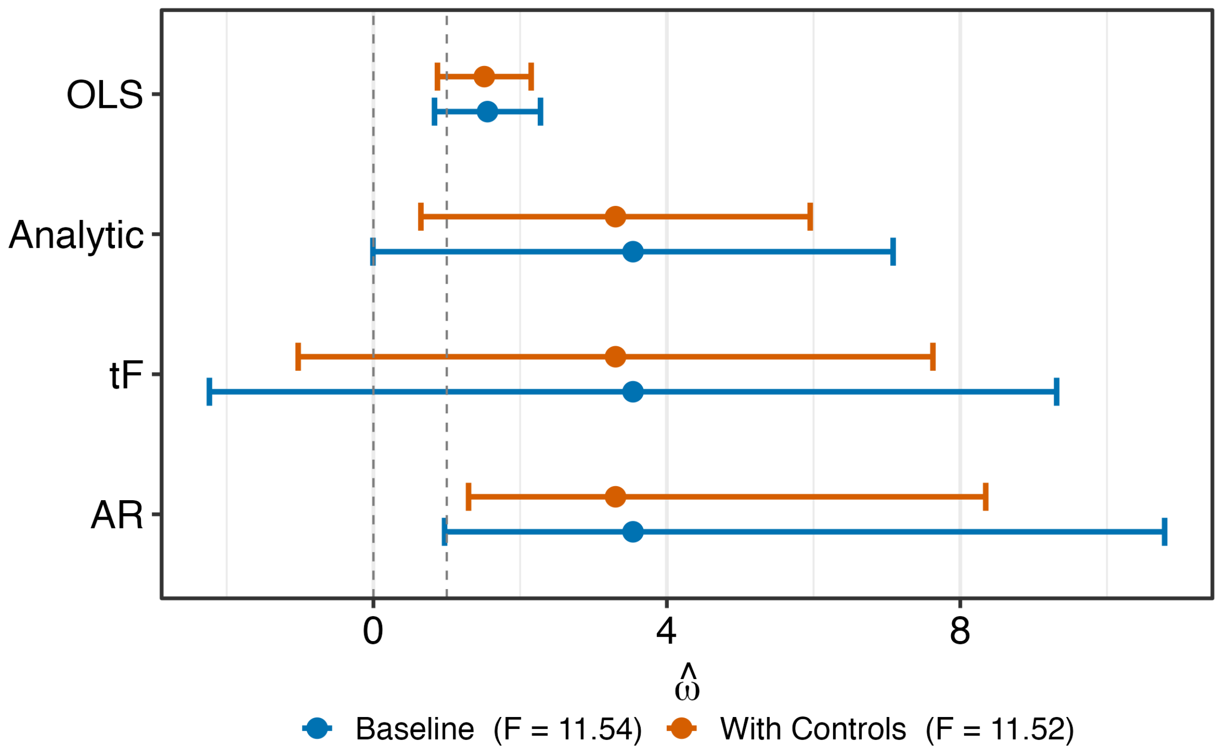
Figure C.7: Balance tests on pre-shock outcomes



Note: This figure plots coefficients from regressing the variable on the y-axis against the instrument $Z_{i,j,t}$ after controlling for firm-asset and year fixed effects and firm trends. Standard errors are clustered by firm.

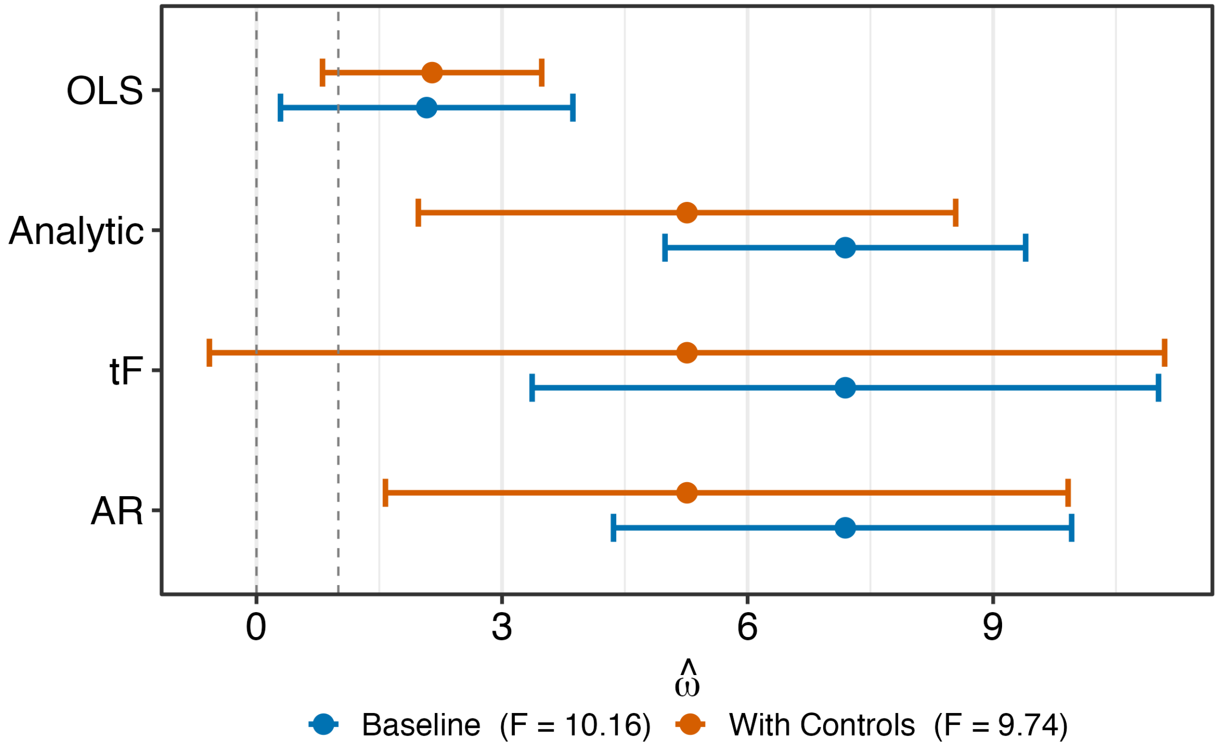
C.4 R1 Additional Results

Figure C.8: Maintenance demand elasticity with 95% confidence interval (Physical Capital)



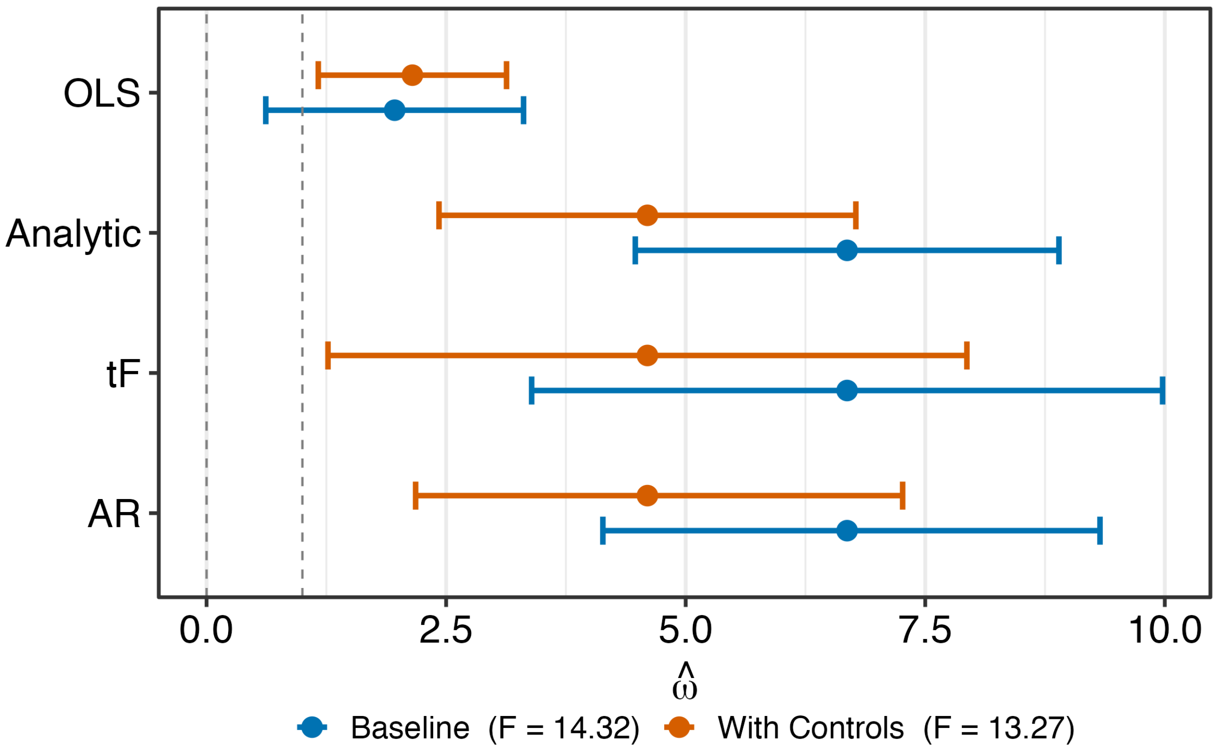
Note: This figure plots the point estimates and result for estimating (9), except I replace the maintenance rate with a physical measure of the capital stock. The blue lines contain no controls, while the orange lines control for local GDP exposure, firm-year trends, and the age of the capital stock. All standard errors are clustered by firm. The top estimate is for OLS only, while the bottom three all correspond to the instrument specified in (10). Analytic confidence intervals are from traditional Wald estimates, while the tF and AR confidence intervals result from inverting the tF (Lee et al. 2022) and Anderson and Rubin (1949) tests, respectively. The F-statistic reported in the legend is the effective F-statistic from Montiel-Olea and Pflueger (2013).

