Stimulus Effects of Investment Tax Incentives:

Production versus Purchases[†]

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ABSTRACT

The distinction between production and purchases of investment goods is essential for quantifying the response to changes in investment tax incentives. If investment goods are tradeable, a large fraction of the demand from changes in tax subsidies will be met from abroad. This difference between production and purchases implies that investment tax incentives will lead to more capital accumulation, but less stimulus to economic activity relative to a no-trade counterfactual. Domestic capacity to produce investment goods is less than perfectly elastic because of quasi-fixed factors of production, adjustment costs, and specialization of labor. This paper builds these features into a DGSE model where key parameters are estimated to match the reduced-form response of investment production and purchases to tax incentives. Typical investment tax policies result in equipment purchases that are split roughly half between domestic and foreign production of equipment.

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I. INTRODUCTION

Does capital accumulation respond strongly to investment tax incentives? Do investment tax incentives stimulate the economy? This paper investigates whether the answer to these two questions is different. The neoclassical theory of investment demand implies that business investment should respond strongly to changes in the after-tax price of capital–particularly for temporary tax policies. Such an increase in purchases of capital goods, however, need not stimulate domestic economic activity if capital goods are imported or if the domestic supply of investment goods is relatively inelastic. Indeed, imported capital equipment has become a common feature of for the U.S. economy over the past 50 years. Figure 1 plots the ratio of the total dollar value of gross imports and exports of capital equipment relative to total equipment investment for 1967-2015. While capital imports were less than five percent of aggregate equipment investment in 1967, this ratio has steadily risen to more than fifty percent in 2015. Capital exports have also gone up steadily over this time period (though not quite as rapidly as imports). Hence, the U.S. economy is increasingly open to trade in capital equipment as both supplier and demander of capital equipment.

In a framework that distinguishes purchases and production, we present both reduced-form estimates and structural estimates of a dynamic equilibrium model of the effects of investment tax subsidies. Because different capital goods receive different investment tax treatments, our empirical and modeling frameworks also feature an analysis of the reallocation of inputs and production across sectors in addition to the aggregate effects of investment tax policy. These approaches show that indeed the production/purchase distinction is essential for understanding the effects of changes in tax policy and for quantifying the magnitude of responses to specific policy interventions.

Notwithstanding the volatility and measurement limitations of industry-level investment data, clear and consistent patterns are evident. Our reduced-form estimates imply that a one percentage point investment tax incentive increases *purchases* of capital equipment by roughly 2 percent. Domestic *production* of capital equipment also increases, though by only about 1 percent. Thus, tax incentives succeed on both margins—they both encourage businesses to expand physical capital, and encourage increased domestic production. Yet, the response of production is about half as large as the increase in purchases.

We find little evidence for pass-through of investment tax subsidies to the pre-tax price of capital goods. Although there are empirical specifications in which a one percentage point subsidy leads to roughly a one percent increase in prices, such findings are not robust to even modest changes in the econometric specification. Overall, the results suggest that either there are no discernible impacts of investment tax subsidies on prices or that the true impact is difficult to measure accurately in the available data. This result differs from Goolsbee's (1998) finding that investment subsidies push up the prices of investment goods. We can replicate his findings using his original sample period and vintage data. Data revisions and additional observations have both led to a reduction in the estimated price responses found in his earlier study. Thus, the effective supply of new capital goods appears substantially more elastic than earlier data suggest.

In the second part of the paper, we construct a general equilibrium model that has key features for understanding the dynamic supply of investment goods. Some of these features increase the effective short-run supply elasticity of capital goods, while others work to reduce it. In addition to imports and the fact that investment goods production is a relatively small part of the economy, the model allows for variable utilization, factor mobility, and factor accumulation as other margins of domestic supply of capital goods. In addition to standard general equilibrium effects, factors adjustment and sectoral specificity of labor limit the elastic supply of capital. Our DGSE model integrates all these margins in a framework that highlights both industrial heterogeneity and a meaningful distinction between production and purchases of capital goods. The reduced-form econometric specification in the first part of the paper serves as the auxiliary model which allows us to estimate the elasticity of supply for foreign equipment–the key structural parameter governing the difference between production and purchases of domestic investment goods. We then use the estimated structural model to study the effects of investment subsidies that match features of commonly-enacted tax policies.

The model illustrates important dynamic effects of the response to policy. In the short run, the increase in investment purchases is largely accommodated by an expansion of imports of equipment. As a result, the immediate stimulus effects of investment tax incentives exhibit "leakage" in the sense that the subsidies are stimulating production and employment of overseas capital producing firms. The fiscal policy channel emphasized in this paper relates to stimulus concentrated on a narrow range of highly tradeable goods. Hence, it is fundamentally different from textbook international aggregate demand spillovers. Over time, investment, domestic production of capital goods, equipment exports, consumption and GDP all increase. The delayed increase in exports of equipment is notable. After investment subsidies expire, as often happens, the increased capacity for domestic production of equipment persists and results in above-trend production of capital goods and equipment exports. Hence, while investment subsidies adversely affect the trade balance in equipment initially, subsequently such policies have favorable effects on the trade balance.

II. RELATED LITERATURE

Economists have attempted to quantitatively address the reaction of investment spending to changes in the after-tax price of capital goods at least since Hall and Jorgensen (1967).[1] Our paper adds to a resurgence of work addressing the effects of tax policy on investment. This renewed interest in investment tax policy is driven in part by the availability of new data and in part by a renewed interest on the part of policy makers in the viability of investment incentives as a policy tool.

Goolsbee (1998) considers whether the pre-tax price of investment typically increases following investment subsidies. For many of the types of capital goods in his dataset, prices appear to rise almost one-for-one with the subsidy. Goolsbee's conclusion is natural—investment tax incentives might have little impact on investment spending because the supply of new capital is effectively price-inelastic. This finding has been challenged by several recent papers including Whelan (1999), House and Shapiro (2008), Edgerton (2010), Mian and Sufi (2012) and Sallee (2011). Whelan argues that after controlling for input cost shocks, there is little evidence that investment incentives bid up prices. House and Shapiro (2008) focus on the cross-sectional impact of bonus depreciation in the early 2000s and conclude that, at least for that episode, there is no clear relationship between the subsidy and capital goods prices.

There are also recent studies that suggest that real investment spending does react to subsidies and other shocks. The estimated reactions to bonus depreciation in House and Shapiro (2008) were surprisingly large. Edgerton (2010) argues that in the mid-2000s, housing prices, farming prices and oil prices all experienced dramatic increases unrelated to the supply of capital goods. He then looks at the production and pricing of construction equipment, agricultural

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[1] The existing literature on investment demand and investment tax incentives is vast and an adequate summary is beyond the scope of this paper. Foundational contributions include Jorgenson (1963), Abel (1981), Hayashi (1982), and Summers (1981).

equipment and mining equipment and finds little evidence that prices of these goods rose despite increases in the production of these capital goods. Mian and Sufi (2012) find that the CARS program (better known as “Cash for Clunkers”) sharply increased automobile purchases while the subsidy was in place. Zwick and Mahon (2017) use business tax return data to re-examine the effects of bonus depreciation and find that investment responded strongly to the subsidy. Zwick and Mahon pay particular attention to financially constrained firms whom, they argue, reacted most sharply to the bonus depreciation subsidy.

III. DATA AND CONCEPTS

A. Production and Purchases

Data on investment *purchases* come from nominal investment spending and investment prices in the Bureau of Economic Analysis’ (BEA) underlying detail tables. We define real purchases as the ratio of total nominal purchases to the type-specific price index. Our data on quantities and prices of domestic *production* of equipment come from the NBER-CES Manufacturing Productivity Database.[2] The NBER database also provides data on inputs and total factor productivity for equipment. Because purchases and production of structures are identical, we use the BEA data for them. We create a quarterly panel of 30 equipment types and 20 structure types shown in Tables 1A and 1B from 1959 to 2009. The BEA purchase data are much more detailed than the NBER production data. Appendix A contains details of how we harmonize the data by type and frequency.[3]

The top panel of Figure 2 shows purchases and production for general industrial equipment (one of the 30 investment categories in our equipment dataset). The bottom panel shows the real relative price. The figure illustrates three noteworthy features common to many investment types in our sample.

First, the quantity series exhibit dramatic movements over time. Real quantities (for either purchases or production) regularly change by more than twenty percent from one year to the next. In contrast, real relative prices are much less volatile. The average volatility of investment

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[2] This dataset was assembled by Eric Bartelsman, Randy Becker, Wayne Gray and Jordan Marvakov. The raw data are freely available at the NBER data website. See Bartelsman and Gray (1996).

[3] We do not use export and import data but instead use type-specific investment aggregates. Existing export and import data do not distinguish goods by end use (consumer purchases or business investment) and as a result are not directly applicable to our analysis.

purchases and production is 11 and 8 percent respectively. In contrast, the average volatility of investment prices is only two percent. Edgerton (2010) argues that, on its face, this observation alone suggests that the supply of investment goods is highly elastic.

Second, while domestic production exceeds purchases for the entire sample period, the gap between the two is gradually closing. As U.S. manufacturing has declined, domestic firms have become more and more reliant on imported capital goods.

Third, there is a dramatic transitory downward spike in the relative price in the early-mid 1970's. This spike is associated with a sharp increase in world oil prices at the same time. Following the increase in oil prices, the Personal Consumption Expenditure (PCE) price series used to construct relative investment-goods prices reacts rapidly while the investment price indices react with a modest delay. This might be because oil prices are passed through directly to gasoline prices, which receive substantial weight in the PCE deflator. The timing of price increases across goods was also likely affected by the Nixon price controls. We address both oil price variation and the Nixon price controls in the econometric specification.

B. Investment Tax Subsidies

Tax policy affects the after-tax purchase price of investment goods via depreciation allowances, the investment tax credit, and tax rates. Building on the framework of Hall and Jorgenson (1967) and using data provided by Dale Jorgenson, we define the comprehensive investment tax subsidy as the tax saving per unit of investment goods purchased.[4] Denote the ITC for type *m* capital at time *t* as ITC_t^m. Let z_t^m denote the present discounted value of tax depreciation allowances for type *m* capital purchased at time *t*. That is, if $1+i_t$ is the gross nominal interest rate and $\left\{D_{j,t}^m\right\}_{j=1}^R$ is a sequence of tax depreciation deductions for a unit of type *m* capital with a tax life of *R* periods, then

$$z_t^m = \sum_{j=1}^{R} \frac{D_{t,j}^m}{\prod_{s=0}^{j-1}\left(1+i_s\right)} \quad . \tag{1}$$

The comprehensive subsidy ζ_t^m is then

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[4] The original annual data on the ITC and the discounted value of depreciation deductions are available from Jorgenson and Yun (1991). We are grateful to Dale Jorgenson and Jon Samuel for providing updates to these data. To match the frequency of our data on investment and investment prices, we construct a quarterly version of these data using the historical record of investment tax changes, some of which have effective dates that do not correspond to calendar years. See Appendix A for further details.

$$\zeta_t^m = ITC_t^m + \tau_t^\pi z_t^m . \tag{2}$$

This measure assumes that the firm writes off depreciation deductions against the corporate tax rate τ_t^π.[5]

Tables 1A and 1B list the average value of the comprehensive subsidy for each investment category. The comprehensive subsidy can change for a variety of reasons. Changes (or expected changes) in nominal interest rates, changes in depreciation schedules or changes in the corporate tax rate can all cause changes in ζ_t^m. The dependence of the comprehensive subsidy on the corporate tax deserves special mention. Notice that the value of the subsidy increases with τ_t^π since the firm is writing off depreciation against the corporate income tax rate. It is not necessarily true however, that an increase in τ_t^π will lead to an increase in investment demand. While the effective subsidy to new capital has gone up, the value of the capital itself may have gone down.

Mapping the comprehensive subsidy into the decisions problem of the firm yields an alternative formulation that has been used in the literature. If there were no change in the price of capital over time, the firms' first order condition for capital implies that firms would invest to the point at which the after-tax marginal product of capital is equal to the tax-adjusted user cost of capital. In such a situation, the first order condition for type *m* capital would require

$$MP_t^{k,m} = p_t^m \left(r + \delta\right) \times \frac{1 - \zeta_t^m}{1 - \tau_t^\pi}, \tag{3}$$

where $MP_t^{k,m}$ is the marginal product of type *m* capital and p_t^m is the real relative price of type *m* capital. Because the "normal" user cost is simply the term $p_t^m \left(r + \delta\right)$ in equation (3), we refer to this measure as the tax adjustment to the user cost.[6] For comparability with the investment tax credit ITC_t^m and the comprehensive subsidy ζ_t^m, we reverse the sign so that an increase in this

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[5] Several details of tax policy affect the calculation of the comprehensive subsidy. First, how the ITC affects the basis for depreciation has changed over time. Additionally, since 2002, there has been "bonus depreciation" that allows immediate write-off of some types of investment in varying amounts. Our implementation of z_t^m includes an adjustment for how the ITC affects the basis and for bonus depreciation. See Appendix A for details.

[6] Goolsbee (1998) calls this variable simply the "tax term." Note that this specification of the tax-adjusted user cost implicitly adopts the "new view" of corporate profit taxation in which we assume that marginal investment projects are financed with retained earnings and are thus unaffected by taxation of distributed corporate earnings. We will return to this issue in the modeling section below, where we observe that the tax on distributions cancels from the relevant first-order conditions. For discussion of this point see Sinn (1991).

measure corresponds to a positive subsidy. More specifically, we denote the tax adjustment to the user cost as Φ_t^m with

$$\Phi_t^m \equiv \frac{\zeta_t^m - 1}{1-\tau_t^\pi} = \frac{ITC_t^m + \tau_t^\pi z_t^m - 1}{1-\tau_t^\pi}. \tag{4}$$

Unlike under the comprehensive subsidy (2), under the tax adjustment to the user cost (4) an increase in the corporate profit tax τ_t^π *reduces* the firm's incentives to accumulate capital. While it enhances the value of the tax subsidy (through the effect on z_t^m) an increase in the corporate profit tax reduces the after-tax marginal product of capital by more.