Figure C.9: Maintenance demand elasticity with 95% confidence interval (National Instrument)



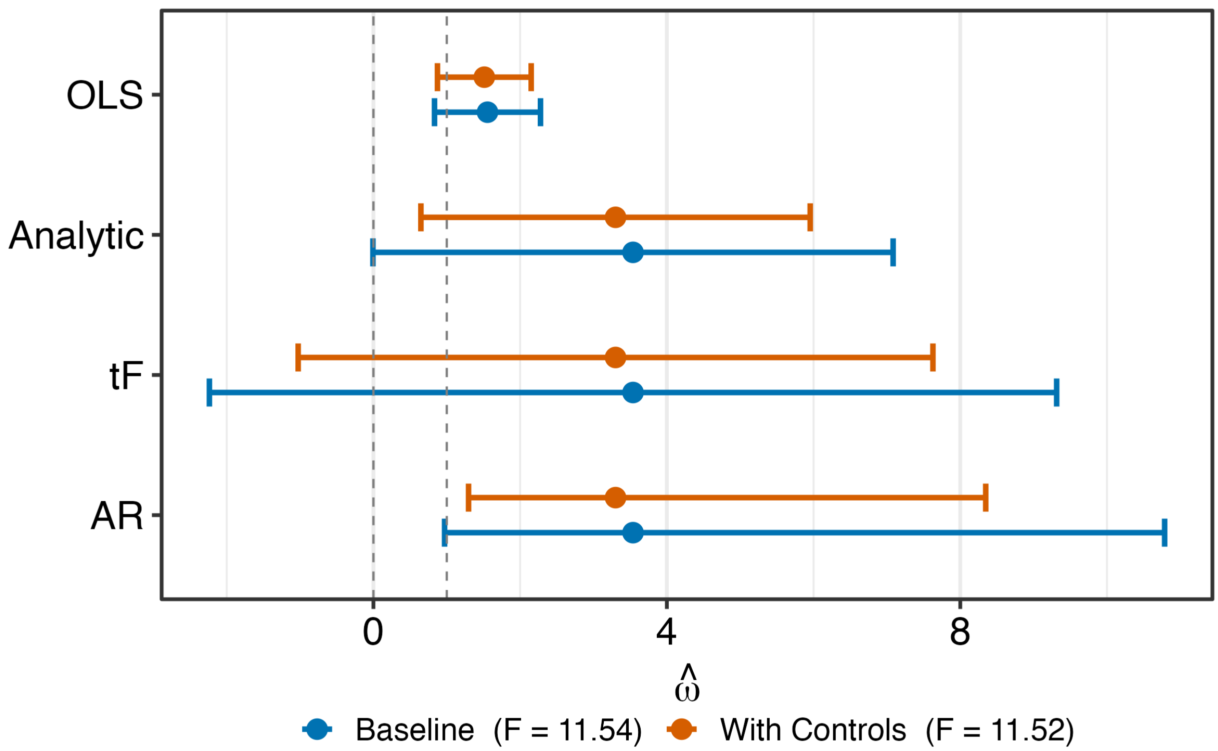
Note: This figure plots the point estimates and result for estimating (9). The blue lines contain no controls, while the orange lines control for local GDP exposure, firm-year trends, and the age of the capital stock. All standard errors are clustered by firm. The top estimate is for OLS only, while the bottom three all correspond to the instrument specified in (10), except that I use a national measure of the wage index so there is no weighting by state.. Analytic confidence intervals are from traditional Wald estimates, while the tF and AR confidence intervals result from inverting the tF (Lee et al. 2022) and Anderson and Rubin (1949) tests, respectively. The F-statistic reported in the legend is the effective F-statistic from Montiel-Olea and Pflueger (2013).

Figure C.10: Maintenance demand elasticity with 95% confidence interval (Thrice-Lagged Instrument)



Note: This figure plots the point estimates and result for estimating (9). The blue lines contain no controls, while the orange lines control for local GDP exposure, firm-year trends, and the age of the capital stock. All standard errors are clustered by firm. The top estimate is for OLS only, while the bottom three all correspond to the instrument specified in (10), except that I use three lags of the shares rather than two. Analytic confidence intervals are from traditional Wald estimates, while the tF and AR confidence intervals result from inverting the tF (Lee et al. 2022) and Anderson and Rubin (1949) tests, respectively. The F-statistic reported in the legend is the effective F-statistic from Montiel-Olea and Pflueger (2013).

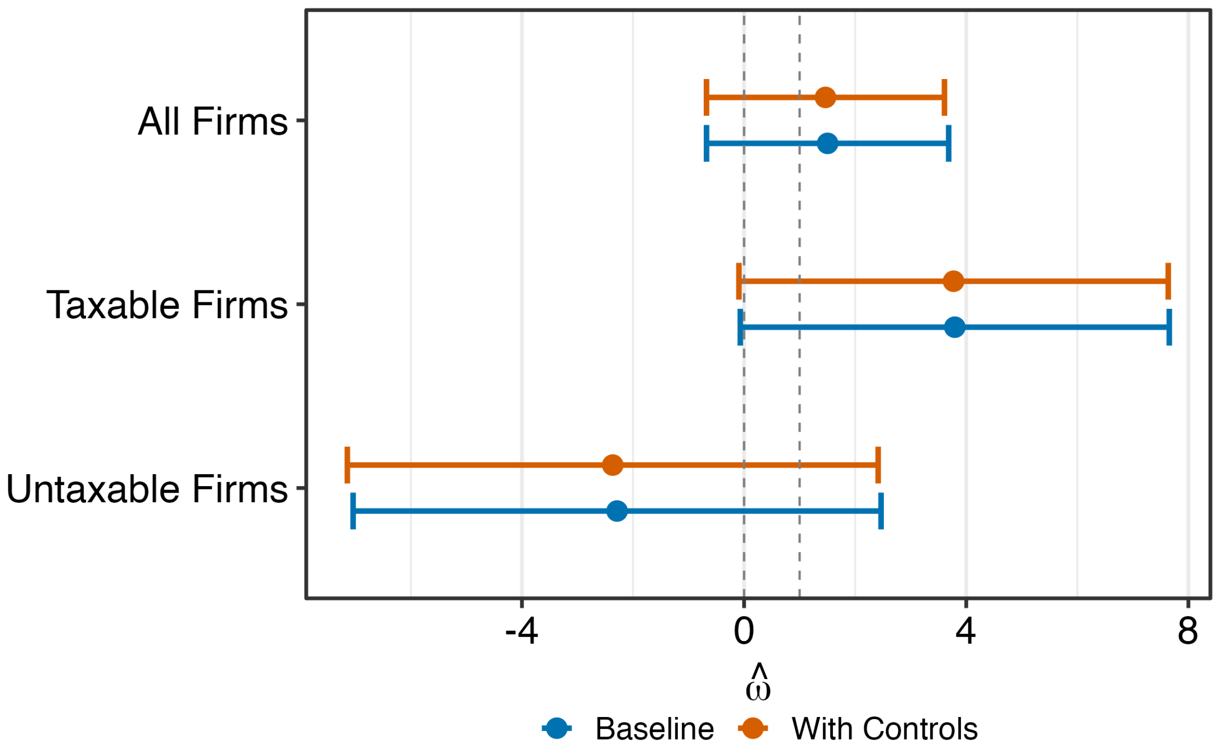
Figure C.11: Maintenance demand elasticity with 95% confidence interval (Controls for Lagged Maintenance)



Note: This figure plots the point estimates and result for estimating (9). The blue lines control for lagged maintenance, while the orange lines add controls for local GDP exposure, firm-year trends, and the age of the capital stock. All standard errors are clustered by firm. The top estimate is for OLS only, while the bottom three all correspond to the instrument specified in (10), except that I use three lags of the shares rather than two. Analytic confidence intervals are from traditional Wald estimates, while the tF and AR confidence intervals result from inverting the tF (Lee et al. 2022) and Anderson and Rubin (1949) tests, respectively. The F-statistic reported in the legend is the effective F-statistic from Montiel-Olea and Pflueger (2013).