Figure 3 plots three measures of the investment tax subsidy for general industrial equipment: the comprehensive subsidy (ζ_t^m), the tax adjustment to user cost (Φ_t^m), and the investment tax credit (ITC_t^m). (In the figure, we normalize Φ_t^m so that it begins at 0.) Notice that the three measures exhibit similar movements over time. Changes in the ITC were made at the same time as changes in tax depreciation rates and changes in the tax rate on corporate profits. While the overall time series variation is similar across the three measures, it is not identical. For instance, while the ITC has been zero since the Tax Reform Act of 1986, there are nevertheless significant changes in the comprehensive investment tax subsidy. These changes arise from changes in tax depreciation and changes in nominal interest rates, both of which factor directly into the computation of the comprehensive subsidy.

Figure 4 plots the comprehensive subsidy ζ_t^m for all of the investment types in our dataset. Notice that, in addition to the time series variation shown in Figure 3, there is also a substantial amount of variation across capital types. One particular event which featured pronounced cross sectional differences in tax treatment was the so-called "bonus depreciation" allowance introduced in 2002. This policy can be seen clearly in Figure 4 as a sudden change in investment tax incentives for a few types starting in 2003. See House and Shapiro (2008) for discussion of this policy.

C. Aggregate Data

In addition to the type-specific data on investment, investment prices and investment tax subsidies, we also make use of several aggregate data series. Specifically, we use data on real GDP, real oil prices and dummy variables for the Nixon price controls. Quarterly data on real GDP are from the BEA. To construct real oil prices, we average the monthly spot oil price (West Texas Intermediate) to construct a quarterly nominal series. We then take the ratio of the quarterly oil price to the PCE deflator for non-durables. Finally, the Nixon price controls were part of the Economic Stabilization Program and went into effect on August 15, 1971 and were removed on April 30, 1974.[7] The price controls play a non-trivial role in price data for that period. We accommodate this policy with dummy variables. Given the timing of the legislation, our dummy variable for the Nixon price controls takes the value 0.6 for 1971:3 and 1.0 for 1971:4 to 1974:1.[8]

IV. REDUCED-FORM EFFECTS OF INVESTMENT TAX SUBSIDIES

This section presents reduced-form empirical results. We begin in section 4.1 by discussing our basic regression specification. In section 4.2 we present the main estimates. The reduced-form coefficients later serve as a basis for the structural estimate of the supply elasticity of foreign equipment used in the quantitative model.

A. Econometric Specification

We estimate the effects of investment tax subsidies on the production and purchases of investment goods, their prices, imports and exports of capital goods as well as variables that reflect producer activity including employment, payroll, production employees, production hours, production wages, TFP, inventories, the cost of materials and the cost of energy used by producers. We present pooled OLS results to paint a broad picture of how tax subsidies affect the production and purchases of capital goods.

The reduced-form econometric specification we consider is

$$y_t^m = b_1 \cdot \zeta_t^m + b^m\left(t\right) + \Gamma^m \mathbf{X}_t^m + e_t^m \tag{5}$$

where y_t^m are different left-hand-side variables, which may be investment, production, prices, and so on. The index *m* denotes the type of investment good and *t* denotes time. Separate estimates are presented for equipment and structures. The variable $\mathbf{X}_t^m$ is a set of covariates (which could include type-specific data and/or aggregate data) and Γ^m is the associated set of type-specific regressors. For each type, we also include a type-specific time trend given by $b^m\left(t\right)$. The coefficient of interest in equation (5) is b_1. This coefficient, which is constrained to be common across the types of capital goods (thus there is no superscript *m*), describes the average change in the variable of

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[7] Source: National Archives. See http://www.archives.gov/research/guide-fed-records/groups/432.html.

[8] Our dates and the dummy variable specification are the dates used by Goolsbee (1998). Robert J. Gordon (1990) dates the expiration of the price controls as 1974:4.

interest y_t^m associated with changes in the comprehensive investment tax subsidy. It is identified from both the persistent time series variation in tax subsidies and the cross-sectional variation in how the subsidies affect types.

We present results for four different regression specifications with different controls. The first is a parsimonious specification including, in addition to the subsidy itself, only a constant and a linear trend. The second and third specifications include a constant, a time trend and a set of macroeconomic covariates: HP-filtered GDP and dummy variables for years affected by the price controls during the Nixon administration. The third specification includes the real price of oil. The fourth specification uses a linear trend, all macroeconomic covariates, and also includes two lags and two leads of the subsidy variable. This last specification is intended to capture anticipation effects or measurement lags in the data. Because investment and investment policy are highly correlated across time and across capital types, we use the heteroskedasticity and autocovariance consistent estimate of the standard errors proposed by Driscoll and Kraay (1998).

Before proceeding to the results themselves it is appropriate to make a remark about the interpretation of the findings. In particular, we want to be upfront about the potentially important endogeneity problems our estimates face. Investment tax policy in the U.S., while capricious, is not truly econometrically exogenous. To the extent that investment tax incentives react endogenously to economic conditions, as for instance the CARS program did in the Mian and Sufi (2012) study, our results will be biased indicators of the true causal effects of investment tax subsidies. On the other hand, many of the legislative changes to investment tax incentives in our sample were made without direct connection to contemporaneous economic conditions and thus were in a certain sense "exogenous" changes. Appealing to a narrative assessment of the legislation, Romer and Romer (2009) argue that most of the major modifications to tax policy in our sample frame were motivated by long-run concerns (see Appendix Table A.1. for the Romer-Romer classifications). In particular, the motivations explicitly cited by law makers when they expanded investment subsidies in the 1960s and 1970s often centered on increasing long-run growth by encouraging firms to increase and modernize the capital stock. When the subsidies were pared back in the 1980s, the goals were reducing the deficit and eliminating tax distortions.

The historical chronology of the main legislative changes to the investment tax subsidies is presented in Table 2. In addition to providing information about the specifics of the policies driving the measures of tax subsidies, the table provides information about the duration of policy that will inform our simulations. The table lists both changes to the ITC and changes to the treatment of tax depreciation allowances. The table also lists the stated duration and actual duration of the policies. Laws are described as "permanent" if the legislation contained no explicit stipulations of subsequent revisions or sunsets in the policies. That is, if the bill did not include an end-date, it is listed as permanent in the table. Temporary policies have an end-date included in the legislation. The *actual* duration of the policy is measured based on the next legislated change in the tax treatment of investment. We date these policy changes according to the dates when the policies were enacted and not necessarily when they went into effect. Changes to investment tax policy have historically been quite common. Typically the tax treatment of investment changes roughly every two and a half years. Policies with announced end-dates (explicitly temporary policies) are rare, though they appear to be more common in recent history. We do not parameterize the duration of the policy for the reduced-form estimate; the subsidy is simply entered at its current value. Hence, the estimated reduced-form response of variables to the subsidy reflects both the average size of the subsidy and its average expected duration. We revisit the evidence and implications of duration when we turn to the structural estimation and simulation in Sections V and VI.

B. Reduced-Form Estimates

Table 3 reports the reduced-form estimates for how the comprehensive investment subsidies affect the production and purchases of capital goods. Table 4 shows how the subsidy affects equipment prices; employment, hours, wages, TFP, the cost of materials, and the cost of energy in the production of equipment. Table 4 also presents estimates of the effect of subsidies on the production and prices of structures. Both tables include estimates for the four econometric specifications discussed above. The data are as described in Section III and Appendix A. For equipment, the reduced-form estimates use the types in Table 1A excluding computers and software. We exclude computers and software because they have such dramatic changes in prices owing to technological progress. For structures, the reduced-form estimates use the types in Table 1B excluding the three residential types.[9]

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[9] When we turn to the model, all types are included because the general equilibrium model needs to account for all components of investment. See Section V.

Purchases and Production of Capital Goods. Table 3 shows our central reduced-form empirical finding, that the response of purchases of equipment to the comprehensive subsidy ζ_t^m is almost twice as large as the response of domestic production. Looking across the first row, the estimates indicate that a one percentage point investment subsidy is associated with an increase in investment production of between 1.08 and 1.19 percent. The second row reports the estimates for investment purchases. Again, the results are economically significant—a one percentage point increase in the investment subsidy is associated with an increase in investment purchases of between 1.76 and 1.97 percent. The third row of Table 3 reports the differences of the coefficient estimates. For instance, if we focus on the column for the "Macro covariates" specification (column 3) the estimated response of production associated with the comprehensive subsidy is 1.08 while the estimated response of purchases to variations in the comprehensive subsidy is 1.76. That is, for every one percentage point increase in the investment tax subsidy, purchases of investment goods rise by 1.76 percent while domestic production of capital goods increases by only 1.08 percent. The difference between the estimates is 0.68 with a standard error of 0.11, so the difference is strongly statistically significantly different from zero. The covariance of the purchases and production coefficient estimates are strongly positive, so the standard error of their differences is substantially less than the sum of the standard errors. Hence, there is strong evidence of substantial leakage—that is, about half of the stimulus benefits foreign rather than domestic producers.[10]

Equipment Prices. Goolsbee's 1998 paper made a case that one of the main reasons that investment tax incentives were not as effective as one might expect is that much of the subsidies are passed through to capital goods prices. An investment subsidy might bid up prices of capital goods, but not cause increased production. The first row of Table 4 presents estimates of the reaction of equipment prices to the comprehensive subsidy using the same four specifications of covariates as in Table 3. Unlike Goolsbee's estimates, our estimates show little or no price response for equipment. The coefficients estimates are close to zero with fairly tight confidence intervals. From the point of view of basic economic analysis, sensible estimates would be anywhere between 0.00

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[10] These findings carry over to the other measures of investment subsidies as well. For the ITC, depending on the econometric specification, production increases by between 2.09 and 2.91 percent while purchases rise by between 2.94 and 3.31 percent. For the tax adjustment to the user cost (Φ^m) the estimates show a similar pattern though they are less statistically significant. See Appendix Table B.1 for these results.

and 1.00 depending on the duration of subsidy, the supply elasticity, the openness of the economy, and durability of the capital goods.[11] As we emphasize in this paper, the open economy channel substantially attenuates the price response. This analysis contrasts with Goolsbee's closed-economy, inelastic supply analysis and findings.

We have made considerable efforts to explain the difference between our findings and the findings in Goolsbee's earlier paper. The two sets of estimates differ both in sample period (Goolsbee's sample was 1962–1988 while we use data from 1959–2009) and in the vintage of the data—that is, the data have been updated and revised substantially since Goolsbee's original paper was published. Both factors contribute to the different results. Appendix B presents a detailed comparison between our findings and Goolsbee's results. In brief, we can replicate Goolsbee's results for his estimation period using vintage data. The main reason for differences between our results and his is that we study a longer, more recent sample period and the data have been revised.

Employment, Wages, Inputs and Productivity of Equipment Producers. Another way to quantify the effects of investment tax subsidies is to examine the productive inputs of capital producing firms. The second three rows of Table 4 report results for employment, hours and wages of production workers in equipment-producing firms. Consistent with the results from Table 3, employment and hours are positively associated with high investment subsidies. The response of employment and hours to the subsidy are strong, but consistently less than the response of production. This finding is consistent with short-run increasing returns to labor, an issue we will return to in the model section.

Wages at equipment-producing firms also increase with investment subsidies. Goolsbee (1998) also emphasizes this point and our updated estimates agree with his earlier results. Note that the response of wages, however, is imprecisely estimated, and unstable across specifications.

Table 4 shows additional measures of production activity at equipment-producing firms. Consistent with earlier results, materials costs, energy costs and measured total factor productivity all rise in response to investment subsidies, which suggests that these firms do actively expand production of capital goods. A one percentage point investment subsidy is associated with an

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[11] The standard neoclassical theory of investment demand predicts that, particularly for temporary investment subsidies, capital goods prices must rise nearly one-for-one with the subsidy regardless of the elasticity of supply. Thus, observing sharp price increases following an investment subsidy does not suggest that the policy has little effect. See House and Shapiro (2008) for extended discussion of this point.

increase in measured TFP of about 1/3 percent. Materials inputs increase roughly one-for-one with the subsidy. The response of energy is imprecisely estimated. Overall, these responses are consistent with an increase in production of capital goods. The increase in measured productivity suggests that firms are varying unmeasured inputs in addition to measured factor inputs such as worker effort.

Investment Subsidies and Structures Investment. While much of the existing literature focuses on investment in equipment, U.S. tax policy also provides varying incentives for purchases of business structures. Importantly, the neoclassical theory of investment suggests that structures investment should be much more sensitive to predictable variations in its after-tax price than equipment investment (see House and Shapiro 2008). Unlike equipment investment, there is essentially no difference between domestic purchases and domestic production of business structures (i.e., there are no imported structures to speak of).

The last two rows of Table 4 present estimates on the effect of investment subsidies for investment in business structures. As we found with the effects of subsidies on purchases and production of equipment, purchases (identically production) of structures respond to variations in investment tax incentives. For a one percentage point investment tax subsidy, structures investment rises between one-half and 1 percent. Unlike the findings for equipment, there is evidence that structures prices do respond strong to investment tax incentives though there is substantial variation in the estimates across econometric specifications.

Although investment subsidies for structures are generally lower than subsidies for equipment, and notably structures do not receive the ITC, the estimated effects are sizeable. Overall, the reduced-form estimates for structures are larger than the estimates for equipment. This pattern could be generated by a variety of factors. First, equilibrium complementarities between equipment and structures may cause structures investment to rise when tax policies stimulate investment in equipment. Second, changes in tax depreciation allowances, which directly affect structures, are correlated with changes in the ITC. The most prominent example is the Tax Reform Act of 1986, which both repealed the ITC and dramatically limited accelerated depreciation. Many other legislative changes modified both forms of tax incentives in the same direction (see Table 2). Lastly, structures have low rates of economic depreciation, which implies high intertemporal elasticities of substitution. As a result, structures investment is more sensitive to changes in the after-tax price of capital.

V. QUANTITATIVE MODEL

In this section we present a quantitative dynamic general equilibrium model that captures the key features observed in the reduced-form relationships between investment subsidies and the production and purchases of capital goods. To capture the heterogeneity in production, use, and tax treatment of capital, the model has *M* capital-producing industries matching the level of detail in Section IV. The model has a single industry that produces the numeraire good *Q*, which can be used for consumption, government purchases, material inputs, or exports. The model features variable effort and capital and labor adjustment costs in all sectors. Labor income, dividends and profits are subject to distortionary taxes, while investment receives subsidies. Equipment and the numeraire good can be traded internationally. We impose period-by-period balanced trade, which requires that trade in equipment is accompanied by offsetting trade flows of the numeraire good.[12] Structures are not traded, so the production and investment in structures are equal. We use the model to estimate the supply elasticity of foreign equipment using an indirect inference procedure that targets the reduced-form empirical results in section IV. We then use the model to quantify the aggregate effects of investment tax policy.