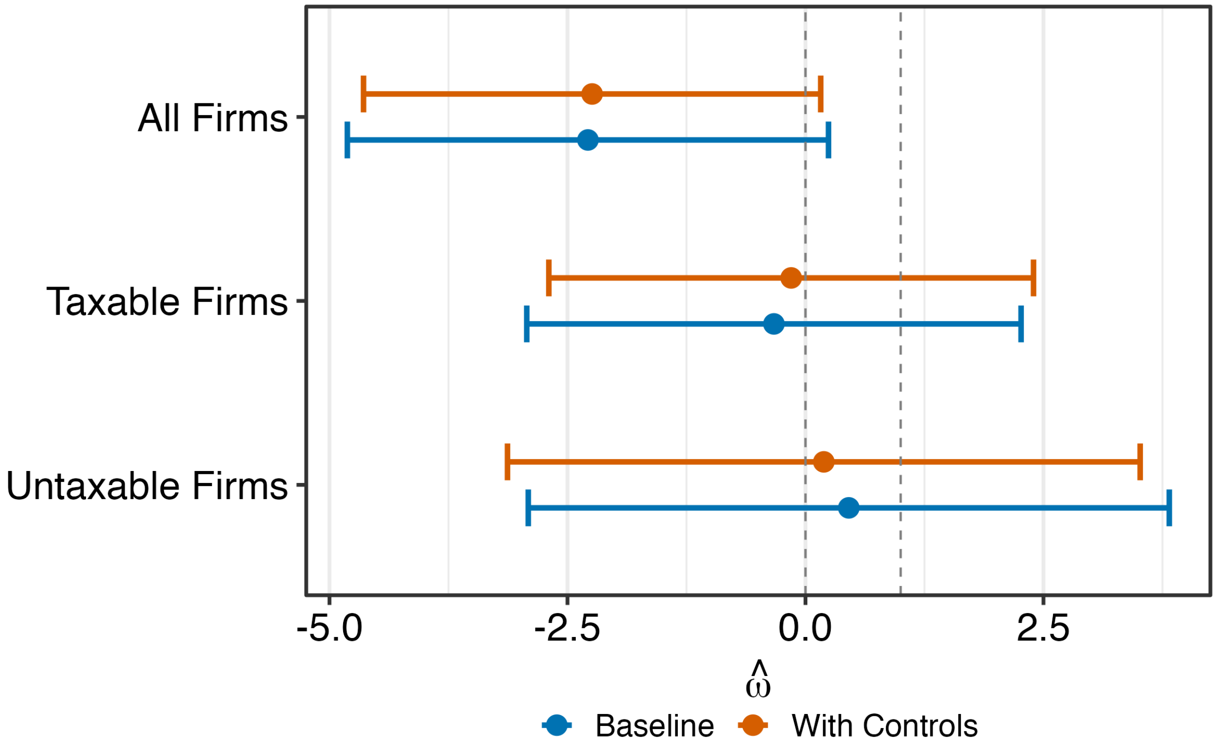
C.5 SOI Additional Results

Figure C.12: Maintenance demand elasticity with 95% confidence interval



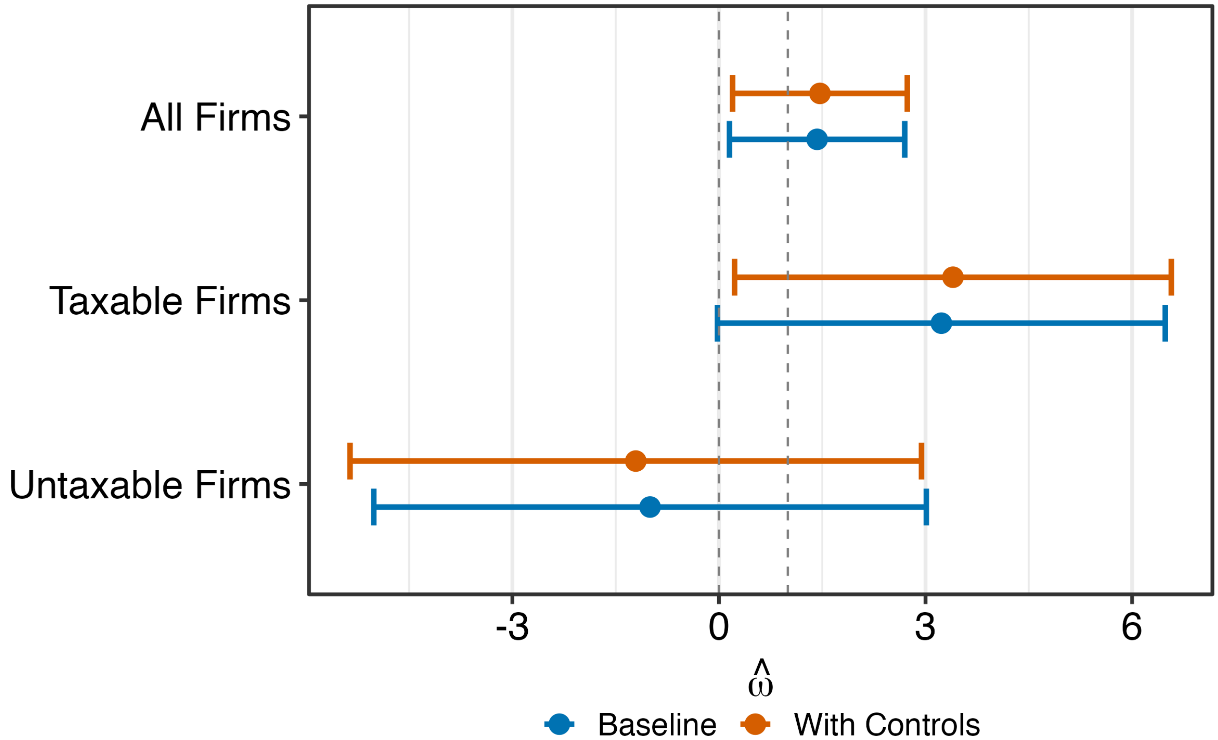
Note: This figure plots the point estimates and result for estimating (11), except it uses the BEA capital stock in the denominator. All estimates have two-way fixed effects together with linear and quadratic trends in two-digit NAICS codes. Orange lines control for the age of the capital stock. All standard errors are clustered by industry. The top estimate is for the All Firm sample, while the bottom two groups of estimates split the SOI into a taxable and an untaxable sample.

Figure C.13: Maintenance demand elasticity with 95% confidence interval



Note: This figure plots the point estimates and result for estimating (11), uses investment weights. All estimates have two-way fixed effects together with linear and quadratic trends in two-digit NAICS codes. Orange lines control for the age of the capital stock. All standard errors are clustered by industry. The top estimate is for the All Firm sample, while the bottom two groups of estimates split the SOI into a taxable and an untaxable sample.

Figure C.14: Maintenance demand elasticity with 95% confidence interval



Note: This figure plots the point estimates and result for estimating (11), except it limits the data to pre-2014. All estimates have two-way fixed effects together with linear and quadratic trends in two-digit NAICS codes. Orange lines control for the age of the capital stock. All standard errors are clustered by industry. The top estimate is for the All Firm sample, while the bottom two groups of estimates split the SOI into a taxable and an untaxable sample.

D Derivations for the Main Model

D.1 Tax Elasticity of User Cost

Benchmark Case

Under the benchmark,

$$\Psi = \frac{r^k + \delta}{1 - \tau}.$$

Consequently, the tax elasticity is

$$\begin{aligned}\varepsilon_\Psi &= \frac{\partial \Psi}{\partial \tau}\frac{\tau}{\Psi} \\ &= \frac{r^k+\delta}{(1-\tau)^2} \times \frac{1-\tau}{r^k+\delta} \times \tau \\ &= \frac{\tau}{1-\tau}.\end{aligned} \tag{A.1}$$

NGMM Tax Elasticity

Under the NGMM with $p^M = p^I$, the user cost of capital is

$$\Psi = \frac{r^k+\delta(m)}{1-\tau} + m.$$

Let $\tilde{\Psi} \equiv r^k + \delta(m) + (1-\tau)m$. The elasticity is therefore

$$\begin{aligned}\varepsilon_\Psi &= \frac{(1-\tau)\Big[\delta'(m)m'(\tau) + (1-\tau)m'(\tau) - m\Big] + \tilde{\Psi}}{(1-\tau)^2} \times \frac{1-\tau}{\tilde{\Psi}} \times \tau \\ &= \frac{\tau}{1-\tau}\left(1 - \frac{m}{\Psi} + \frac{\delta'(m)m'(\tau) + (1-\tau)m'(\tau)}{\Psi}\right)\end{aligned} \tag{A.2}$$

By the envelope theorem, we could discard the terms $\delta'(m)m'(\tau) + (1-\tau)m'(\tau)$ because when m is chosen optimally they cancel out since $\delta'(m) = -(1-\tau)$. However, it will behoove us to instead rewrite them in elasticity form. Let

$$\varepsilon_m = \frac{\partial m}{\partial(1-\tau)}\frac{1-\tau}{m},$$

so

$$m'(\tau) = -\frac{m}{1-\tau}\varepsilon_m,$$

where ε_m is the maintenance demand elasticity. Next, define

$$\varepsilon_\delta = \frac{\partial \delta}{\partial m}\frac{m}{\delta} \Rightarrow \delta'(m)m'(\tau) = \frac{\delta(m)}{m}\varepsilon_\delta \times \left(-\frac{m}{1-\tau}\right) = \frac{\delta(m)}{1-\tau}\varepsilon_\delta\varepsilon_m,$$

where ε_δ is the elasticity of depreciation with respect to maintenance. Putting those pieces together yields

$$\delta'(m)m'(\tau) + (1-\tau)m'(\tau) = -\varepsilon_m\left[\frac{\delta(m)\varepsilon_\delta}{1-\tau} + m\right]$$

Thus,

$$\varepsilon_\Psi = \frac{\tau}{1-\tau}\left(1 - \frac{m}{\Psi} - \frac{\varepsilon_m}{\Psi}\left[\frac{\delta(m)\varepsilon_\delta}{1-\tau} + m\right]\right). \tag{A.3}$$

D.2 The Tax Elasticity of Investment

In steady state, investment is given by $I = \delta(m)K$. Defined explicitly in terms of tax rates,

$$I(\tau) = \delta(m(\tau)) \cdot K(\tau, m(\tau), \delta(m(\tau))) \tag{A.4}$$

To first order,

$$\begin{aligned} \varepsilon_I &\approx \tau\left[\frac{\delta'(m(\tau))}{\delta(m(\tau))}m'(\tau) + \frac{1}{K}\left(\frac{\partial K}{\partial \tau} + \frac{\partial K}{\partial m(\tau)}m'(\tau) + \frac{\partial K}{\partial \delta(m(\tau))}\delta'(m(\tau))m'(\tau)\right)\right] \\ &= \varepsilon_\delta + \varepsilon_K. \end{aligned} \tag{A.5}$$

With the Cobb-Douglas user cost specification and a depreciation technology

$$\delta(m) = \delta_0 - \frac{\gamma^{1/\omega}}{1-1/\omega}m^{1-1/\omega}$$

and replacing m with the corresponding optimality condition, steady state investment becomes

$$X = \left(\delta_0 - \frac{\gamma}{1-1/\omega}(1-\tau)^{1-\omega}\right)\left(\frac{r^k + \delta_0 + \frac{\gamma}{1-\omega}(1-\tau)^{1-\omega}}{\alpha(1-\tau)}\right)^{\frac{-1}{1-\alpha}}, \tag{A.6}$$

I derive each in component in steps. Given τ small,

$$\delta(m) \approx \delta_0 + \frac{\gamma\omega}{1-\omega}\left(1 - (1-\omega)\tau\right).$$

Since

$$\frac{\partial \delta(m)}{\partial \tau} = -\gamma\omega,$$

the tax semi-elasticity is

$$\varepsilon_\delta \approx \frac{-\gamma\omega}{\delta_0 + \frac{\gamma\omega}{1-\omega}}, \tag{A.7}$$

where I assume that $\tau \approx 0$. Since the pre-reform tax rate is 4%, this is a sensible approximation.

Now consider the tax semi-elasticity of capital. In the first step,

$$\begin{aligned}
\frac{\partial K}{\partial \tau}\frac{1}{K} &= \frac{-1}{1-\alpha}\left(\frac{\alpha(1-\tau)}{r^k+\delta_0+\frac{\gamma}{1-\omega}(1-\tau)^{1-\omega}}\right)\left(\frac{\alpha\left(\gamma(1-\tau)^{1-\omega}+r^k+\delta_0+\frac{\gamma}{1-\omega}(1-\tau)^{1-\omega}\right)}{(\alpha(1-\tau))^2}\right)\\
&= \frac{-1}{1-\alpha}\frac{1}{1-\tau}\left(1-\frac{\gamma(1-\tau)^{1-\omega}}{r^k+\delta_0+\frac{\gamma}{1-\omega}(1-\tau)^{1-\omega}}\right)
\end{aligned}$$

To first order, the semi-elasticity becomes approximately

$$\varepsilon_K \approx \frac{-1}{1-\alpha}\left(1-\frac{\gamma}{r^k+\delta_0+\frac{\gamma}{1-\omega}}\right). \tag{A.8}$$

Consequently, the tax semi-elasticity of investment is approximately

$$\begin{aligned}
\varepsilon_I &\approx \varepsilon_\delta+\varepsilon_K\\
&\approx \frac{-\gamma\omega}{\delta_0+\frac{\gamma\omega}{1-\omega}}+\frac{-1}{1-\alpha}\left(1-\frac{\gamma}{r^k+\delta_0+\frac{\gamma}{1-\omega}}\right).
\end{aligned} \tag{A.9}$$

Applying the parameters used in the quantitative section implies that $\varepsilon_I \approx -5$.

D.3 Omitted Variable Bias in Investment Regressions

Standard approaches to recovering the tax elasticity of investment are flawed. A typical approach runs a cross-sectional regression like

$$f\left(I_{i,t},K_{i,t}\right)=\alpha_i+T_t+\hat{\beta}\log\left(\frac{r^k+\delta}{1-\tau_{i,t}}\right)+\epsilon_{i,t}, \tag{A.10}$$

where $f\left(I_{i,t},K_{i,t}\right)$ is typically the investment rate $I_{i,t}/K_{i,t}$ or $\log I_{i,t}$, α_i is a firm fixed effect, and T_t is a time fixed effect. The estimated coefficient $\hat{\beta}$ yields the price elasticity of investment. For example, Kitchen and Knittel (2011), Zwick and Mahon (2017), and Garrett, Ohrn, and Suárez Serrato (2020) use such regressions to evaluate bonus depreciation, while Kennedy et al. (2023) and Chodorow-Reich et al. (2025) do the same for the the 2017 Tax Cuts and Jobs Act. The maintenance model suggests that (A.10) is misspecified. Instead, economists should estimate

$$f\left(I_{i,t},K_{i,t}\right)=\alpha_i+T_t+\beta\log\left(\frac{r^k+\delta(m_{i,t})}{1-\tau_{i,t}}+m_{i,t}.\right)+\epsilon_{i,t}. \tag{A.11}$$

Misspecification arises because the demand for investment depends on the demand for maintenance and hence standard regressions do not properly capture the true change in the incentive to build new capital. This introduces an omitted variable bias in standard regressions which biases downward estimated investment elasticities. The insight is analogous to the lesson of Goolsbee (1998a), which emphasizes that an underlying model of a perfectly competitive capital goods market leads to an underestimate of the investment demand elasticity if the supply of equipment is not perfectly competitive. In the same way that regressing investment on a tax term alone assumes perfect competition in the supply of investment goods, so too does omitting maintenance imply a particular model of capital production.