A. Households

The representative household consumes the non-durable final good, supplies labor and effort on the job, saves at the risk-free rate, pays taxes and owns the capital stock. The household derives utility from consumption and disutility from labor and effort. Its flow utility function is

$$U\left(C_t, L_t, e_t^1, \ldots, e_t^M, e_t^Q\right) = \frac{C_t^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \phi \frac{L_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} - \psi\left(e_t^Q n_t^Q + \sum_{m=1}^{M} e_t^m n_t^m\right) \tag{6}$$

where

$$L_t = \left[a^Q \left(n_{t+j}^Q\right)^{1+\psi_n} + \sum_{m=1}^{M} a^m \left(n_{t+j}^m\right)^{1+\psi_n}\right]^{\frac{1}{1+\psi_n}} \tag{7}$$

is a labor index that aggregates work over the *M*+1 sectors with the constant elasticity of substitution (CES) form. Total hours spent working is denoted by

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[12] We suppress international borrowing and lending primarily for simplicity. Whether we allow international borrowing has little effect on the structural estimate of the supply elasticity of foreign investment goods, but it does matter for the timing of the model-implied aggregate effects of stimulus policy. We report results allowing for international borrowing and lending in Appendix E. See also the discussion of the policy simulations in Section VI .

$$N_t = n_t^Q + \sum\nolimits_{m=1}^{M} n_t^m \, . \tag{8}$$

The elasticity of labor substitution in equation (7) across sectors is ψ_n. If $\psi_n > 0$, then there is limited substitutability of labor across sectors. We introduce this form of labor specificity as a realistic device for specialization in labor that limits the flexibility in changing the composition of output. It thus limits the response to an investment tax subsidy. Indeed, a permanent investment tax subsidy will drive a permanent wedge between wages in subsidized and not-subsidized sectors. This specification also nests the special case when $\psi_n = 0$, where the household supplies labor to each sector symmetrically. The household spends n_t^m hours working in each capital-producing sector *m* and n_t^Q hours working in the final goods sector. For each hour of labor, the household receives pre-tax real wages W_t^m and W_t^Q in the capital industries and the numeraire sector, respectively.

We choose parameters to ensure that, in the steady state, the CES labor aggregate and total hours are equivalent, i.e. $L = N$. This relationship is obtained by choosing the constant terms a^Q, a^m in (7) such that $a^m = (n^m / N)^{-\psi_n}$ for $m = 1,...,M$. We introduce variable effort, a margin of adjustment that makes supply more elastic. Effort in each capital-goods producing sector *m* is denoted by e_t^m and e_t^Q indicates effort in the numeraire sector. Each hour of effort entails a utility cost of ψ to the representative household.

To summarize, each period the household seeks to maximize its expected discounted utility

$$E_t \left[\sum_{j=0}^{\infty} \beta^j \left\{ \frac{C_{t+j}^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \phi \frac{L_{t+j}^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} - \psi \left(e_{t+j}^Q n_{t+j}^Q + \sum_{m=1}^{M} e_{t+j}^m n_{t+j}^m \right) \right\} \right] \tag{9}$$

subject to the budget constraint

$$\begin{aligned} &\left(1-\tau^N\right)\left[W_t^Q n_t^Q + \sum_{m=1}^{M} W_t^m n_t^m\right] + \left(1-\tau_t^d\right)\left(1-\tau_t^\pi\right)\sum_{m=1}^{M} R_t^m K_t^m + T_t + S_{t-1}\left(1+r_{t-1}\right) \\ &\qquad = C_t + S_t + \left(1-\tau_t^d\right)\sum_{m=1}^{M} P_t^m\left[1-\zeta_t^m\right]\left(I_t^m + IMP_t^m\right), \end{aligned} \tag{10}$$

and the capital accumulation constraints

$$K_{t+1}^m = K_t^m\left(1-\delta^m\right) + I_t^m + IMP_t^m \tag{11}$$

and the definition of L in equation (7). The representative household owns the capital stock K_t^m for all types $m = 1,...,M$. The household may purchase new capital from domestic producers I_t^m or from foreign importers IMP_t^m. The pre-tax price of type *m* capital in units of the numeraire good at date *t* is P_t^m. The pre-tax real rental price of type *m* capital is R_t^m. Each type of capital has a type-specific depreciation rate δ^m. In addition to investing in physical capital, the household saves in bonds S_t, which earn the net real safe rate of return r_t.

One of the key features of the model is its realistic treatment of tax policy, which allows us to analyze the aggregate effects of investment tax incentives once we estimate the structural parameters. Purchases of capital goods receive type-specific investment subsidies. The comprehensive investment tax subsidy for type *m* at date *t* is ζ_t^m. Capital income is taxed twice—once at the profit tax rate τ_t^π and again according to the tax rate on distributed capital earnings τ_t^d. Labor income is taxed at the constant rate τ_t^N. In addition to the distortionary taxes τ^N, τ_t^d and τ_t^π, the government also remits excess revenue to the household through a lump-sum transfer (or tax) T_t.

The solution to the household's optimization problem requires the following first order conditions,

$$W_t^m = \frac{C_t^{\frac{1}{\sigma}}}{1-\tau^N}\left[\phi L_t^{\frac{1}{\eta}}\left(\frac{L_t}{L}\right)^{-\psi_n}\left(\frac{n_t^m}{n^m}\right)^{\psi_n} + \psi e_t^m\right], \tag{12}$$

$$C_t^{-\frac{1}{\sigma}} = \beta\left(1+r_t\right)E_t\left[C_{t+1}^{-\frac{1}{\sigma}}\right], \tag{13}$$

$$q_t^m = \beta E_t\left[C_{t+1}^{-\frac{1}{\sigma}}\left(1-\tau_{t+1}^\pi\right)\left(1-\tau_{t+1}^d\right)R_{t+1}^m + q_{t+1}^m\left(1-\delta^m\right)\right] \tag{14}$$

$$q_t^m = C_t^{-\frac{1}{\sigma}}\left(1-\tau_t^d\right)P_t^m\left[1-\zeta_t^m\right]., \tag{15}$$

Equation (12) is the household's labor supply condition for sector *m* (abusing notation somewhat, we have implicitly included the first order condition for $m = Q$ in equation (12) as well). This equation serves as the wage-effort menu faced by the firms. Equation (13) is the stochastic Euler equation. Equation (14) is the shadow value of type *m* capital and equation (15) is investment demand for type *m* capital (either imported or domestically produced).[13]

B. Firms and Production

Aggregate Capital Services. The individual capital types $m = 1,...M$ owned by the household are aggregated to produce a single capital input. The aggregate capital good is denoted by H_t and is produced according to the Cobb-Douglas production function

$$H_t = \left(\prod_{m=1}^{M} {\gamma_m}^{-\gamma_m} \right) \left(\prod_{m=1}^{M} \left(K_t^m \right)^{\gamma_m} \right). \tag{16}$$

We assume that $\sum_{m=1}^{M} \gamma_m = 1$ so the production of the aggregate capital good has constant returns to scale. Firms that produce the capital aggregate sell the aggregate good for a rental price R_t and pay type-specific rental prices R_t^m. Each period these firms choose a combination of type-specific capital inputs $\left\{ K_t^m \right\}_{m=1}^{M}$ to maximize profits

$$R_t H_t - \sum_{m=1}^{M} R_t^m K_t^m \tag{17}$$

subject to the production function (16). The first order condition for the choice of K_t^m is

$$R_t \gamma_m \frac{H_t}{K_t^m} = R_t^m . \tag{18}$$

The scalar term $\prod_{m=1}^{M} {\gamma_m}^{-\gamma_m}$ in (16) ensures that the rental price for the capital aggregate is a weighted average of the rental prices of the type-specific rental prices. In equilibrium profits are zero for these firms.

The Numeraire Good. The numeraire good can be used either as the final consumption good, government purchases, payment for purchases of imported capital goods or as material input for the capital goods industries. The numeraire good is produced with aggregate capital h_t^Q, labor n_t^Q and effort e_t^Q. The output elasticity of effort is given by the parameter *θ*. The production function for the numeraire good is

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[13] If the distribution tax were to remain constant over time (as we assume in the analysis below), then the tax-adjusted user cost expression in the steady state is given by equation 3. That is, the distribution tax cancels from the first-order condition under the "new view" of dividend taxation.

$$Q_t = A\left[h_t^Q\right]^{\alpha}\left[\left(e_t^Q\right)^{\theta} n_t^Q\right]^{1-\alpha}. \tag{19}$$

The producers of the numeraire good rent capital and labor and choose effort to maximize their discounted profits

$$E_t\left[\sum_{j=0}^{\infty}\beta^j C_{t+j}^{-\frac{1}{\sigma}}\left\{Q_{t+j} - W_{t+j}^Q n_{t+j}^Q - R_{t+j}h_{t+j}^Q - \frac{\xi^n}{2}n_{t+j-1}^Q\left(\frac{n_{t+j}^Q - n_{t+j-1}^Q}{n_{t+j-1}^Q}\right)^2 - \frac{\xi^h}{2}h_{t+j-1}^Q\left(\frac{h_{t+j}^Q - h_{t+j-1}^Q}{h_{t+j-1}^Q}\right)^2\right\}\right] \tag{20}$$

subject to the production function (19) and the wage-effort supply schedule (12). The parameters ξ^n and ξ^h are adjustment cost parameters for labor and capital. It is important to note that in a multi-sector model adjustment costs act through two distinct channels: they temper both the intertemporal substitution and the reallocation of capital and labor inputs across sectors.

Firms may ask workers to provide additional effort but doing so requires a higher wage. Note that, as long as the elasticity of effort in production is below unity ($\theta < 1$), the firm's demand for additional effort will be bounded. Another interpretation of effort input, which is effectively equivalent with the specification we adopt in this paper, is overtime to extend the work week. In this case, the elasticity of effort θ represents the shift premium households require to compensate them for working outside standard work hours. Including effort as a separate input allows measured TFP to increase in response to investment tax incentives, as it does in the data. This simple specification imparts realism to the model, but as we show in Section VI below, it remains somewhat limited in its ability to match the magnitude of the measured response of TFP in our reduced-form estimates.

The solution to the firm's optimization problem requires the following first order conditions,

$$\xi^h\left(\frac{h_t^Q - h_{t-1}^Q}{h_{t-1}^Q}\right) = \left[\alpha\frac{Q_t}{h_t^Q} - R_t\right] + \beta E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\frac{1}{\sigma}}\frac{\xi^h}{2}\left(\frac{h_{t+1}^Q - h_t^Q}{h_t^Q}\right)\left(\frac{h_{t+1}^Q + h_t^Q}{h_t^Q}\right)\right], \tag{21}$$

$$\xi^n\left(\frac{n_t^Q - n_{t-1}^Q}{n_{t-1}^Q}\right) = \left[(1-\alpha)\frac{Q_t}{n_t^Q} - W_t^Q\right] + \beta E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\frac{1}{\sigma}}\frac{\xi^n}{2}\left(\frac{n_{t+1}^Q - n_t^Q}{n_t^Q}\right)\left(\frac{n_{t+1}^Q + n_t^Q}{n_t^Q}\right)\right], \tag{22}$$

and

$$\psi n_t^Q = C_t^{-\frac{1}{\sigma}}\left(1-\tau^N\right)\theta\left(1-\alpha\right)\frac{Q_t}{e_t^Q}. \tag{23}$$

Equations (21) and (22) are the firm's intertemporal demand curves for capital and labor respectively. Equation (23) gives the firm's demand for effort. This condition says that the firm's choice of effort balances the after-tax marginal benefit of additional effort (the left-hand-side) with the marginal cost of additional effort (the right-hand-side). Not surprisingly, demand for effort is an increasing function of the marginal product of labor.

Domestic Capital Producers. Each type of capital is produced with units of the capital aggregate h_t^m, labor n_t^m, effort e_t^m and materials x_t^m (units of the numeraire good). The production function for each type of capital is

$$I_t^m = B^m\left\{\mu_x\left(x_t^m\right)^{\frac{\rho-1}{\rho}} + \left(1-\mu_x\right)\left[\left(h_t^m\right)^{\mu_h}\left(e_t^m\right)^{\theta\left(1-\mu_h\right)}\left(n_t^m\right)^{\left(1-\mu_h\right)}\right]^{\frac{\rho-1}{\rho}}\right\}^{\frac{\rho}{\rho-1}} \tag{24}$$

where B^m is a scalar and the parameter μ_x governs the share of materials in production. The capital producers maximize the expected discounted value of profits,

$$E_t\left[\sum_{j=0}^{\infty}\beta^j C_{t+j}^{-\frac{1}{\sigma}}\left\{P_{t+j}^m I_{t+j}^m - W_{t+j}^m n_{t+j}^m - x_t^m - \frac{\xi^n}{2}n_{t+j-1}^m\left(\frac{n_{t+j}^m - n_{t+j-1}^m}{n_{t+j-1}^m}\right)^2 - \frac{\xi^h}{2}h_{t+j-1}^m\left(\frac{h_{t+j}^m - h_{t+j-1}^m}{h_{t+j-1}^m}\right)^2\right\}\right] \tag{25}$$

The first order conditions for the optimal choices of x_t^m, n_t^m, h_t^m and e_t^m are

$$1 = P_t^m\mu_x\left(B^m\right)^{\frac{\rho-1}{\rho}}\left(\frac{I_t^m}{x_t^m}\right)^{\frac{1}{\rho}}, \tag{26}$$

$$\xi^n\left(\frac{n_t^m - n_{t-1}^m}{n_{t-1}^m}\right) = \left[P_t^m MP_t^{n,m} - W_t^m\right] + \beta E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\frac{1}{\sigma}}\frac{\xi^n}{2}\left(\frac{n_{t+1}^m - n_t^m}{n_t^m}\right)\left(\frac{n_{t+1}^m + n_t^m}{n_t^m}\right)\right], \tag{27}$$

$$\xi^h\left(\frac{h_t^m - h_{t-1}^m}{h_{t-1}^m}\right) = \left[P_t^m MP_t^{h,m} - R_t\right] + \beta E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\frac{1}{\sigma}}\frac{\xi^h}{2}\left(\frac{h_{t+1}^m - h_t^m}{h_t^m}\right)\left(\frac{h_{t+1}^m + h_t^m}{h_t^m}\right)\right], \tag{28}$$

and

$$\psi n_t^m = C_t^{-\frac{1}{\sigma}}\left(1-\tau^N\right)\theta\left(1-\mu\right)\frac{P_t^m I_t^m}{e_t^m}. \tag{29}$$

The marginal product of capital and the marginal product of labor are given by

$$MP_t^{m,h} \equiv \mu_h \left(1-\mu_x\right)\left(B^m\right)^{\frac{\rho-1}{\rho}} \left(\frac{I_t^m}{U_t^m}\right)^{\frac{1}{\rho}} \frac{U_t^m}{h_t^m}, \tag{30}$$

and

$$MP_t^{m,n} \equiv \left(1-\mu_h\right)\left(1-\mu_x\right)\left(B^m\right)^{\frac{\rho-1}{\rho}} \left(\frac{I_t^m}{U_t^m}\right)^{\frac{1}{\rho}} \frac{U_t^m}{n_t^m}, \tag{31}$$

where $U_t^m \equiv \left(h_t^m\right)^{\mu_h} \left(e_t^m\right)^{\theta(1-\mu_h)} \left(n_t^m\right)^{(1-\mu_h)}$. Equations (26), (27) and (28) are the firm's demand curves for materials, labor hours and the aggregate capital input, respectively. Equation (29), which is analogous to (23), is the firm's effort demand curve.