Corollary 3 *With a constant elasticity of demand for maintenance $m_{i,t} = \gamma(1-\tau_{i,t})^{-\omega}$, the true price elasticity of investment is*

$$\beta \approx \frac{\hat{\beta}}{1 - \frac{\gamma}{r^k + \delta_0 + \frac{\gamma}{1-\omega}}}. \tag{A.12}$$

Proof. Consider the regressions

$$f\left(I_{i,t}, K_{i,t}\right) = \alpha_i + T_t + \hat{\beta} \log\left(\frac{r^k + \delta}{1 - \tau_{i,t}}\right) + \epsilon_{i,t}, \tag{A.13}$$

and

$$f\left(I_{i,t}, K_{i,t}\right) = \alpha_i + T_t + \beta \log\left(\frac{r^k + \delta(m_{i,t})}{1 - \tau_{i,t}} + m_{i,t}\right) + \epsilon_{i,t}. \tag{A.14}$$

Under the assumption that $\tau_{i,t}$ is small, the omitted term is

$$\begin{aligned}
\text{Omitted Term} &= \log\left(\frac{r^k + \delta_0 + \frac{\gamma}{1-\omega}(1-\tau_{i,t})^{1-\omega}}{1-\tau_{i,t}}\right) - \log\left(\frac{r^k + \delta}{1 - \tau_{i,t}}\right) \\
&\approx \log\left(\frac{r^k + \delta_0 + \frac{\gamma}{1-\omega}(1 - (1-\omega)\tau_{i,t})}{r^k + \delta}\right) \\
&= \log\left(\frac{r^k + \delta_0 + \frac{\gamma}{1-\omega}}{r^k + \delta}\left(1 - \frac{\gamma \tau_{i,t}}{r^k + \delta_0 + \frac{\gamma}{1-\omega}}\right)\right) \\
&\approx \frac{\gamma \tau_{i,t}}{r^k + \delta_0 + \frac{\gamma}{1-\omega}},
\end{aligned}$$

where I omit the constants since they will not affect the covariance. Using that, the omitted variable bias is given by:

$$\begin{aligned}
\text{Bias} &= \beta \cdot \frac{\text{Cov}\left(\log\left(r^k + \delta\right) - \log\left(1 - \tau_{i,t}\right), \frac{\gamma \tau_{i,t}}{r^k + \delta_0 + \frac{\gamma}{1-\omega}}\right)}{\text{Var}\left(\log\left(\frac{r^k + \delta}{1 - \tau_{i,t}}\right)\right)} \\
&\approx \beta \cdot \frac{\text{Cov}\left(\tau_{i,t}, \frac{\gamma \tau_{i,t}}{r^k + \delta_0 + \frac{\gamma}{1-\omega}}\right)}{\text{Var}\left(\tau_{i,t}\right)} \\
&= \beta \cdot \frac{\gamma}{r^k + \delta_0 + \frac{\gamma}{1-\omega}}
\end{aligned} \tag{A.15}$$

Since we can write

$$\hat{\beta} = \beta \left(1 + \text{Bias}\right),$$

a general expression for the true elasticity parameter is

$$\beta \approx \frac{\hat{\beta}}{1 - \frac{\gamma}{r^k + \delta_0 + \frac{\gamma}{1-\omega}}}. \tag{A.16}$$

Therefore, we cannot use the standard tools of public finance to assess the effects of tax reforms unless we also know the maintenance demand function. Under this paper's parameterization, a maintenance-corrected coefficient boosts the estimated elasticity by a factor of about 1.5. Note, moreover, that this formula corresponds to many estimated elasticities. For example, many papers regress investment or the investment rate on the tax term alone, which itself comes from an approximation of the log user cost above. Therefore, the consensus range of investment rate elasticities from Hassett and Hubbard (2002) of 0.5-1 is perhaps more like 0.75-1.5. □

D.4 Adjustment Costs

In the general case, consider a firm choosing sequences of maintenance, investment, labor, and capital to maximize profits:

$$\begin{aligned}
\max_{I_t, M_t, L_t, K_{t+1}} \sum_{t=0}^{\infty} \left(\frac{1}{1 + r^k}\right)^t \Bigg\{ &\left(1 - \tau_t^c\right) \left(F\left(K_t, L_t\right) - w_t L_t - \frac{\phi}{2} \left(\frac{I_t}{K_t} - \delta(m_t)\right)^2 K_t - p_t^M M_t\right) \\
&- \left(1 - c_t - z_t \tau_t\right) p_t^I I_t \Bigg\} \quad \text{s.t.} \quad K_{t+1} = \left(1 - \delta\right) K_t + I_t.
\end{aligned} \tag{A.17}$$

Letting q_t denote the multiplier on the law of motion for capital, the first-order conditions on maintenance and investment are

$$-q_t\delta'(m_t) = (1-\tau_t^c)\left(p_t^M - \phi\delta'(m_t)\left(\frac{I_t}{K_t} - \delta(m_t)\right)\right) \tag{A.18}$$

$$(1-\tau_t^c)\phi\left(\frac{I_t}{K_t} - \delta(m_t)\right) = q_t - \left(1 - c_t - z_t\tau_t^c\right)p_t^I. \tag{A.19}$$

Using the investment FOC, the maintenance FOC can be rewritten as

$$-\delta'(m_t) = \frac{1-\tau_t^c}{1-c_t-z_t\tau_t^c}\frac{p_t^M}{p_t^I}. \tag{A.20}$$

Rearranging the investment FOC, we have

$$\frac{I_t}{K_t} = \frac{1}{(1-\tau_t)\phi}\left(q_t - (1-c_t-z_t\tau_t^c)p_t^I\right) + \delta(m_t) \tag{A.21}$$

For simplicity, define

$$\kappa \equiv (1-c_t-z_t\tau_t^c)p_t^I \qquad i_t \equiv I_t/K_t$$

and drop time subscripts so

$$i = \frac{q-\kappa}{(1-\tau^c)\phi} + \delta(m).$$

In steady state, it is clear that

$$-\delta'(m) = \frac{1-\tau^c}{q}p^M.$$

Consequently,

$$\frac{\partial i}{\partial q} = \frac{1}{1-\tau^c}\frac{1}{\phi} + \frac{\partial\delta(m)}{\partial q}$$

Re-expressing as elasticities,

$$|\varepsilon_I| \equiv \left|\frac{\partial\ln i}{\partial\ln q}\right| = \left|\frac{\partial i}{\partial\kappa}\right|\frac{q}{i}, \tag{A.22}$$

$$|\varepsilon_\delta| \equiv \left|\frac{\partial\ln\delta}{\partial\ln q}\right| = \left|\frac{\partial\delta}{\partial q}\right|\frac{q}{\delta(m)}. \tag{A.23}$$

Since i and δ both rise when q rises, the partial derivatives are positive. The short-run elasticity is therefore, after substituting $\delta = i$ in steady state,

$$|\varepsilon_I| = \frac{\kappa}{i(1-\tau^c)\,\phi} + |\varepsilon_\delta|\,. \tag{3}$$

Local to a zero marginal tax rate (*i.e.*, $\kappa = q \approx 1$) and given estimates for the short-run elasticities $\hat{\varepsilon}_I$ and $\hat{\varepsilon}_\delta$, we can solve for the adjustment cost parameter as

$$\phi^{NGMM} = \frac{1}{\delta(m)} \frac{1}{|\hat{\varepsilon}_I| - |\hat{\varepsilon}_\delta|}.$$

When maintenance demand is inelastic, this collapses to

$$\phi = \frac{1}{\delta(m)} \frac{1}{|\hat{\varepsilon}_I|}.$$

Since $\hat{\varepsilon}_I$ is smaller in the NGMM than the NGM even with inelastic demand demand for maintenance, adjustment costs will be larger in the NGMM. Finally, if demand is elastically zero for maintenance, then we recover the NGM adjustment cost expression

$$\phi = \frac{1}{\delta} \frac{1}{|\hat{\varepsilon}_I|}.$$

D.5 Stability Under Cobb-Douglas Production

Profit Function

Consider a firm with Cobb-Douglas production

$$F(K_t, L_t) = K_t^{\alpha_K} L_t^{\alpha_L}.$$

The firm pays a wage bill $w_t L_t$. We can use the first-order condition to write the expression $F(K_t, L_t) - w_t L_t$ entirely in terms of labor by manipulating the static optimization problem for labor demand. Since

$$w_t = \alpha_L K_t^{\alpha_K} L_t^{\alpha_L - 1},$$

we can rewrite income net of the wage bill as

$$\begin{aligned} K_t^{\alpha_K} L_t^{\alpha_L} - w_t L_t &= (1 - \alpha_L) K_t^{\alpha_K} L_t^{\alpha_L} \\ &= (1 - \alpha_L) K_t^{\alpha_K} \left(\frac{\alpha_L K_t^{\alpha_K}}{w_t} \right)^{\frac{\alpha_L}{1-\alpha_L}} \\ &= Z_t K_t^{\alpha}, \end{aligned}$$

where

$$\alpha \equiv \frac{\alpha_K}{1 - \alpha_L} \quad \text{and} \quad Z_t \equiv (1 - \alpha_L) \left(\frac{\alpha_L}{w_t} \right)^{\frac{\alpha_L}{1-\alpha_L}}.$$

Linearized System

As in Chodorow-Reich et al. (2025), I make the assumption that the tax policy parameters are already at their steady state values. That means maintenance is already at its steady state value when considering convergence toward the post-TCJA steady state and hence depreciation is also fixed.[22] Let variables with hats denote log-deviations and note that the deviation for λ_t is additive, *i.e.*, $\hat{\lambda}_t = \lambda_t - \bar{\lambda}$. In steady state,

$$h(\bar{\lambda}) = 0 \tag{A.24}$$

$$h'(\bar{\lambda}) = \frac{1}{\phi(1-\tau)}. \tag{A.25}$$

The linearized system therefore reduces to

$$\hat{\lambda}_t(1+r^k) = (1-\tau)F''(\bar{K})\bar{K}\hat{K}_{t+1} + \hat{\lambda}_{t+1}\left(1-\delta(m)+\delta'(\bar{m})\bar{m}\right) \tag{A.26}$$

$$\hat{K}_{t+1} = \frac{\hat{\lambda}_t}{\phi(1-\tau)} + \hat{K}_t \tag{A.27}$$

From Equations (A.26) and (A.27), the system can be represented as:

$$\begin{bmatrix} \hat{\lambda}_{t+1} \\ \hat{K}_{t+1} \end{bmatrix} = \boldsymbol{A} \begin{bmatrix} \hat{\lambda}_t \\ \hat{K}_t \end{bmatrix}$$

where

$$\boldsymbol{A} = \begin{bmatrix} \dfrac{1+r^k-\frac{1}{\phi}F''(\bar{K})\bar{K}}{1-\delta(\bar{m})+\delta'(\bar{m})\bar{m}} & \dfrac{-(1-\tau)F''(\bar{K})\bar{K}}{1-\delta(\bar{m})+\delta'(\bar{m})\bar{m}} \\ \dfrac{1}{\phi(1-\tau)} & 1 \end{bmatrix}$$