Imported Capital. To avoid having to specify the rest of the world in detail, we model the international trade margin with an investment import supply curve. We assume that in the initial non-stochastic steady state, there are no imported capital goods. The parametric form for the import supply curve is

$$IMP_t^m = \overline{I}^m \left[\left(\frac{P_t^m}{P^m}\right)^{\chi} - 1\right] \tag{32}$$

where $\overline{I}^m$ is the amount of type *m* capital produced in the steady state and χ is the import supply elasticity. If $\chi = 0$ then the model collapses to a closed economy with no interaction with foreign capital importers. If $\chi = \infty$ then the model becomes a "small open economy" with regard to the capital goods markets. In this latter case, the domestic price of capital goods will be pinned down by the import prices. The parameter χ combines the supply elasticity of foreign producers and the demand elasticity of foreign buyers. A domestic investment subsidy increases domestic demand for capital and results in higher prices. Higher prices should increase foreign production of capital goods, but it should also decrease foreign purchases. The net effective foreign supply includes both effects.

It is interesting to ask why the share of imported capital has gone up so dramatically. Changes in trade policy no doubt play a role as does increased globalization overall. The growth in trade in the long run is captured by time trends in our reduced form estimates. The elasticity χ

governs the effects of investment subsidies on trade at the margin, which is what is relevant for our analysis.

Trade Balance. For simplicity and transparency, we assume period-by-period trade balance, so exports of the numeraire good increase to balance imports of equipment goods and vice versa. Our analysis—focused on a relatively small equipment goods sector—has little to say about the extent to which international borrowing and lending changes in response to fiscal shocks. Instead, Appendix E presents a variant of the model that allows for different extents of international borrowing and lending and allows us to evaluate the robustness of our findings with respect to the behavior of the trade balance across time.

C. Resource Constraints and Real GDP

The total amount of the numeraire good is used for either consumption of the final good, materials inputs for the capital producers, government purchases or payment for imported capital goods from abroad. The resource constraint for the numeraire good is

$$Q_t = C_t + X_t + \sum_{m=1}^{M} P_t^m IMP_t^m + G_t . \tag{33}$$

Aggregate capital and materials must satisfy

$$H_t = h_t^Q + \sum_{m=1}^{M} h_t^m \tag{34}$$

and

$$X_t = \sum_{m=1}^{M} x_t^m . \tag{35}$$

Real gross domestic product (GDP) is the sum of all final goods and services produced in a given period evaluated at the steady state pre-tax prices. We let Y_t denote real GDP. Thus,

$$Y_t = C_t + \sum_{m=1}^{M} P^m \left[I_t^m + IMP_t^m \right] + G_t . \tag{36}$$

Note that $I_t^m + IMP_t^m$ is total investment purchases (production plus imports). Because the model assumes period-by-period balanced trade, there is no net export term in (36). While equipment can be imported, equal exports of the numeraire good are offered in exchange.

D. Exogenous Processes

To close the model, we need to specify the stochastic process for the tax policy variables. This plays two roles in the analysis below. First, we need an empirical process for the estimation of structural parameters. Second, we consider alternative processes for simulating the effects of tax policies. Let

$$\Xi_t = \left[\tau_t^{\pi}, \zeta_t^{1}, \ldots, \zeta_t^{M}\right]' \tag{37}$$

denote the vector of exogenous tax variables at date *t* where τ_t^{π} is the tax rate for corporate profits and ζ_t^{m} is the comprehensive investment tax subsidy for type *m* capital. We assume that the law of motion for Ξ_t is given by

$$\Xi_t = \bar{\Xi}_t + \tilde{\Xi}_t \tag{37}$$

where $\tilde{\Xi}_t = \left[\tilde{\tau}_t^{\pi}, \tilde{\zeta}_t^{1}, \ldots, \tilde{\zeta}_t^{M}\right]'$ is the percent deviation of the tax variables from a time varying trend $\bar{\Xi}_t$. We assume that $\tilde{\Xi}_t$ follows a VAR process

$$\tilde{\Xi}_t = \Lambda \tilde{\Xi}_{t-1} + \boldsymbol{\varepsilon}_t, \tag{38}$$

where $\boldsymbol{\varepsilon}_t$ is a date-*t* vector of structural innovations and $E\left[\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}'\right] = \Omega$ is a variance-covariance matrix.

For the indirect inference estimation, we assume that Λ is diagonal with an autoregressive root $\lambda < 1$ that is equal across types of capital. The time varying trend $\bar{\Xi}_t$ is a step function with a single break occurring at the 1986 tax reform. Hence, $\bar{\Xi}_{t \leq 1986}$ is set equal to the average value of the tax variables prior to 1986 and, $\bar{\Xi}_{t > 1986}$ is set equal to the average value of the tax variables after 1986. Thus, agents perceive the majority of the changes in investment subsidies as being transitory. The exception to this is the 1986 tax change which is interpreted as an unanticipated, permanent change. Hence, in the simulations, the tax vector Ξ_t experiences a one-time, unanticipated shift in 1986. Given this specification of shocks, for any given λ we choose the sequence of vectors of structural tax shocks $\boldsymbol{\varepsilon}_t$ to exactly match the observed time paths of the tax rates and investment subsidies, and feed them into the simulations used for the indirect inference.

E. Steady State and Calibrated Parameters

The model is solved using a log linear approximation to the equilibrium conditions in the neighborhood of a non-stochastic steady state. Here we briefly review the parameter choices used and the solution of the steady state.

Non-Stochastic Steady State. We choose the scaling parameters $\phi,\ \psi$ and $B^m = B$ to ensure that $P^m = P = N = e = 1$ in the non-stochastic steady state. Without loss of generality, we express steady state investment in type *m* capital in proportion to type 1. It is easy to show that $I^m = \Psi^m I^1$ where the scaling factors Ψ^m are

$$\Psi^m = \frac{\gamma_m \delta^m}{\gamma_1 \delta^1}\left(\frac{r+\delta^1}{r+\delta^m}\right)\left(\frac{1-\zeta^1}{1-\zeta^m}\right). \tag{39}$$

Additionally, $n^m = \Psi^m n^1$ and $x^m = \Psi^m x^1$ so there is a constant material-to-labor ratio across investment sectors. Similarly, $K^m = (\delta^m / \delta^1)\Psi^m K^1$ and $h^m = \Psi^m h^1$ for all *m*. Additional details on the steady state solution can be found in Appendix C.

Baseline Calibration. Most of the parameters are calibrated to standard values used in the macroeconomic literature on DSGE models. In this subsection, we focus on parameters that are important to the baseline, but not pivotal for the margins of adjustment that are the focus of the analysis. Table 5.A summarizes the baseline values for the calibrated parameters used in the model that are constant across all model simulations. We set the quarterly discount factor β to 0.99 which implies a 4 percent annual real interest rate. The Frisch labor supply elasticity η is set to 0.5, in line with recent estimates (see Farber 2005 and Kimball and Shapiro 2008). We set σ, the elasticity of intertemporal substitution, to 0.2, roughly the average of the estimates in Hall (1988), Campbell and Mankiw (1989) and Barsky, et al. (1997). Based on calculations in House and Shapiro (2008), we set the steady state tax rates to $\tau^N = 0.36$, $\tau^d = 0.30$ and $\tau^\pi = 0.43$ (the tax rate on corporate profits is a time series average of marginal tax rates taken over the sample period).

To calibrate labor's share for the numeraire (*Q*) sector, we take total employee compensation as a fraction of total GDP less proprietors' income. This share has been roughly constant in the post-war period and, using data up to 2009, implies $1-\alpha = 0.62$.[14] This calculation implicitly assumes that proprietors' income is divided proportionally between labor income and capital income.

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[14] See Elsby et al. (2013) for a discussion of recent changes to the U.S. labor's share.

The model has $M = 50$ different types of capital. There are 30 equipment classes and 20 structures classes. (The model includes all types of capital, while the reduced-form estimates exclude computers, software, and residential types.) Together with data on average investment shares (I^m / I^1) and average investment subsidies (ζ^m) we use equation (39) to calculate implied values for γ_m. Tables 1A and 1B lists the capital classes in the model together with their associated depreciation rates, investment shares (as a fraction of total investment) and their average investment subsidies over the sample period.

To calibrate the share parameters μ_h and μ_x we use data on input shares from the NBER productivity dataset. We use the same parameters for structures as for equipment though we have no independent input data for structures to verify our calibration. Relative to labor's share for GDP, labor's share of gross investment output (for equipment production) is quite low and has been falling over the sample period. Averaging over all of the types in our data, labor's share in capital producing industries fell from roughly 20 percent in the late 1960's to roughly 9 percent by 2009. For purposes of calibrating the model we assume that labor's share of gross output in the capital-producing sectors is 14 percent (roughly the average over all types and time periods). Material's share of gross output is approximately 45 percent.[15] The implied capital share in gross output (Rh^m / I^m) is $1-0.14-0.45=0.41$. In steady state, $Rh^m / Wn^m = \mu_h / (1-\mu_h)$. Using

$$\frac{Rh^m}{Wn^m} = \frac{0.41}{0.14} = 2.93, \tag{40}$$

implies that $\mu_h = 0.75$. We calibrate the parameter μ_x to match the observed materials ratio X^m / I^m given the elasticity of substitution ρ. In the steady state,

$$\mu_x = \left(1 + \left(MC^U \right)^{\frac{1-\rho}{\rho}} \left(\frac{I^m}{X^m} - 1 \right)^{\frac{1}{\rho}} \right)^{-1}. \tag{41}$$

Where $MC^U \equiv \left(1-\mu_h\right)^{\mu_h - 1} \left(\mu_h\right)^{-\mu_h} W^{1-\mu_h} R^{\mu_h}$ is the "marginal cost" of U^m. For each substitution parameter ρ, we set μ_x according to (41) to match a materials-to-investment ratio $X^m / I^m = 0.45$. For our baseline calibration we set $\rho = 0.01$, which implies that there is essentially no substitution

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[15] We include energy in total material inputs. Energy is a very small fraction of gross investment output, roughly 1 percent.

between materials and the input composite U_t^m (for this value of ρ, the implied calibration for μ_x is extremely small).[16]

Calibrations Affecting Domestic Adjustment. Several parameters directly affect the elasticity of domestic supply. Because of how they interact with the estimated import supply elasticity, we will consider estimates of model parameters under alternative calibrations of these parameters. Table 5.B shows the baseline and alternative values of these parameters.

The labor and capital adjustment cost parameters ξ^n and ξ^h are calibrated using combined evidence from several different studies. Caballero and Engel (1993) use data on gross and net employment flows for U.S. manufacturing from the Bureau of Labor Statistics. They estimate an annual quadratic adjustment cost parameter of 0.53 for net flows and 0.28 for gross flows, although they prefer a specification with fixed costs.[17] Shapiro (1986) estimates employment adjustment costs of 0.23–0.34 for non-production workers, and zero for production workers. If we take 0.25 as a representative estimate, the corresponding quarterly adjustment cost is 1.0 (four times the annual value). We use $\xi^n = 1.00$ as our baseline calibration.

There is a wide range of estimates of capital adjustment costs in the literature. For our baseline, we use a calibration with moderate adjustment costs—consistent with the moderate (Shapiro 1986) to low (Hall 2004) estimates in the literature. Specifically, we set $\xi^h = 8.00$ for our quarterly model. Following the thought experiment in Hall (2004) this implies that the doubling time for capital in response to a permanent increase in its shadow value is roughly two years (8 quarters).

Given the relatively wide range of adjustment costs estimated in the literature, and that we specify a multi-sector model rather than a single sector like in most of these studies, we also consider how our results change if we adopt lower factor adjustment costs ($\xi^n = 0$ and $\xi^h = 2$) and higher factor adjustment costs ($\xi^n = 4.00$ and $\xi^h = 16.00$), which doubles the adjustment time.

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[16] If we estimate the materials substitution elasticity (ρ) the estimates are pushed to 0.00. We suspect this reflects the fact that there is a high degree of correlation between production and materials throughout the data sample. This estimate echoes a recent finding by Boehm et al. (2014). See also Atalay (2014).

[17] Cooper and Willis (2009) use the empirical results of Caballero and Engel (1993) to estimate a set of structural models with asymmetric labor adjustment costs. Their estimates for the quadratic costs specification are 7.9 for positive adjustment and -0.28 for negative adjustment, however neither coefficient is statistically significant.

The model allows for unobserved effort in production. The magnitude of this effect is captured by the production elasticity of effort θ. In the model, θ must be between 0 and 1. There are few reliable estimates of utilization elasticities that we can turn to.[18] There are some estimates from the DSGE literature on reactions to identified monetary shocks, but these estimates are quite wide and are often estimated to be at on or the other corner of admissible values. For our baseline calibration we will choose the intermediate value $\theta = 0.5$ and consider how our estimates change for higher or lower values.

The final parameter governing the domestic supply of investment is ψ_n which limits the long-run substitution of labor across sectors. $\psi_n = 0$ implies that labor is perfectly substitutable across sectors in the long run. $\psi_n = \eta^{-1} = 2$ implies that each sector has a separate labor supply curve with no possibility of substitution. Our baseline calibration of this parameter is to set $\psi_n = 1.00$, with 0.25 and 1.75 as low and high alternatives.

Persistence of Tax Policy Changes. We also calibrate the (perceived) persistence of policy changes. This persistence is determined by the parameter λ in the transition matrix in (38). If λ is close to 1.00 then tax changes are perceived as permanent in the sense that agents believe that it is equally likely for tax subsidies to increase or decrease in the future. If λ is less than 1.00 then agents interpret changes in tax policy as transitory events which are expected to be undone in the future. It is convenient to discuss this calibration when we discuss introducing the policy shocks into the estimation, so that discussion is deferred to the next section.

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[18] The elasticity is identified by the derivative of the cost of increasing utilization (e.g., the shift premium or incremental depreciation). There are estimates of the *level* of this cost in the literature, but not of its derivative. We are grateful to Susanto Basu for a discussion of this issue.

F. Estimating the Supply Elasticity of Foreign Equipment

Here we estimate the foreign supply elasticity of equipment χ. This structural parameter is of central importance in determining the reactions of domestic production and domestic purchases of equipment to changes in investment tax subsidies.[19] We use an indirect inference approach similar to the one proposed by Gourieroux, Montfort and Renault (1993). Given any value of χ, we simulate the post-war investment paths implied by the model using the observed shocks to investment subsidies and tax rates as forcing variables. We then run regressions of the form (5) for the simulated data and recover the implied reduced-form coefficients. We choose the parameter χ to make the simulated regression coefficients and their reduced-form analogues match as closely as possible.

Simulating the Path of Investment Subsidies in the Post-War Period. To implement the indirect inference, we simulate the model using variation in tax subsidies as the stochastic forcing variation. As is clear from Figure 4, there is substantial variation in tax subsidies both across types and over time (that is, relative to the numeriaire good). We do not include variation in productivity shocks as is conventional in DSGE modeling.[20]

Equation (38) describes the evolution of the exogenous forcing processes. We assume that the tax changes are perceived as autoregressive with common persistence across types, so $\Lambda = \text{diag}(\lambda)$. We construct a path of shocks that generates the investment subsidies and tax rates observed over the time period of our data sample as

$$\boldsymbol{\varepsilon}_t = \tilde{\tilde{\Xi}}_t - \Lambda \tilde{\tilde{\Xi}}_{t-1}. \tag{42}$$

The subsidy and the tax rates are mechanically related to each other (recall (2) and (4)), so we include the exact path of both in the simulation. With the structural innovations, we can simulate the economy's dynamic reaction to the shocks. Note, we do not have to specify the covariance of

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[19] We limit our attention to this parameter for several reasons. It is central for quantitatively distinguishing between production and purchases of capital goods. Moreover, it is sharply identified by the difference in the reduced-form response of production versus purchases to investment subsidies, which is the key empirical finding of the paper. Conversely, while we can estimate other model parameters and have done so in earlier version of this paper, the data and the model are not particularly informative vehicles for estimating them.

[20] As long as technology shocks are uncorrelated with the tax subsidies, including them would not change the average simulated response that we are using for estimation.

the shocks. Instead, since we use the actual realization of the shocks in the estimation, the simulation exactly reflects the strong common movements of tax rates and investment subsidies.

We calibrate λ to 0.9167, which, in our quarterly model, corresponds to a three-year expected duration of tax changes. This expected duration is roughly in line with the evidence in Table 2 on the frequency of tax changes. The alternative values of 0.8750 and 0.9375 correspond to two and four-year expected durations. The expected duration of the investment subsidy powerfully affects how much it increases investment, with shorter durations leading to larger increases in investment as firms take advantage of the temporary reduction of the cost of durable investment. This parameter therefore has a considerable effect on the magnitude of response to a policy shock.

Indirect Inference. To implement the indirect inference, we simulate the path of endogenous variables given a value of χ and for the path of policy variables as just described. We estimate the reduced-form regressions (5) on the simulated data, which generates the model-implied moments. The indirect inference approach then adjusts the estimate of the model parameter to find the best fit of the model-implied moments with the analogous moments in the data (the "targeted moments"). Specifically, the targeted moments are the estimated coefficients on the comprehensive subsidy (b_1 in equation 5) for five different regressions with the following left-hand-side variables: equipment production, equipment purchases, hours, material inputs, and measured productivity (TFP).[21] Denote the vector of these b_1 estimates as $\hat{\mathbf{b}}^{\text{data}}$ and let $\mathbf{b}(\chi)$ denote the corresponding vector of regression coefficients for the model simulation given a vector of parameters χ.[22] Our parameter estimate $\hat{\chi}$ is the solution to the minimum distance problem

$$\hat{\chi} = \arg\min_{\chi} \left\{ \left[\hat{\mathbf{b}}^{\text{data}} - \mathbf{b}(\chi) \right]' \hat{\Omega}^{-1} \left[\hat{\mathbf{b}}^{\text{data}} - \mathbf{b}(\chi) \right] \right\} \tag{43}$$

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[21] We target equipment production and purchases because their distinct behavior is central to our analysis of subsidies. We also target materials, TFP, and hours because they carry important information about domestic supply elasticity. We do not target wages because it is well understood that measured wage payments may not be allocative on a spot basis (see Basu and House 2017 and the references therein). While we do not target equipment prices and structures prices and quantities we do examine the fit of the model for these untargeted moments (see below).

[22] We use the estimates of $\hat{\mathbf{b}}^{\text{data}}$ from the "macro covariates" columns of Table 3 and 4 in the indirect inference. The trend, oil prices, and Nixon price controls are not generated in the simulations and do not enter as exogenous forcing variables in the model, so we do not attempt to match the coefficients on the control variables (Γ^m in equation 5).

where $\Omega = \mathrm{Var}\left[\hat{\mathbf{b}}^{\mathrm{data}}\right]$. Under the usual conditions, the estimate is asymptotically normally distributed $\hat{\chi} \sim N\left(\chi^{*}, \sigma_{\chi}^{2}\right)$. The estimated variance of the indirect inference estimate is

$$\hat{\sigma}_{\chi}^{2} = \left[\left(\frac{\partial \mathbf{b}(\hat{\chi})}{\partial \chi}\right)\hat{\Omega}^{-1}\left(\frac{\partial \mathbf{b}(\hat{\chi})}{\partial \chi}\right)'\right]^{-1} . \tag{44}$$

Recall that $\hat{\Omega}$ accounts for heteroskedasticity and autocorrelation, so the estimated variance $\hat{\sigma}_{\chi}^{2}$ will also be heteroskedasticity and autocorrelation consistent.

Estimates of model parameters. The indirect inference estimates of the import supply elasticity χ are reported in Table 6. The first column gives the targeted moments previously reported in the third column of Tables 3 and 4, i.e., the reduced-form regression coefficient of the response of the equipment production, equipment purchases, hours, materials, and TFP to the comprehensive subsidy for the "macro covariates" specification. The top row gives the estimates of the import elasticity for the baseline and various alternatives of the calibrated parameters. The rest of the table reports the model-implied moments given the estimated supply elasticity.

There are several noteworthy features of these estimates. First, the estimates for the import supply elasticity are substantial. For the baseline specification, the estimate is 6.53. Inelastic values are far outside of the confidence interval. These estimates suggest that the U.S. faces an elastic international supply of capital goods. While this estimate changes as we change the calibrated parameters, the estimated elasticity is always above 3.

Table 6 also reports the model implied moments for the parameter estimates. Overall the model does a reasonably good job of reproducing the broad features of domestic production of investment equipment. The model matches the key reduced-form finding, that the response of investment production is substantially less than the response of purchases. For the baseline specification and other specifications, the modeled reduced-form coefficients come very close to the 1.08 value in the data. It is instructive to see how the modeled coefficients vary under alternative calibrations.

Policy persistence. The persistence parameter λ controls how much investment demand responds to a policy shock. The lower the persistence, the more demand increases to take advantage of the temporary subsidy. Since the size of the shocks is given by the history of actual policy, low λ implies a bigger increase in investment and vice versa. These outcomes are apparent in the modeled reduced-form estimates (the value of 1.59 in the baseline increases to 1.73 in the low persistence parameterization and decrease to 1.45 in the high persistence parameterization). Implicitly, imports take up more or less of the gap between domestic demand and domestic production. Even though the low persistent calibration fits the equipment investment moment a bit better than the baseline, we prefer the baseline value of λ because its half-life of three years fits our reading of the narrative a bit better than the shorter half-life implied by the low persistence. With the higher increase in demand corresponding to the lower persistence, the estimated import supply elasticity is higher. That is, the model must estimate more responsive imports to accommodate the observed shift in demand.

Margins Affecting Domestic Supply Response. The other alternatives to the baseline shown in Table 6 relate to the elasticity of domestic supply. Higher or lower supply response to effort (θ) imply more or less responsive domestic supply. Higher adjustment costs imply less responsive domestic supply. Higher or lower sectoral labor supply specificity (ψ_n) imply less or more responsive domestic supply. Varying these parameters has the expected effects on the modeled reduced-form coefficients and on the estimate of the supply elasticity.

Other moments. The estimated model does a good job of hitting the targeted moments for hours. There is slight undershooting in the data of the theoretically-mandated one-for-one movement of production and materials, perhaps because of measurement problems. The most substantial discrepancy is for TFP. In the data, measured TFP rises by 0.28 log points for a 1 percentage point investment subsidy. In the model, the effort margin generates a reaction in TFP but it is substantially smaller than the estimate from the actual data.

Non-targeted moments. The model generates predictions for moments that are not targeted in the indirect inference procedure. Appendix Table D.1 shows results. The model predicts substantially larger response of structures than seen in the data. Given that the model leaves out features that make it hard to have structures respond quickly (within a quarter in the model) such as time to plan and time to build, this miss is not surprising or troubling. Similarly, the model implies a larger short-run effect on wages than seen in the data, again presumably because it does include frictions that might keep spot wages from being non-allocative. On the other hand, the model does a remarkably good job of hitting non-targeted movements in prices of capital goods.

VI. SIMULATED RESPONSE TO INVESTMENT SUBSIDIES

We now use the estimated model to quantify the effects of investment tax policies on macroeconomic activity. We consider a policy that returns the ITC to the pre-1986-reform level of 10 percent. Consistent with historical practice, the simulated ITC applies to equipment, but not structures. We consider various scenarios for the expected and actual duration of the policy. For each simulation, we report the effects of the policy on investment (both aggregate and by type), the prices of capital goods, imports of equipment goods and macroeconomic aggregates. The simulation is based on the baseline estimate and calibration as reported in Table 6.

A. Temporary Subsidy with Uncertain Expiration (Baseline case)

For our baseline policy simulation, we consider a policy where the ITC is temporarily set to 10 percent and will sunset with a known probability. In particular, we assume that the sunset is described by a Poisson process with a constant hazard rate per unit time. The hazard rate is chosen to imply an expected duration of 3 years, which corresponds to the baseline value of λ used to generate the parameter estimates for the simulations.[23]

To simulate sample realizations of the policy with constant hazard of return to baseline, we can model the ITC as having an expected path given by an AR(1) as in (38) with the diagonal elements of Λ given by $\lambda = 1-(1/12)$ (implying an expected policy horizon of 12 quarters as long as the policy stays in effect). Each period the policy continues conveys news, so results in a shock to the subsidy relative to its expected path. Thus, each sample path will look like a constant subsidy while the policy is in effect followed by a sudden removal of the subsidy at a random point in time.

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[23] Mertens and Ravn (2012) show how differences in the anticipation, implementation lag, and duration of tax changes affects aggregate economic outcomes (see also Mertens and Ravn 2013). Our approach gives an alternative method for incorporating duration into a DGSE model. Note that our identification comes from the medium frequency and cross-sectional response of variables to tax subsidies. We do not rely on the precise timing of shocks as one might do in a VAR approach. Because of the smoothed and lagged response of investment to changes in policy (owing to adjustment costs, sectoral mobility of factors, anticipation of policy changes, and general equilibrium effects), the impulse response approach to identification may be less fruitful in this context.

Figure 5 shows a set of impulse response paths for several variables in the model under this temporary investment subsidy scenario. The figure depicts a policy that happens to last exactly 3 years—the expected duration of the policy. Again, the exact duration of the policy is unknown at the date the subsidy is introduced and so, much like the policies facing firms in the real world, there is an important element of uncertainty in the simulated tax policy. Figure 5.A reports domestically-produced investment goods for all of the types in the model. The differential response of equipment and structures production can be seen clearly in the figure. Since all types of equipment receive the subsidy, production of all types expand. The expansion is limited by the factor adjustment costs initially, but gradually rises as the subsidy continues. Structures do not receive the subsidy.[24] Production of business and residential structures contracts while the policy is in effect. The cost of producing investment goods has gone up for all types (wages, capital services, and the effective cost of material inputs all rise), so structures production falls. Notice that once the subsidy is removed in period 13, production in the equipment categories does not return to steady state immediately, but instead falls only gradually over time. This is again due to the factor adjustment costs, which keep labor and capital in the equipment-producing sectors temporarily above steady state.

Figure 5.B displays the equilibrium real relative (pre-tax) prices of the capital goods. Again, the differences between equipment and structures are easy to identify. Equipment prices rise immediately and remain high for the duration of the policy. For long-lived capital goods (i.e., capital goods with low depreciation rates) the price increase is on the order of the subsidy itself (see House and Shapiro 2008). Prices fall for the structures. Factor inputs are still attached to these industries because of the adjustment costs and this puts downward pressure on prices while the inputs are gradually reallocated to other sectors.

Figure 5.C shows imported capital goods (total additions to capital for each type is the sum of the lines in the Figure 5.A and Figure 5.C). Obviously, there is no response for structures (the line at zero). Given the imports supply curve (32), the response of imported equipment is simply a scaled-up version of the price response where the scaling factor is the estimated import elasticity (6.53).

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[24] Residential structures get either business or household treatment depending on the form of tenancy. In the simulations, we presume residential treatment on the margin, so they get zero subsidy each period.

Finally, Figure 5.D reports the simulated time paths for GDP, aggregate employment, aggregate consumption, aggregate investment production, aggregate investment purchases, and aggregate investment imports. In the short run, the increased investment is supplied primarily by imports. Only after domestic industries have had the opportunity to respond by expanding their productive capacity does domestic production rise. Notice that despite the large subsidy, the aggregate effects on GDP, employment and consumption are relatively modest. GDP rises by only 0.9 percent by the end of the policy. Employment rises immediately; even though it has adjustment costs, its maximal response is on impact because of the greater quasi-fixity of capital. Investment is a relatively small share of total employment, the subsidy affects only a portion of investment, and much of the short term stimulus is transmitted to foreign rather than domestic firms. All of these features limit the aggregate stimulus from investment tax subsidies.[25] Nonetheless, a one to two percent of GDP effect could be noticeable in aggregate time series and significant as a counter-cyclical policy.