This matrix has eigenvalues

$$\mu = \frac{C_1 \pm \sqrt{C_1^2 - 4(1+r^k)C_2}}{2C_2}$$

where

$$C_1 = 2 + r^k - \delta(\bar{m}) + \delta'(\bar{m})\bar{m} - \frac{1}{\phi}F''(\bar{K})\bar{K}$$

$$C_2 = 1 - \delta(\bar{m}) + \delta'(\bar{m})\bar{m}$$

22. Introducing adjustment costs on maintenance would change the results quantitatively, but not qualitatively.

and associated eigenvector

$$\mathbf{v} = \begin{bmatrix} 1 \\ \dfrac{-1}{\phi(1-\tau)(1-\mu)} \end{bmatrix}.$$

Short-Run to Long-Run Investment Ratio χ_{SR}

This subsection shows that there is a constant ratio between investment deviations in the short run and the long run. The proof is similar to Chodorow-Reich et al. (2025), but instead is in discrete time. Because maintenance instantaneously adjusts, it suffices to show that the ratio of capital deviations is constant. First, note that

$$\begin{aligned}
\frac{K_{t+1}-K_t}{K_0} &= \frac{\bar{K}}{K_0}\frac{K_{t+1}-K_t}{\bar{K}} \\
&= \frac{\bar{K}}{K_0}\frac{(K_{t+1}-\bar{K})-(K_t-\bar{K})}{\bar{K}} \\
&= \frac{\bar{K}}{K_0}\left(\hat{K}_{t+1}-\hat{K}_t\right) \\
&= \frac{\bar{K}}{K_0}\left(\mu_1^{t+1}\hat{K}_0-\mu_1^t\hat{K}_0\right) \\
&= (\mu_1-1)\,\mu^t\frac{\bar{K}}{K_0}\hat{K}_0 \\
&= (1-\mu_1)\,\mu_1^t\tilde{k},
\end{aligned}$$

where

$$\tilde{k} = \frac{\bar{K}-K_0}{K_0}$$

is the long-run change in capital given the initial position K_0. We can then derive the average change in investment from period zero to T relative to period zero as

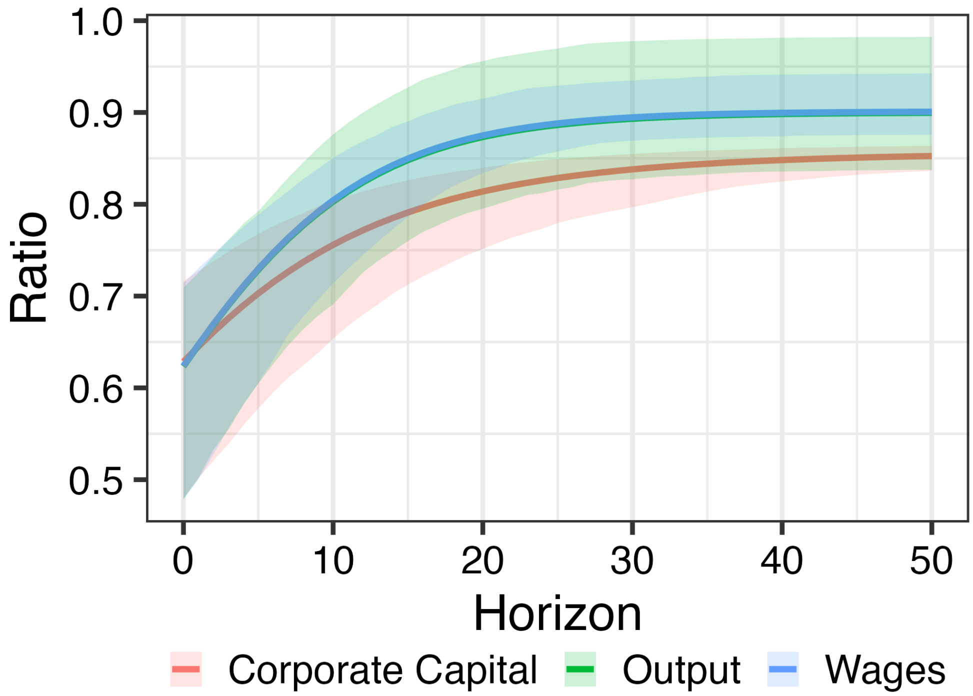
$$
\begin{aligned}
\frac{1}{T+1}\sum_{t=0}^{T}\frac{I_t-I_0}{I_0} &= \frac{1}{T+1}\sum_{t=0}^{T}\frac{K_{t+1}-(1-\delta(m))K_t-\delta(m)K_0}{\delta(m)K_0} \\
&= \frac{1}{\delta(m)\,(T+1)}\sum_{t=0}^{T}\left(\delta(m)\frac{K_t-K_0}{K_0}+\frac{K_{t+1}-K_t}{K_0}\right) \\
&= \frac{1}{\delta(m)\,(T+1)}\sum_{t=0}^{T}\left(\delta(m)\frac{K_t-K_0}{K_0}+(1-\mu_1)\mu_1^t\tilde{k}\right) \\
&\approx \frac{1}{\delta(m)\,(T+1)}\sum_{t=0}^{T}\left(\delta(m)\left(\tilde{k}+\frac{K_t-\bar{K}}{K_0}\right)+(1-\mu_1)\mu_1^t\tilde{k}\right) \\
&\approx \frac{1}{\delta(m)\,(T+1)}\sum_{t=0}^{T}\left(\delta(m)\left(\tilde{k}-\mu_1^t\tilde{k}\right)+(1-\mu_1)\mu_1^t\tilde{k}\right) \\
&= \tilde{k}\left(1+\frac{(1-\mu_1-\delta(m))(1-\mu^{T+1})}{\delta(m)(1-\mu_1)(T+1)}\right)
\end{aligned}
$$

Therefore the ratio of short-run to long-run investment is a constant:

$$
\begin{aligned}
\chi_{SR} = \frac{\text{Average Deviation}}{\text{Long-Run Deviation}} &= \tilde{k}\left(1+\frac{(1-\mu_1-\delta(m))(1-\mu^{T+1})}{\delta(m)(1-\mu_1)(T+1)}\right)/\tilde{k} \\
&= 1+\frac{(1-\mu_1-\delta(m))(1-\mu^{T+1})}{\delta(m)(1-\mu_1)(T+1)}.
\end{aligned}
\tag{A.28}
$$

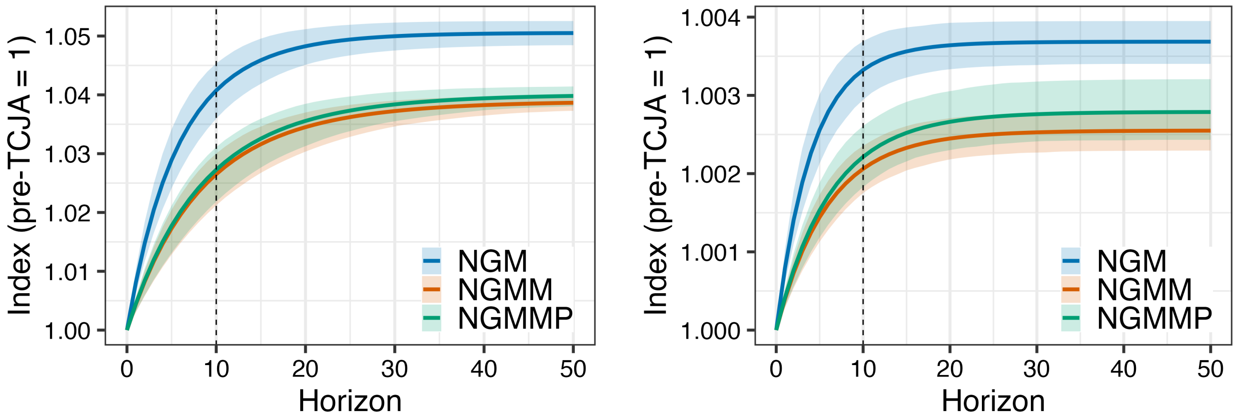
E Quantification

Figure E.1: NGMMP-NGM Ratio of Aggregates



Notes: The NGM corporate capital, output, and wages are exactly as in the main text. The NGMMP is an extension of the baseline NGMM which specifies that the price of maintenance rises with wages. I assume that wages are half the cost of maintenance.

Figure E.2: The Effect of TCJA on Corporate Capital and Aggregate Output with Crowding Out

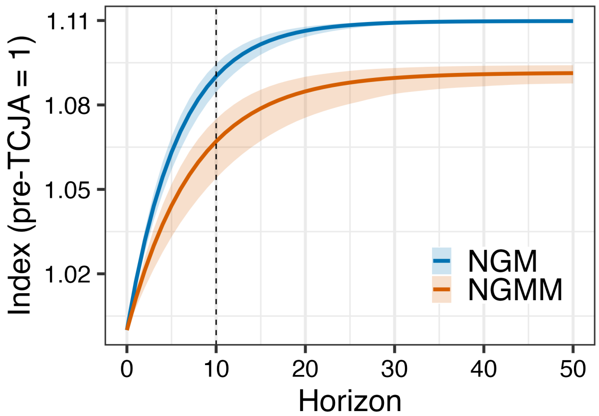


(a) Paths of Corporate Capital

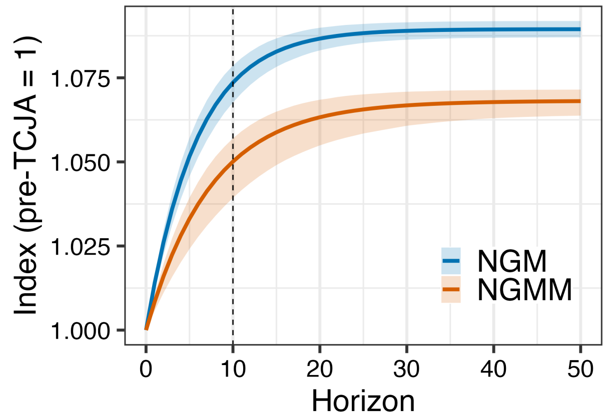
(b) Paths of Output

Notes: Panel (a) shows the response of capital to the TCJA in the NGMM (orange line) and the NGM (blue line), and the NGMMP (green line), and Panel (b) plots the corresponding IRFs for aggregate output. To account for crowding out, we translate the 2027 debt-output ratio into an increase in discount rates using the static score of each model. The increase in debt-output corresponds to an increase in discount rates drawn from Neveu and Schafer (2024). A one percentage point increase in the debt-GDP ratio corresponds to a 2.2 percentage point increase in the discount rate (SE = 1.0). All lines are bootstrapped with a 95% confidence interval accounting for uncertainty in maintenance demand and crowding out.