B. Comparison with no trade case

To illustrate the role of trade in the response of the economy to an investment tax subsidy, we compare the responses in the baseline case to a case where trade is shut down. Figure 6 shows the response of GDP, aggregate investment purchases, aggregate investment production, and aggregate imports of capital goods for the baseline specification and for the no trade case to the same temporary shock to investment subsidies illustrated in Figure 5. Because of the more elastic supply of investment goods in the baseline case with international trade, the response of purchases to the tax subsidy is substantially greater on impact in the our model than in the no trade specification. On impact, aggregate purchases of investment goods increase by 15 percent in our model versus 3 percent with no imports. The peak response at quarter 12 (the period before the temporary subsidy has its random termination) is also about 15 percent versus 5 percent for the no trade case.[26]

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[25] Note that aggregate consumption changes only slightly in response to the subsidy. Hence, relaxing the assumption of period-by-period balanced trade would not change the results appreciably.

[26] Aggregate GDP increases substantially more in the baseline case with trade in equipment than in the no-trade alternative. Because of the assumption of period-by-period trade balance, exports of numeraire good expand to pay for the imports of equipment. This finding depends on our specification of period-by-period balanced trade. If there were international borrowing, the increase in exports of numeraire can be spread out over many periods, so GDP rises less immediately, but more later. Appendix E presents simulations under alternative degrees of international borrowing and lending. The degree of borrowing does affect the timing of aggregate GDP substantially, but has little effect on the paper's central results relating to investment production and purchases. See Appendix Figure E1. The central

Interestingly, when the tax subsidy expires, there is a more rapid decline of purchases in our baseline model than in the no trade case. Domestic production has increased by approximately the same amount with and without trade. When the subsidy expires, this above-steady-state capacity to produce equipment leads to exports of equipment. Production also remains high longer because of the ability to sell into international markets. Hence, the presence of an import margin attenuates the stimulus to the overall economy of temporary investment subsidies, but leads to incremental stimulus after the policy has expired.

C. Temporary Subsidy with Alternative Expirations

There are multiple ways to model temporary tax policies. The simulation in Figure 5 is a realistic depiction of actual tax policies recently adopted in the U.S. It combines two distinct effects—the temporary nature of the policy change and the unanticipated expiration of the policy. Here we present two alterative simulations that separate these effects. In Figure 7, we simulate a subsidy that follows an AR(1) process with the same autoregressive coefficient as used in the simulation behind Figure 5. But, unlike Figure 5, the subsidy simply decays at the AR rate and thus gradually declines from 10% to zero. This simulation is instructive, but not realistic. The AR(1) phase out in Figure 7 and the Poisson expiration in Figure 5 have similar patterns during the first 12 quarters except with the AR(1) decay, the magnitudes of the responses are lower because the value of the subsidy is uniformly lower. In both cases, the responses build over time as the capacity to produce equipment gradually increases. Upon expiration of the subsidy (that occurs randomly in Figure 5 at quarter 12), the dynamics look similar, though without the sharp jump. In Figure 5, there is a protracted period of exports of capital goods once domestic production has expanded sufficiently and the subsidy has been removed.

Alternatively, Figure 8 shows a constant subsidy with *known* expiration date at three years from its onset. This case has precedent in actual policy where temporary investment incentives are not uncommon (e.g., bonus depreciation, at least as initially legislated). Because we have calibrated the Poisson hazard (Figure 5) and AR(1) decay rate (Figure 7) and the duration of the policy (Figure 8) to each have an expected duration of three years, each model features the same reaction for all endogenous variables in the period in which the policy is announced and put into effect (the impact period). After the first period, the simulated paths diverge with the known

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empirical finding of the paper, that production versus purchases of equipment move quite differently in response to tax subsidies has little bearing on the extent to which the resulting imports are finance by international borrowing.

temporary subsidy in Figure 8 having larger effects than in the policy where the tax subsidy decays (Figure 7) or gets extended in expectation by a period (Figure 5). The known and increasingly impending expiration in Figure 8 creates an urgency to invest during the known period of the subsidy. This effect is also seen in the prices. With the known, temporary subsidy, they are higher uniformly.

D. Permanent Subsidy

Figure 9 displays the impulse responses for a permanent investment subsidy, that is, a change in the subsidy that is expected to be permanent and actually is so. (It also represents policies that are expected to be temporary, but where the subsequent policy symmetrically increases or decreases the subsidy so that the continuation has the same expected value as the current subsidy. Obviously, the simulated paths would change when the future subsidy actually changes.)

As in Figure 5, there are clearly identifiable differences between equipment and structures. There are several differences between the two figures that deserve emphasis. Notice that in the long run, production of structures increases even though it is not subsidized. This is due to the fact that the capital aggregate (16) is a Cobb-Douglas aggregate over all of the capital types in the model. As a result, if the subsidy encourages firms to increase the total number of units of medical equipment, it is indirectly encouraging firms to increase the total number of hospitals as well (though to a lesser degree). Also, the price responses are not as great as they were in the temporary subsidy. For the permanent subsidy, the policy is anticipated to have a long-run impact on the stock of subsidized equipment. Since the price reflects the present value of the after-tax marginal products of capital, the anticipated increase in the stock of capital implies lower future marginal products and thus relatively lower current prices. Under the temporary policy, the long-run impact on the stock of equipment was not affected as much and so the prices were comparatively high. Finally, the aggregate effects of the permanent subsidy are not as great. Under the permanent subsidy there is no urgency to purchase the capital goods while the subsidy is in place and thus the firms can wait to acquire the goods. This delay—reflected in a smaller price increase—implies that the short-run increase in overall investment production and aggregate employment is somewhat smaller than with a temporary subsidy.

E. Elasticity of Domestic Supply of Investment Goods (Alternative Parameter Values)

The less-than-infinite elasticity of investment supply is the key driver of the analysis. Our model features a number of margins of adjustment that allow domestic production to respond to subsidies.

Of course, the main sources of the finite supply elasticity are the quasi-fixity of capital and the upward sloping supply of labor that are a feature of our DGSE model. These alone, however, will not make supply of investment goods very inelastic because the investment-goods-producing sector is relatively small. So if factors of production are mobile across sectors, production of investment goods could increase in response to tax subsidies with little increase in price.

Factors of production are not, however, very mobile across sectors (Ramey and Shapiro 1998, 2001). Our DGSE model introduces two sources of frictions relating to factor mobility: quadratic costs of adjusting labor and capital and specificity in sectoral labor supply. Working in the opposite direction of increasing elasticity of investment supply, the model allows for an intensity-of-work margin modeled as variable effort. Figure 10 quantifies the importance of these features of the model by showing how different parameter value in the model for these margins of adjustment effect the aggregate outcomes relative to the baseline case. For this exercise, we return to the case of the temporary subsidy with uncertain expected duration. The baseline results are the same as in Figure 5 and 6. Reducing the adjustment cost parameters ξ^n and ξ^h from their baseline values (1 and 8 respectively) to 0 and 2 makes all aggregates more responsive to the subsidy. Reducing the labor specificity parameter ψ^n from its baseline value of 1 to 0.25, in contrast, has little effect.[27] Eliminating the variable effort margin (by setting θ to approximately 0) in contrast considerably decreases the flexibility of domestic supply, so it reduces the expansion of purchase, production, and GDP.

VII. CONCLUSION

Investment tax incentives are used both to encourage capital accumulation in the long run and to stimulate economic activity in the short run. This paper highlights the distinction between the purchase and production of capital goods affected by these tax incentives. It finds that, in response to typical changes in investment tax incentives, only part of the observed increase in investment is met by domestic production. A substantial fraction of the increase in investment demand is met by imports. While investment tax incentives do promote capital accumulation, their ability to stimulate aggregate economic activity—especially in the sectors producing the subsidized capital

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[27] For temporary policies, labor specificity has little effect on the simulated responses. It does have important effects for permanent policies.

goods—is limited to an extent by leakage of the stimulus to foreign producers through imports of capital goods. Hence, the production versus purchases mechanism identified and quantified in this paper is important for understanding the effects of investment tax policy.

Goolsbee (1998) argued that the stimulative effects of investment tax subsidies might be limited because the supply of capital goods was relatively inelastic. The production versus purchases mechanism in our analysis is quite different from the one identified by Goolsbee where investment incentives bid up the prices of capital goods. In our mechanism, the bidding up of prices is limited by foreign supply. Indeed, we do not find evidence that investment subsidies much affect the prices of investment goods in our sample. Using vintage data and his original estimation period, we can partially reproduce the original findings reported by Goolsbee. Hence, the differences in our empirical results for prices reflect changes in the economy since his work and, to an extent, revisions of the data used in the earlier analysis.

How does the economy respond to investment tax subsidies? To answer this question, the paper presents an equilibrium analysis of investment tax incentives. To capture important margins of adjustment across investment sectors and to include a distinction between domestic purchases and domestic production of capital goods, we specify a dynamic stochastic general equilibrium model with capital and labor adjustment costs, variable effort, and international trade in equipment. We estimate parameters of the model using indirect inference based on the reduced-form responses of production, purchases and inputs in the investment sector to investment tax subsidies.

The structural estimates indicate the import supply of equipment is quite elastic and thus the purchase/production distinction that is central to our analysis is quantitatively important. For typical changes in investment incentives, in the short run about half the increase in demand for investment is met by imports over the duration of the change. Moreover, because imports limit the increase in the price of investment goods, an investment tax incentive causes a greater increase in the stock of productive capital relative to an economy where all investment goods were produced domestically. On the other hand, production of domestic capital goods expands less than it would in an economy without international trade in capital goods, so the stimulus of domestic capital producers is less than it would be in the no-trade case during the period of the subsidy. Because capacity has increased, domestic producers export equipment following the expiration of the subsidy.

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FIGURE 1. EXPORTS AND IMPORTS OF CAPITAL EQUIPMENT, RELATIVE TO EQUIPMENT INVESTMENT

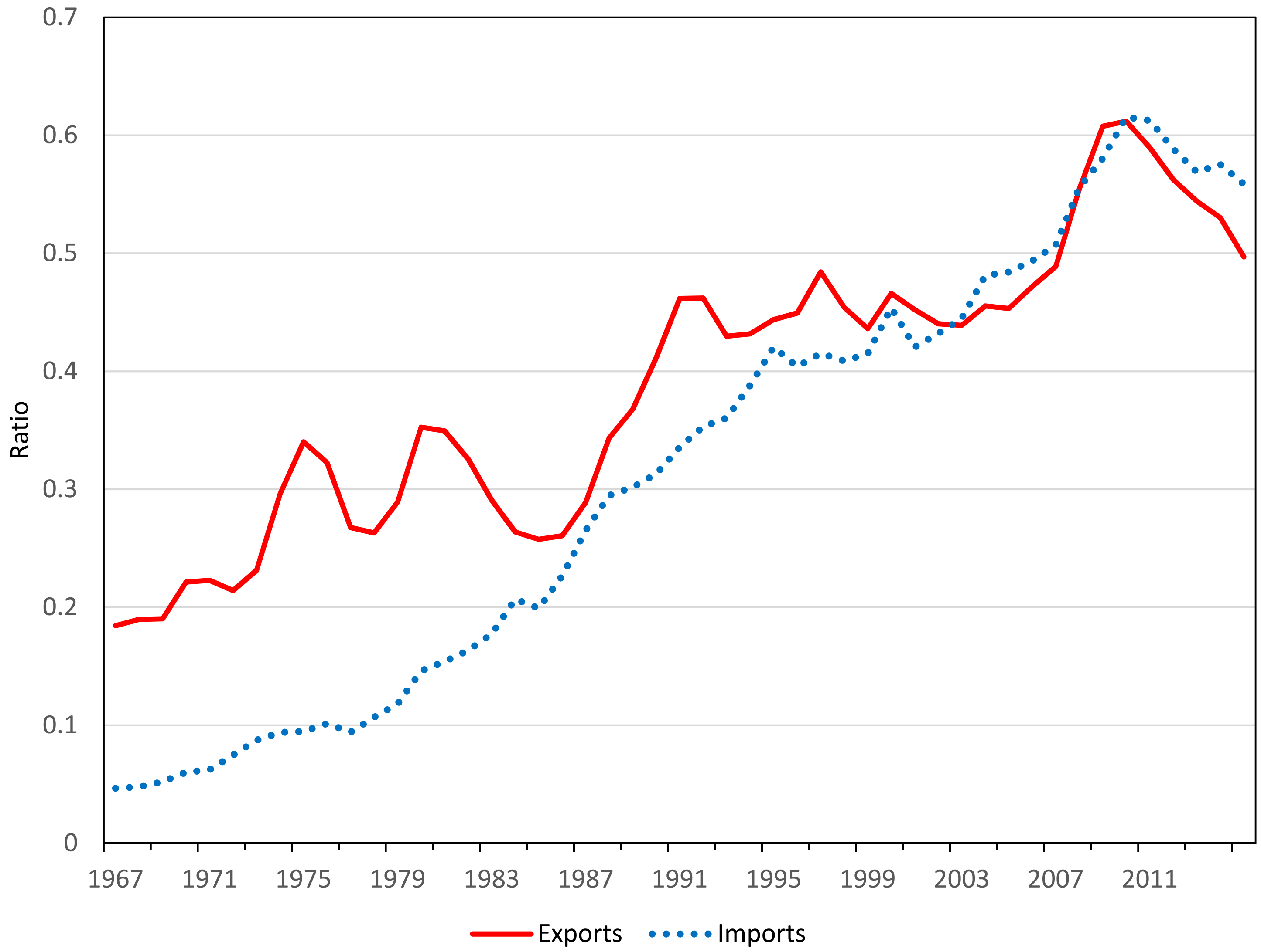
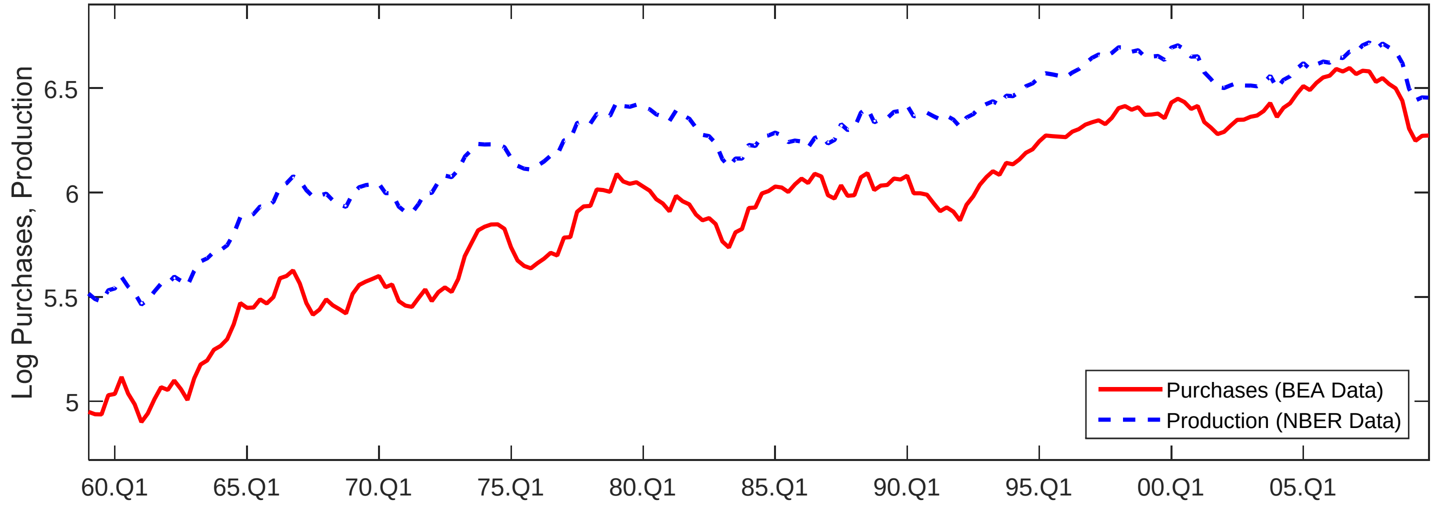