Figure E.3: The Effect of TCJA on Corporate Capital in Partial Equilibrium



(a) Baseline



(b) Crowding Out

Notes: Panel (a) shows the response of corporate capital to the TCJA in the NGMM (orange line) and the NGM (blue line), and Panel (b) plots the corresponding IRFs with crowding out. To account for crowding out, we translate the 2027 debt-output ratio into an increase in discount rates using the static score of each model. The increase in debt-output corresponds to an increase in discount rates drawn from Neveu and Schafer (2024). A one percentage point increase in the debt-GDP ratio corresponds to a 2.2 percentage point increase in the discount rate (SE = 1.0). All lines are bootstrapped with a 95% confidence interval accounting for uncertainty in maintenance demand and crowding out.

F Model Extensions

F.1 Capital Reallocation

This subsection extends the base model to heterogeneous firms which only differ in their tax status. That leads to reallocation through variation in the marginal product of capital. A fraction $\lambda \in (0, 1)$ of firms is taxable (Type T) and the remaining $1 - \lambda$ are untaxed (Type U). Variation in taxability comes from realization of an i.i.d. fixed cost F, which is assumed to be sufficiently large that it exceeds profits. Untaxed firms also pay a higher cost of investment $p^I + b$, which is meant to account (in a reduced-form way) for the fact that untaxable firms often face some kind of financial constraint that hinders their ability to access new investment (Lian and Ma 2020). This formulation allows us to model the fact that investment is typically more expensive for unprofitable firms without explicitly modeling the borrowing constraint.

Each period, a firm observes its tax type $\theta \in \{T, U\}$:

- Type T (taxable) firms face corporate tax τ^c.
- Type U (untaxed) firms pay no corporate tax because they have a fixed cost F. They also have a higher cost of investment $p^I + b$.

After observing its type, a firm chooses:

1. Maintenance expenditure M, with $m = \frac{M}{K}$ being the maintenance intensity.
2. Investment I (at new capital price p^I).
3. Net used–capital sales s, where $s > 0$ indicates selling a fraction of the capital and $s < 0$ indicates buying used capital. Firms pay a convex adjustment cost $G(s)$ for participating in the used capital market, which can be thought of as accounting for information frictions in a reduced–form way. For example, a firm selling a used car must furnish information about the vehicle, which is costly to do. The equilibrium used–capital price is denoted by q.

Putting together maintenance expenditures $m = M/K$, investment I, and capital sales s, the law of motion for capital (independently of tax status) is

$$K' = \Big[1 - \delta(m)\Big](1 - s)K + I. \tag{A.29}$$

Because firms vary in their tax status, they also vary in their cash flows. Profitable firms have cash flows

$$\pi^T = (1 - \tau^c)\Big[F(K) - p^m M + q\,s\,K - G(s)\Big] - \big(1 - c - \tau^c z\big)p^I I,$$

where z incorporates the possibility that the firm may be untaxable in the future and hence will not always be able to take advantage of a tax depreciation allowance. Note that capital sales are taxed at rate τ^c, reflecting current policy practice. Given those cash flows, we get the following recursive formulation for a firm choosing K', s, M:

$$\begin{aligned} V^T(K) = \max_{m,s,K'} \Bigg\{ &(1 - \tau^c)\Big[F(K) - p^m\, mK + q\,s\,K - G(s)\Big] \\ &- \big(1 - c - \tau^c z\big)p^I\Big(K' - [1 - \delta(m)](1 - s)K\Big) + \frac{V^*(K')}{1 + r^k}\Bigg\}, \end{aligned} \tag{A.30}$$

where

$$V^*(K') = \lambda\, V^T(K') + (1 - \lambda)\, V^U(K')$$

is the expected continuation value. Taxable firms therefore have the following FOCs:

$$\textbf{Investment:} \quad \frac{V^{*'}(K')}{1 + r^k} = \big(1 - c - \tau^c z\big)p^I, \tag{A.31}$$

$$\textbf{Maintenance:} \quad -\delta'(m) = \frac{1 - \tau^c}{1 - c - \tau^c z}\frac{p^m}{p^I\,(1 - s)}, \tag{A.32}$$

$$\textbf{Sales:} \quad (1 - \tau^c)\Big[q - G'(s)\Big] = \big(1 - c - \tau^c z\big)p^I\,[1 - \delta(m)]. \tag{A.33}$$

On the other hand, untaxed type U firms do not face any tax, so their cash flows are

$$\pi^U = F(K) - p^m M + q\,s\,K - G(s) - (1-\tau^c\tilde{z})(p^I + b)I - F.$$

Given those cash flows, we get the following recursive formulation for a firm choosing K', s, M:

$$\begin{aligned} V^U(K) = \max_{m,s,K'} \Bigg\{ & F(K) - p^m\, mK + q\,s\,K - G(s) \\ & - (1-\tau^c\tilde{z})(p^I + b)\Big(K' - [1-\delta(m)](1-s)K\Big) + \frac{V^*(K')}{1+r^k}\Bigg\}. \end{aligned} \tag{A.34}$$

The type U FOCs are:

$$\textbf{Investment:} \quad \frac{V^{*'}(K')}{1+r^k} = (1-\tau^c\tilde{z})(p^I + b), \tag{A.35}$$

$$\textbf{Maintenance:} \quad -\delta'(m) = \frac{p^m}{(1-\tau^c\tilde{z})(p^I + b)(1-s)}, \tag{A.36}$$

$$\textbf{Sales:} \quad q - G'(s) = (1-\tau^c\tilde{z})(p^I + b)\,[1-\delta(m)]. \tag{A.37}$$

The envelope condition enables us to define the user cost of capital in this economy. For taxed firms,

$$V^{T\prime}(K) = (1-\tau^c)\Big[F'(K) - p^m\, m^T + q\, s^T\Big] + \big(1 - c - \tau^c z\big)p^I\,(1-\delta(m^T)),$$

while for untaxed firms we have

$$V^{U\prime}(K) = F'(K) - p^m\, m^U + q\, s^U + (1-\tau^c\tilde{z})(p^I + b)\,(1-\delta(m^U)).$$

The combined envelope condition is

$$V^{*'}(K) = \lambda\, V^{T\prime}(K) + (1-\lambda)\, V^{U\prime}(K).$$

Equilibrium

An equilibrium in this economy is a collection of policies $\{V^T,\, V^U\}$, prices $\{q, p^I, p^M\}$ (the latter two exogenous) and allocations $\{\, m^T,\, s^T,\, K'^T,\, m^U,\, s^U,\, K'^U\}$ such that:

1. For all K, the Bellman equations for $V^T(K)$ and $V^U(K)$ are satisfied with the corresponding optimal policies.

2. The chosen policy functions satisfy the FOCs for investment, maintenance, and used–capital sales (with type–specific controls m^θ and s^θ) and the envelope conditions hold.

3. The law of motion for capital,

$$K' = \Big[1 - \delta(m^{\theta})\Big](1 - s)K + I,$$

is satisfied for each firm.

4. The used–capital market clears at the equilibrium price q; that is, the total net sales of used capital by all firms (taxable and untaxed) sum to zero:

$$\int s^T(K)\, d\mu(K) + \int s^U(K)\, d\nu(K) = 0,$$

where $\mu(K)$ and $\nu(K)$ are the distributions of capital among taxable and untaxed firms.

5. The expected continuation value is given by

$$V^*(K') = \lambda\, V^T(K') + (1 - \lambda)V^U(K'),$$

and firms form rational expectations consistent with the aggregate outcomes.

Trading Conditions

Trading of used capital will only arise under certain conditions. In particular, an active trading market is characterized by:

- Taxable firms choosing $s^T > 0$ (selling used capital) because their subsidized cost $\frac{1-c-\tau^c z}{1-\tau^c}\, p^I(1-\delta(m^T))$ is lower than that faced by untaxed firms.
- Untaxed firms choosing $s^U < 0$ (buying used capital) because the equilibrium used capital price q (adjusted by the marginal cost $G'(s^U)$) falls below the cost of acquiring new capital $p^I(1 - \delta(m^U))$.
- An equilibrium price q that satisfies

  $$q = \frac{1 - c - \tau^c z}{1 - \tau^c}\, p^I(1 - \delta(m^T)) + G'(s^T) = (1 - \tau^c \tilde{z})(p^I + b)(1 - \delta(m^U)) + G'(s^U),$$

  along with the market clearing condition

  $$\lambda\, s^T + (1 - \lambda)\, s^U = 0.$$

Essentially, we require that the gap between the pre–tax price and after–tax price of new capital is sufficiently large that it is worth it for firms to sell used capital and for untaxed firms to buy it, i.e.,

$$\frac{(1-c-\tau^c z)p^I\,[1-\delta(m^T)]}{1-\tau^c} < q < (1-\tau^c\tilde{z})(p^I+b)[1-\delta(m^U)].$$

I focus on this equilibrium because we observe active used capital trading in practice.

Aggregate User Cost of Capital

It is straightforward to observe that the aggregate user cost of capital in this economy is a weighted average of user costs for the taxable and untaxable firms:

$$\boxed{\Psi_{\text{agg}} = \frac{\lambda\,K^T}{K}\,\Psi^T + \frac{(1-\lambda)\,K^U}{K}\,\Psi^U, \quad \text{with } K = \lambda\,K^T + (1-\lambda)\,K^U.}$$

Indeed, one can observe that the proportional change in user cost will be strictly smaller to first order in this economy than in the representative firm economy in the main model because the share of untaxable firms will not react very much. Moreover, capital sales will prop up the maintenance rate (since the maintenance optimality condition implies a higher maintenance rate for untaxable firms), so maintenance and depreciation change less in this economy in the aggregate.

F.2 Extension to Multiple Maintenance Inputs

In this section, I extend the model to consider multiple inputs to maintenance production as well as a choice between using internal or external maintenance services. Production is carried out entirely using capital:

$$Y_t = F(K_t).$$

Capital evolves according to

$$K_{t+1} = \Big[1-\delta(m_{I,t}, m_{E,t})\Big]K_t + I_t,$$

where $m_{I,t}$ is internal maintenance intensity and $m_{E,t}$ is external maintenance intensity. I assume that internal maintenance is the sum of labor and materials purchases

$$M_{I,t} = g(L_{m,t}, I_{m,t}).$$

The firm purchases internal maintenance labor at price w_t materials at price p_t^X. External maintenance $m_{E,t} = M_{E,t}/K_t$ is purchased at price p_t^m and faces some convex cost of adjustment $C(M_{E,t}, M_{E,t-1})$, with $C(M_E, M_E) = 0$ in steady state. This is to reflect the fact that external maintenance contracts are typically quite sticky. Since internal maintenance also includes labor, then internal maintenance is also sticky, but presumably less so than external maintenance because internal resources can be reallocated more quickly. I could capture that by having an outside option for labor or introducing a separate adjustment cost for internal maintenance, but it would be unneccessarily complicated. Note that with multiple maintenance types, the price of maintenance is a weighted average of each.

Taking K_0 as given, the firm chooses the sequence $\{K_{t+1},\ L_{m,t},\ I_{m,t},\ M_{E,t}\}_{t\geq 0}$ to maximize

$$\mathcal{L} = \sum_{t=0}^{\infty} \left(\frac{1}{1+r^k}\right)^t \Bigg\{(1-\tau_t^c)\Big[F(K_t) - w_t\, L_{m,t} - p_t^I\, I_{m,t} - M_{E,t} - C\big(M_{E,t}, M_{E,t-1}\big)\Big] \\ - \ (1-\tau_t^c z_t)p_t^I\Big[K_{t+1} - \Big(1-\delta\Big(m_{I,t}, m_{E,t}\Big)\Big)K_t\Big]\Bigg\},$$

subject to $m_{i,t} = \frac{g(L_{m,t}, I_{m,t})}{K_t}$. The first-order conditions are not substantially different from the baseline model. Starting with the capital Euler equation, we have The capital Euler equation is:

$$(1-\tau_t^c z_t)p_t^I = \frac{1}{1+r^k}\Bigg\{(1-\tau_{t+1}^c)\, F_K(K_{t+1}) + (1-\tau_{t+1}^c z_{t+1})\, p_{t+1}^I\Big[1-\delta\big(m_{I,t+1}, m_{E,t+1}\big) \\ + p_{t+1}^{M,I} m_{I,t+1} + p_{t+1}^{M,E} m_{E,t+1}\Big]\Bigg\}, \tag{A.38}$$

which in steady state simplifies to

$$F_K = p^I(1-\tau^c z)\left(\frac{r^k + \delta(m_I, m_E)}{1-\tau^c}\right) + p^{M,I} m_I + p^{M,E} m_E, \tag{A.39}$$

where $p^{M,I}$ is the price of internal maintenance. If internal maintenance is a CES aggregator of labor and materials, then $p^{M,I}$ would just be the usual CES price index of p^I and w.

There are three maintenance choices. Beginning with the choice of internal labor $L_{m,t}$, the firm's optimal choice is satisfied when

$$-\delta_1(t)\, g_L(t) = \frac{(1-\tau_t^c)w_t}{(1-\tau_t^c z_t)p_t^I}. \tag{A.40}$$

Similarly, optimal materials is given by

$$-\delta_1(t)\, g_M(t) = \frac{(1-\tau_t^c)p_t^X}{(1-\tau_t^c z_t)p_t^I}, \tag{A.41}$$

which implies the marginal rate of substitution between materials and labor is

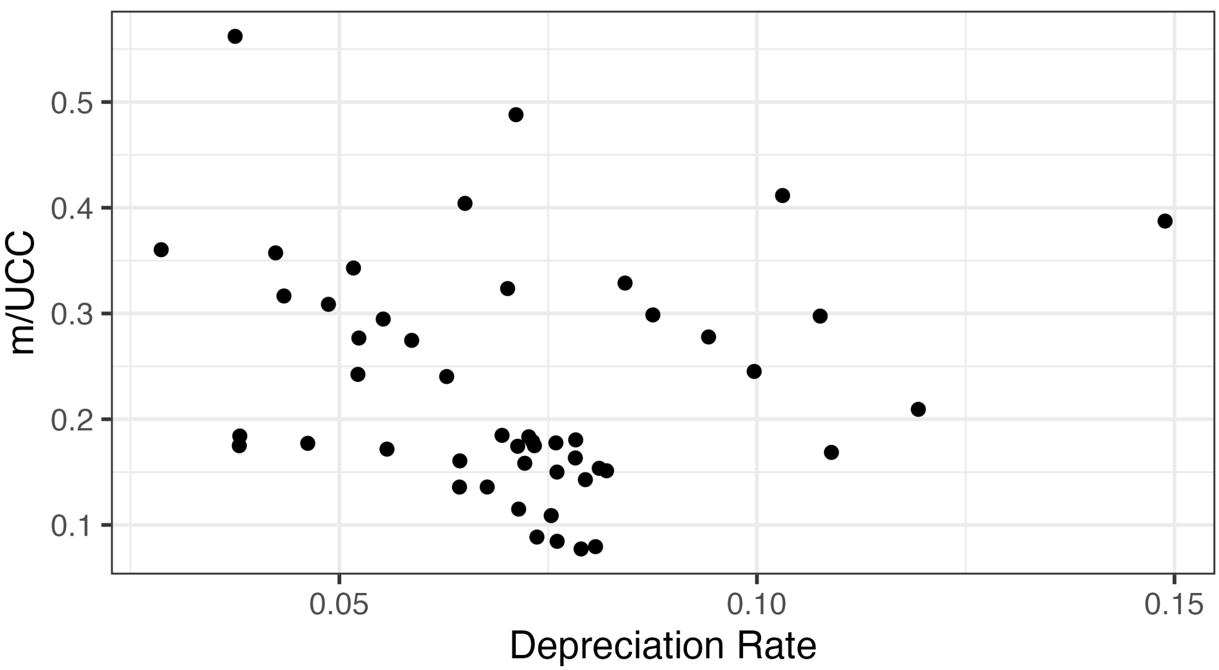
$$\frac{g_L(t)}{g_M(t)} = \frac{p_t^I}{w_t}. \tag{A.42}$$

On the other hand, external maintenance choice is given by

$$-\delta_2(t) = \frac{(1-\tau_t^c)\Big[1+C_1(t)\Big] + \frac{1}{1+r^k}(1-\tau_{t+1}^c)\,C_2(t+1)}{(1-\tau_t^c z_t)p_t^I}. \tag{A.43}$$

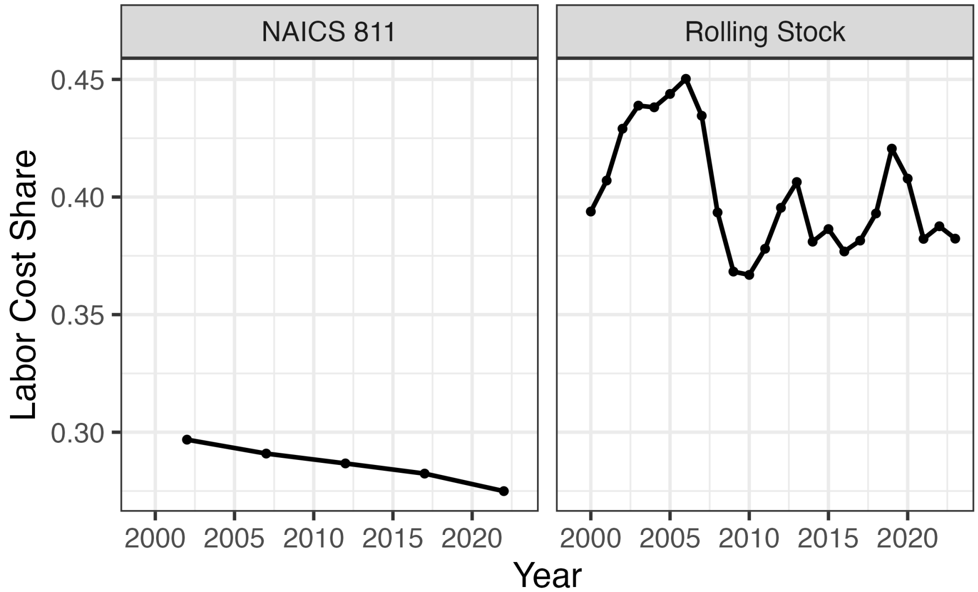
G Additional Figures and Tables

Figure G.1: The industry maintenance share of user cost is decreasing in the depreciation rate



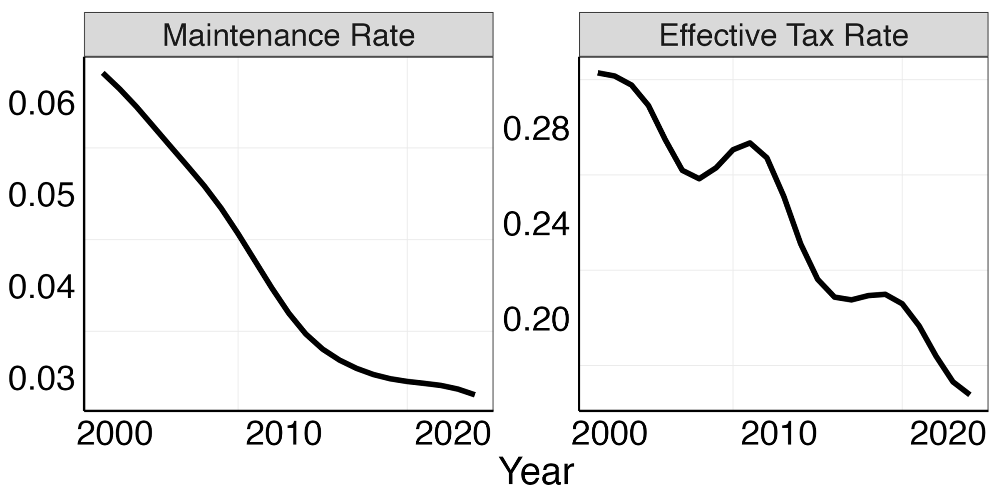
Note: Each point is the time series average of maintenance shares and depreciation rates within an industry.

Figure G.2: Aggregate Internal Labor Cost Share



Notes: The share is computed by dividing labor costs by total internal maintenance costs. The left panel plots the ratio of labor costs to total receipts for NAICS code 811, which is the maintenance and repair sector, from 2002-2022. Each data point comes from the Economic Census. The right panel is the average for all rolling stock in the R-1 data.

Figure G.3: Trends in Maintenance and Corporate Tax Rates



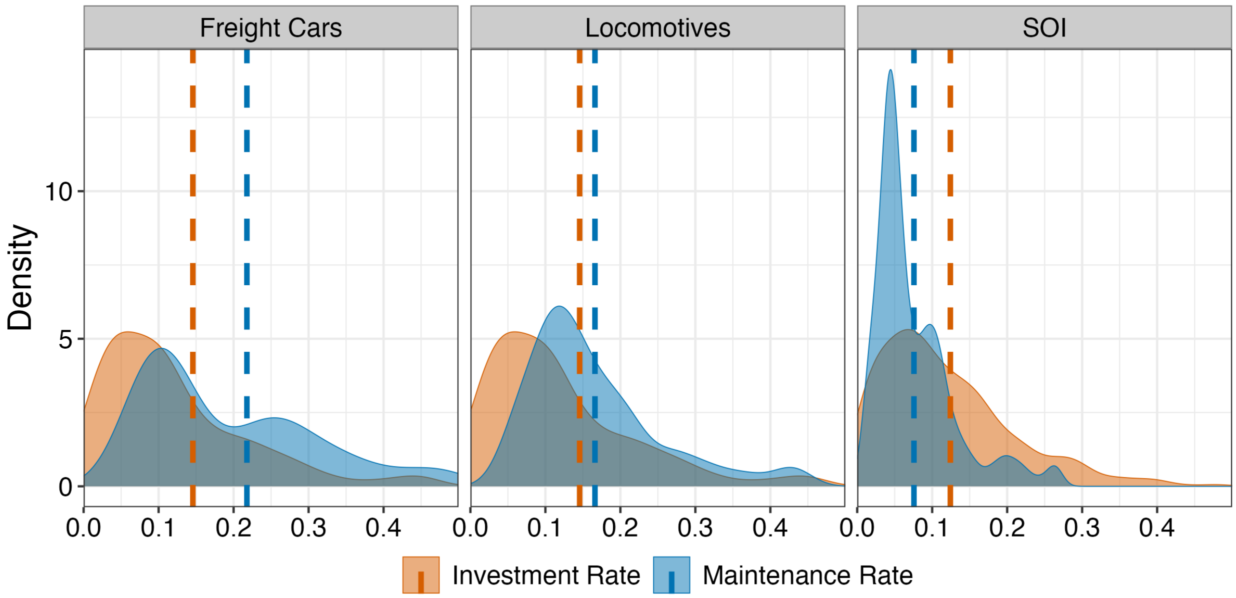
Notes: The maintenance rate is constructed as gross output in NAICS 811 excluding home repair as a share of current cost private equipment capital. The effective tax rate is the ratio of domestic corporate taxes paid to pre-tax profits from BEA Tables 6.16D and 6.17D. The cyclical component of each series has been removed with a Hodrick-Prescott filter.