Figure 2. Purchases, Production and Prices, General Industrial Equipment (Log)

A. Real Purchases and Production



B. Real Prices

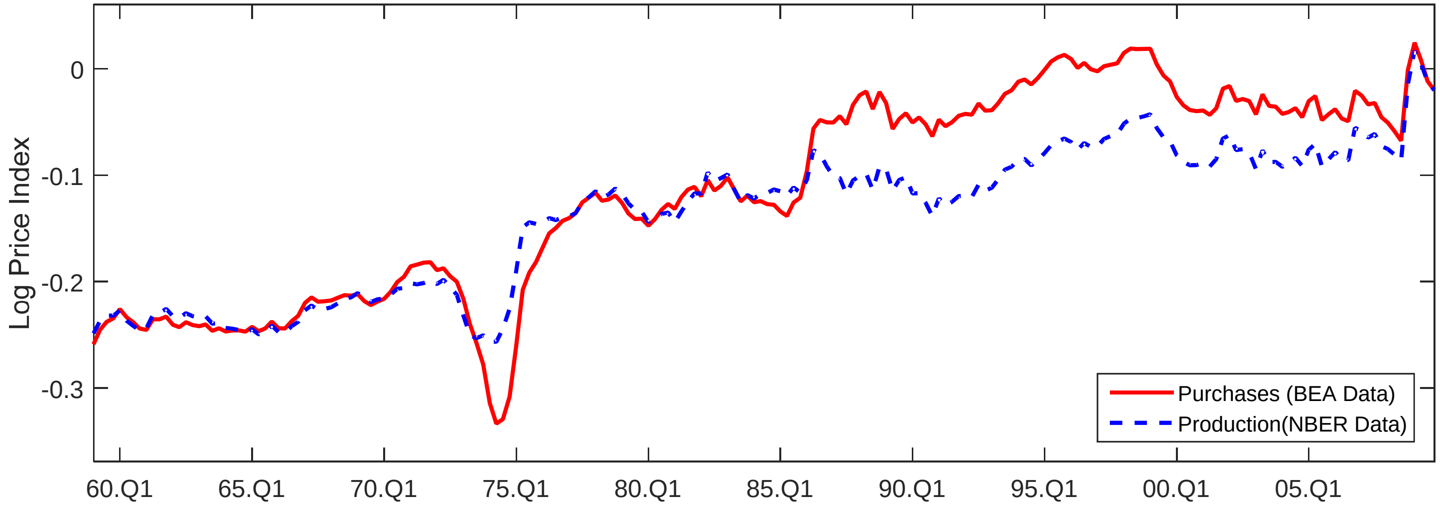
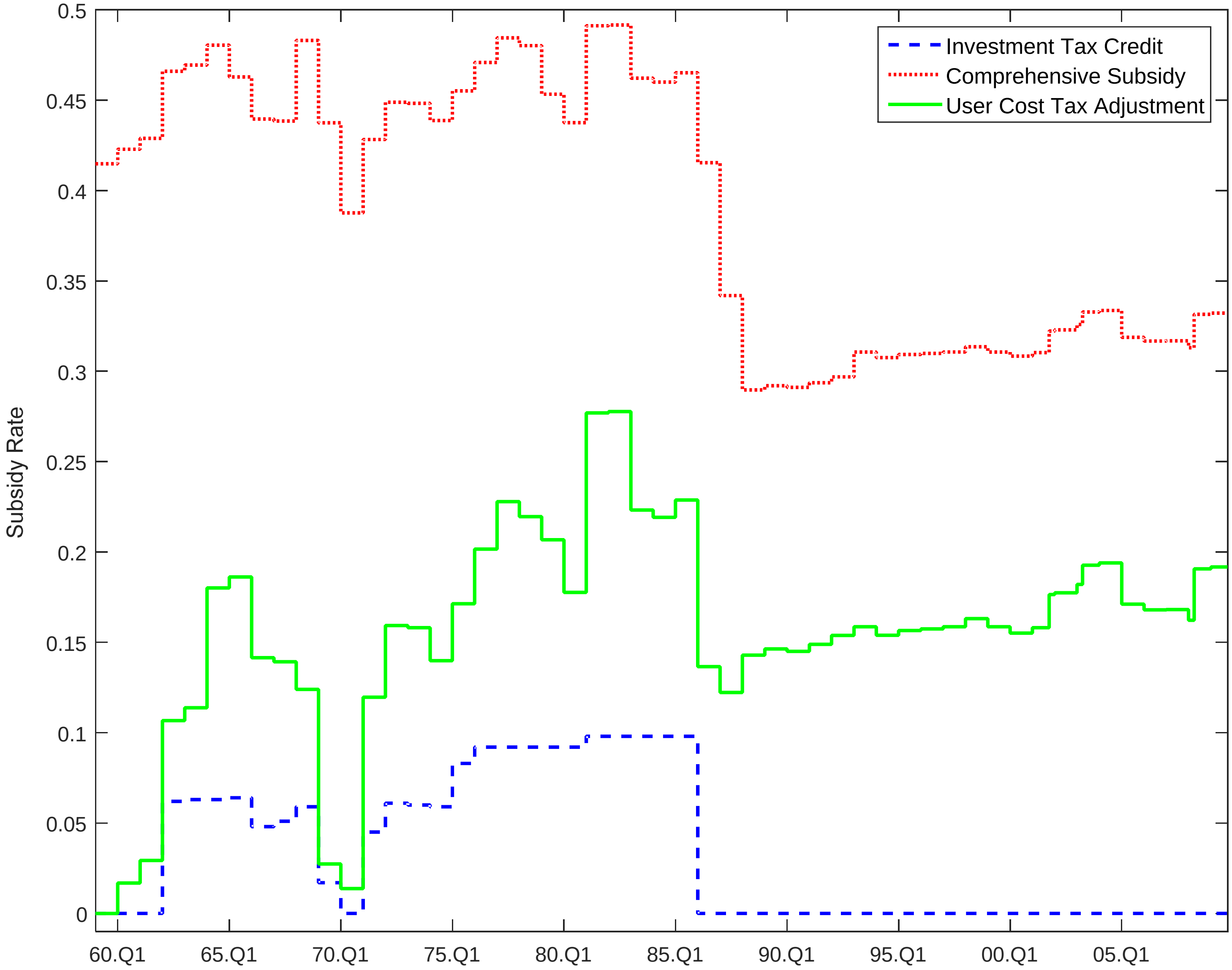
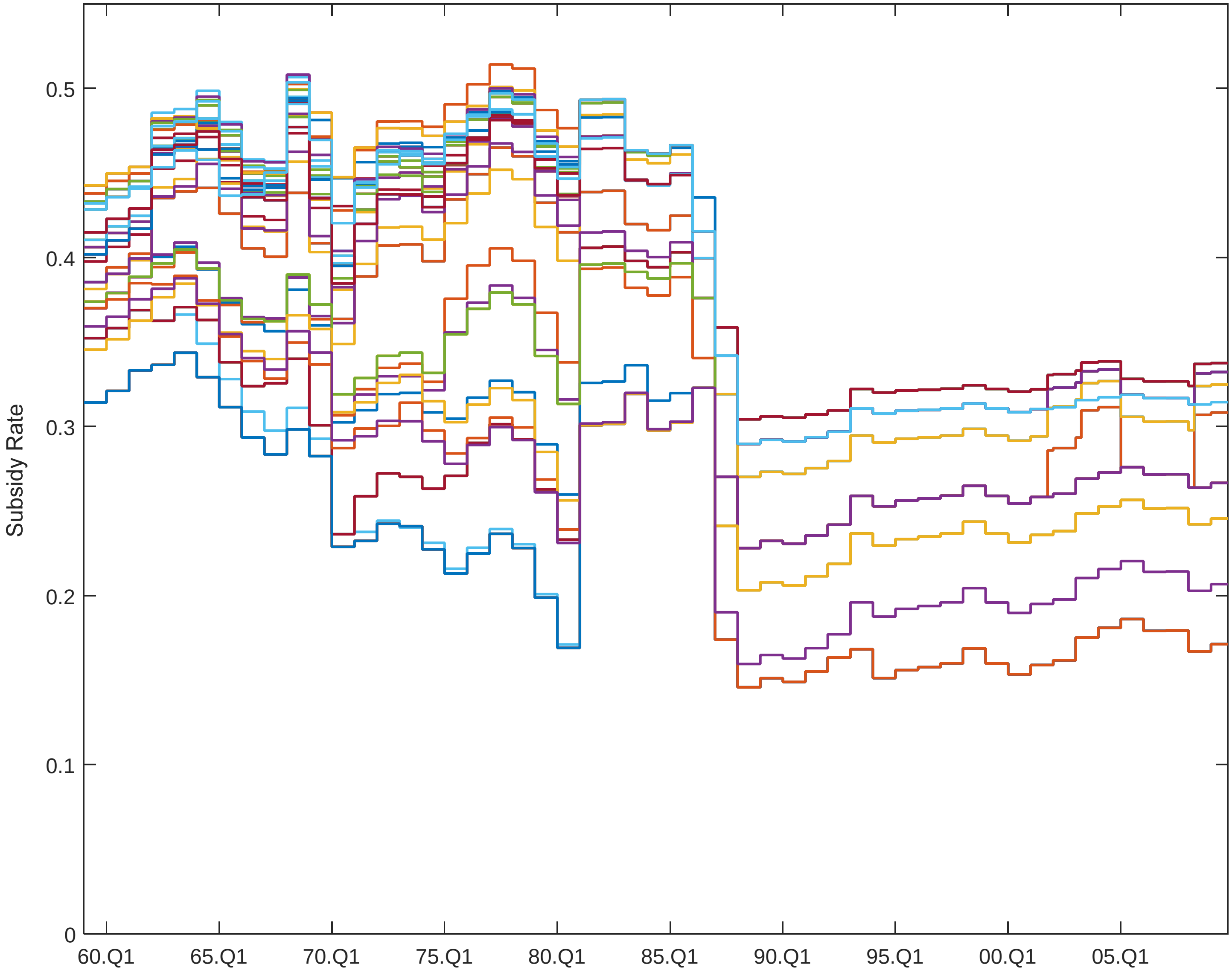


FIGURE 3. INVESTMENT SUBSIDY, GENERAL INDUSTRIAL EQUIPMENT



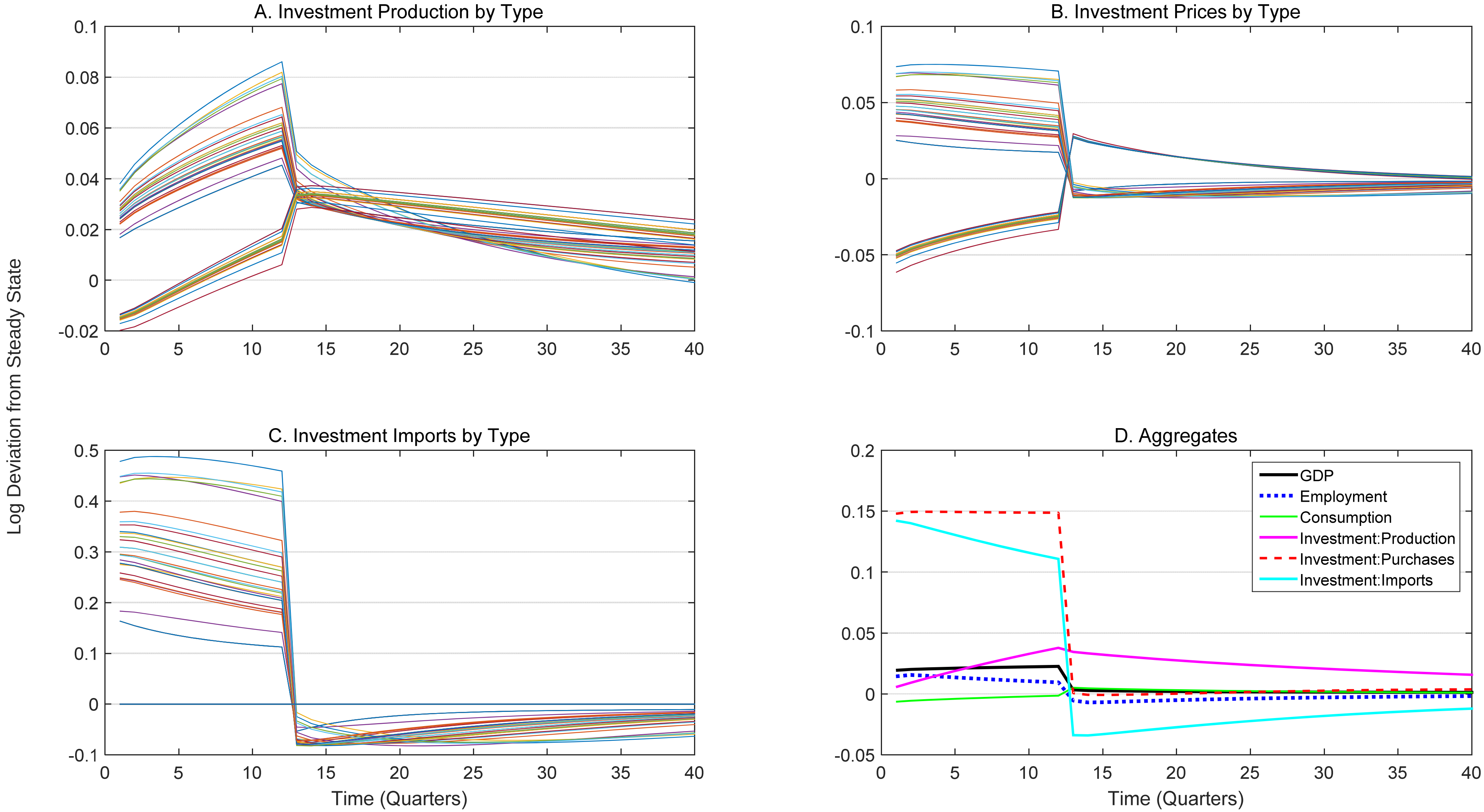
Notes: The figure plots the investment tax credit, the comprehensive subsidy ζ^m (given by equation 2 in the text) and the tax adjustment to the user cost Φ^m (given by equation 4). For the vertical axis, a value of 0.10 indicates that the after tax purchase price is 10 percent less than the pre-tax price.