Table G.1: NAICS Industries and Maintenance Rates

NAICS Industry Name	NAICS Code	$\frac{M}{K}$	s_m
Agriculture, Forestry, Fishing and Hunting	11	0.17	0.49
Mining, Quarrying, and Oil and Gas Extraction	21	0.02	0.07
Utilities	22	0.03	0.23
Construction	23	0.08	0.29
Manufacturing	31	0.05	0.25
Manufacturing	32	0.03	0.18
Manufacturing	33	0.04	0.22
Wholesale Trade	42	0.06	0.25
Retail Trade	44	0.09	0.39
Retail Trade	45	0.07	0.31
Transportation and Warehousing	48	0.13	0.40
Transportation and Warehousing	49	0.08	0.32
Information	51	0.05	0.29
Real Estate and Rental and Leasing	53	0.05	0.23
Professional, Scientific, and Technical Services	54	0.11	0.43
Management of Companies and Enterprises	55	0.11	0.47
Administrative Services	56	0.11	0.39
Educational Services	61	0.11	0.42
Health Care and Social Assistance	62	0.10	0.44
Arts, Entertainment, and Recreation	71	0.05	0.26
Accommodation and Food Services	72	0.08	0.31
Other Services (except Public Administration)	81	0.24	0.64

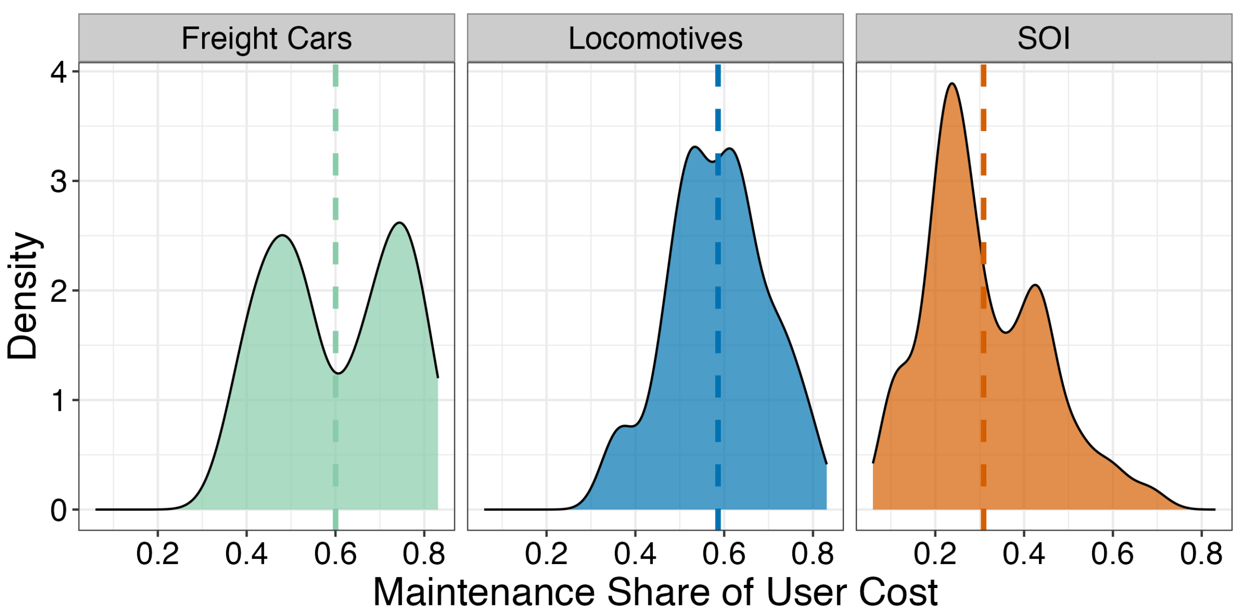
Notes: This table computes the mean maintenance rate M/K and the maintenance share of user cost s_m (adjusted for labor) for NAICS two-digit industries in the SOI from 1998-2021 using the All Firms sample.

Figure G.4: Density plots for maintenance and gross investment rates



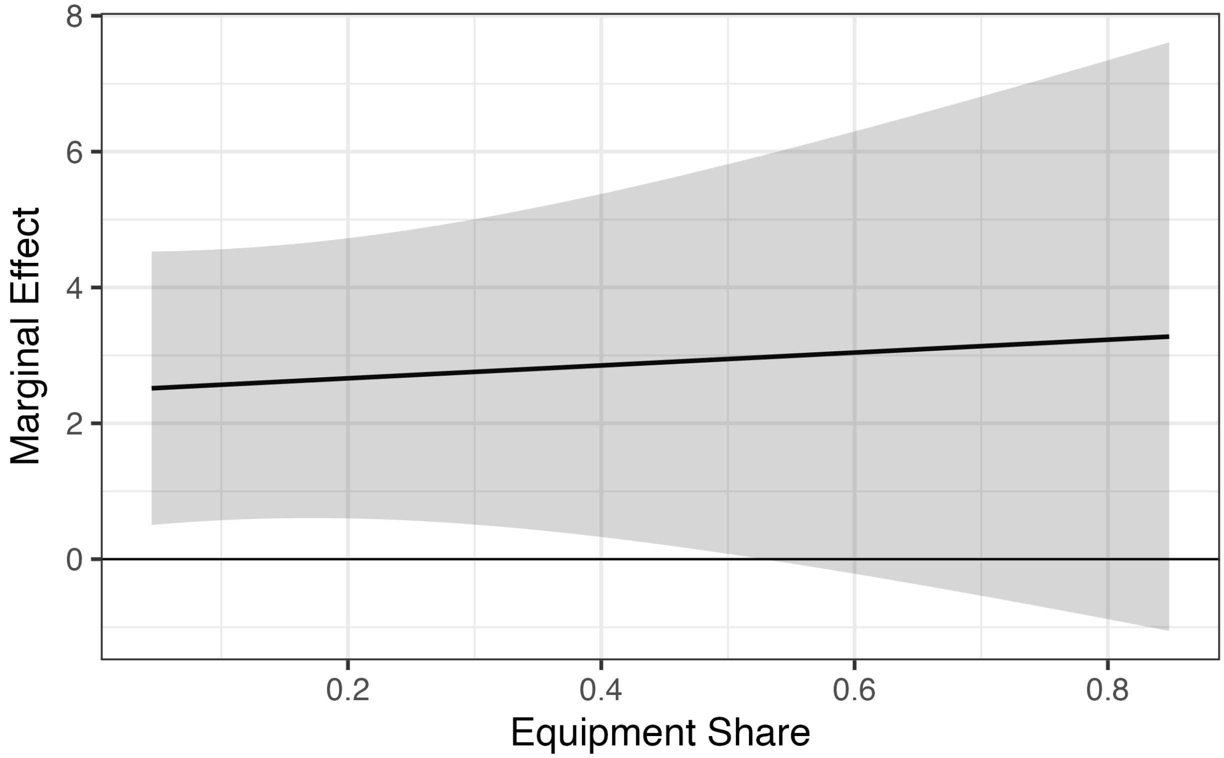
Note: Each density plot is constructed with beginning of period book capital in the denominator. The dashed lines are mean maintenance and investment rates. From left to right, the mean maintenance rates are 7.9%, 21.8%, and 16.6%. The corresponding investment rates are 13.8%, 7.9%, and 14.6%. The SOI maintenance rate is adjusted for missing labor and materials costs.

Figure G.5: Density plots for the maintenance share of user cost



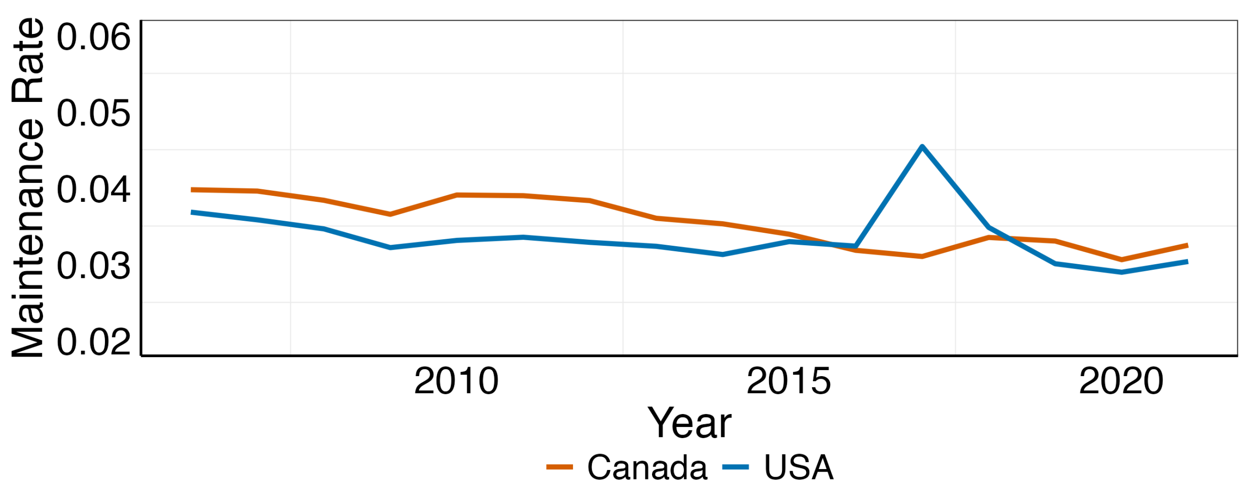
Note: Each density plot is constructed with beginning of period book capital in the denominator. The dashed lines are mean maintenance shares. Across the SOI, freight cars, and locomotives, the mean maintenance shares are 30%, 60%, and 58.6%. The maintenance rate is adjusted for labor costs.

Figure G.6: Marginal Effect of Wedge on Maintenance Rate by Equipment Share



Note: Marginal (absolute-value) maintenance-wedge elasticity by equipment-capital ratio. The black line plots $\left|\partial \log m / \partial \log(\{wedge\})\right|$ against each industry's average equipment-capital ratio. Shaded bands are 95 % confidence intervals.

Figure G.7: American vs. Canadian Maintenance Rates



Note: This figure plots the maintenance rate (net of govenrnment capital and maintenance) from Statistics Canada against the SOI maintenance rate.