FIGURE 4. COMPREHENSIVE SUBSIDY BY INVESTMENT TYPE



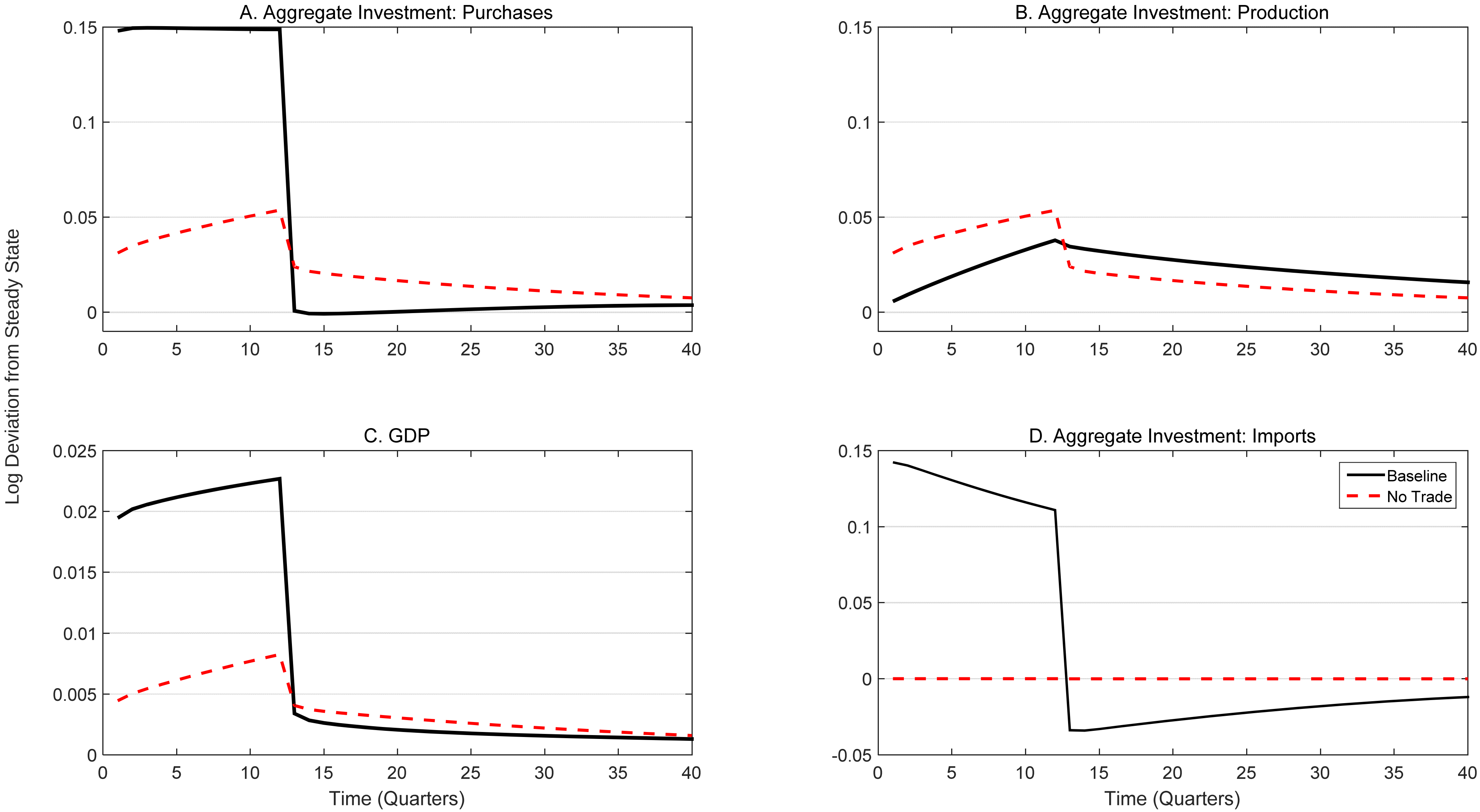
Notes: The figure plots the comprehensive subsidy ζ^m (given by equation 2 in the text) for all of the investment types in the dataset. For the vertical axis, a value of 0.10 indicates that the after tax purchase price is 10 percent less than the pre-tax price.

FIGURE 5. TEMPORARY INVESTMENT SUBSIDY FOR EQUIPMENT: UNCERTAIN EXPIRATION



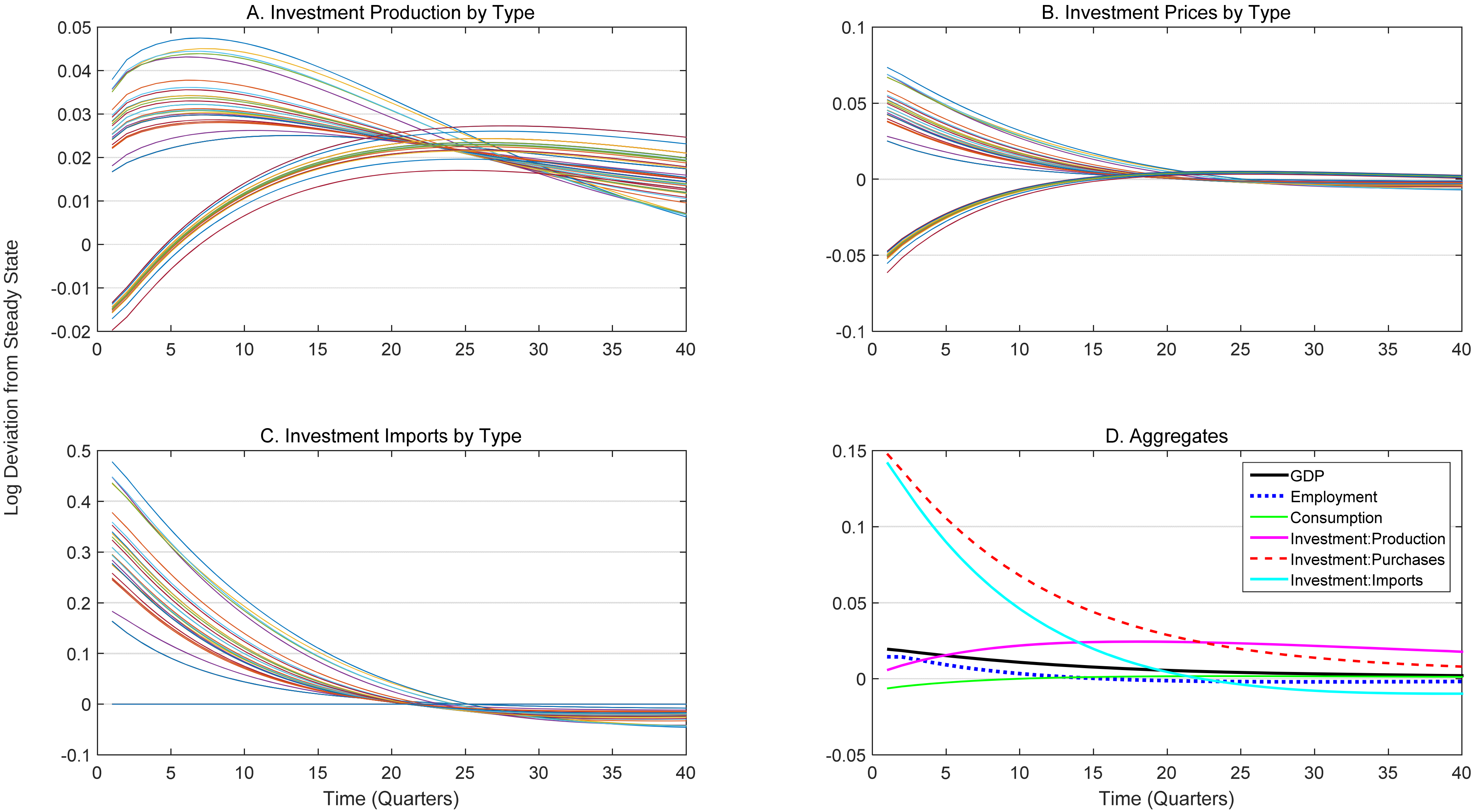
Notes: The figure reports the simulated impulse response functions for the selected variables. The investment subsidy is a 10 percent subsidy for equipment (structures are not eligible) and has an expected horizon of 3 years as described in the text. The figure plots a sample realization in which the policy sunsets in exactly 3 years.

FIGURE 6. AGGREGATE RESPONSE TO TEMPORARY INVESTMENT SUBSIDY: BASELINE VERSUS NO TRADE



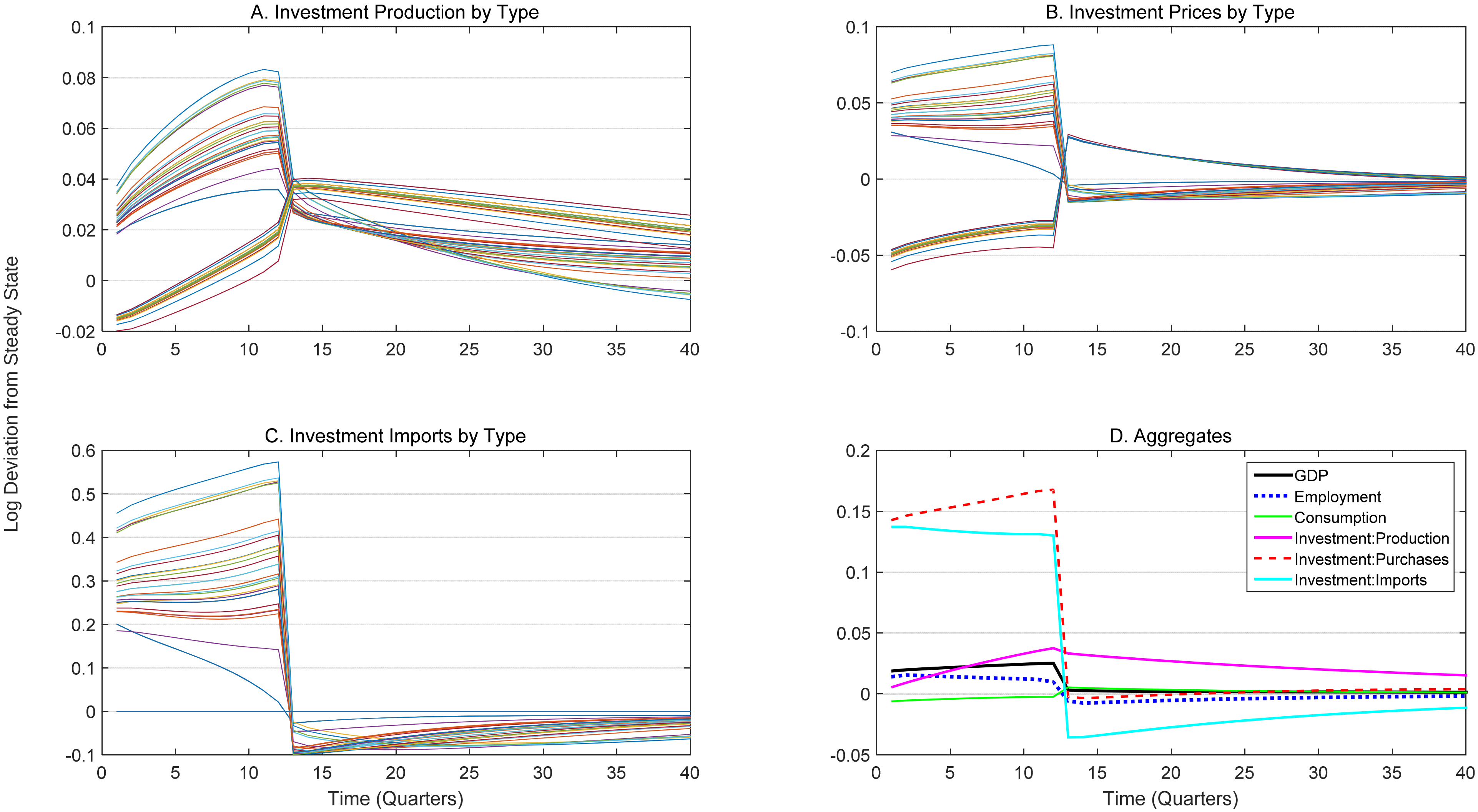
Notes: The figure reports the simulated impulse response functions for the selected variables. The policy experiment is identical to the one in Figure 4. The solid line corresponds to the model with parameters set to the baseline simulation in Figure 4. The dashed line shows results for the model with no international trade.

FIGURE 7. TEMPORARY INVESTMENT SUBSIDY FOR EQUIPMENT: AR(1) PHASE OUT



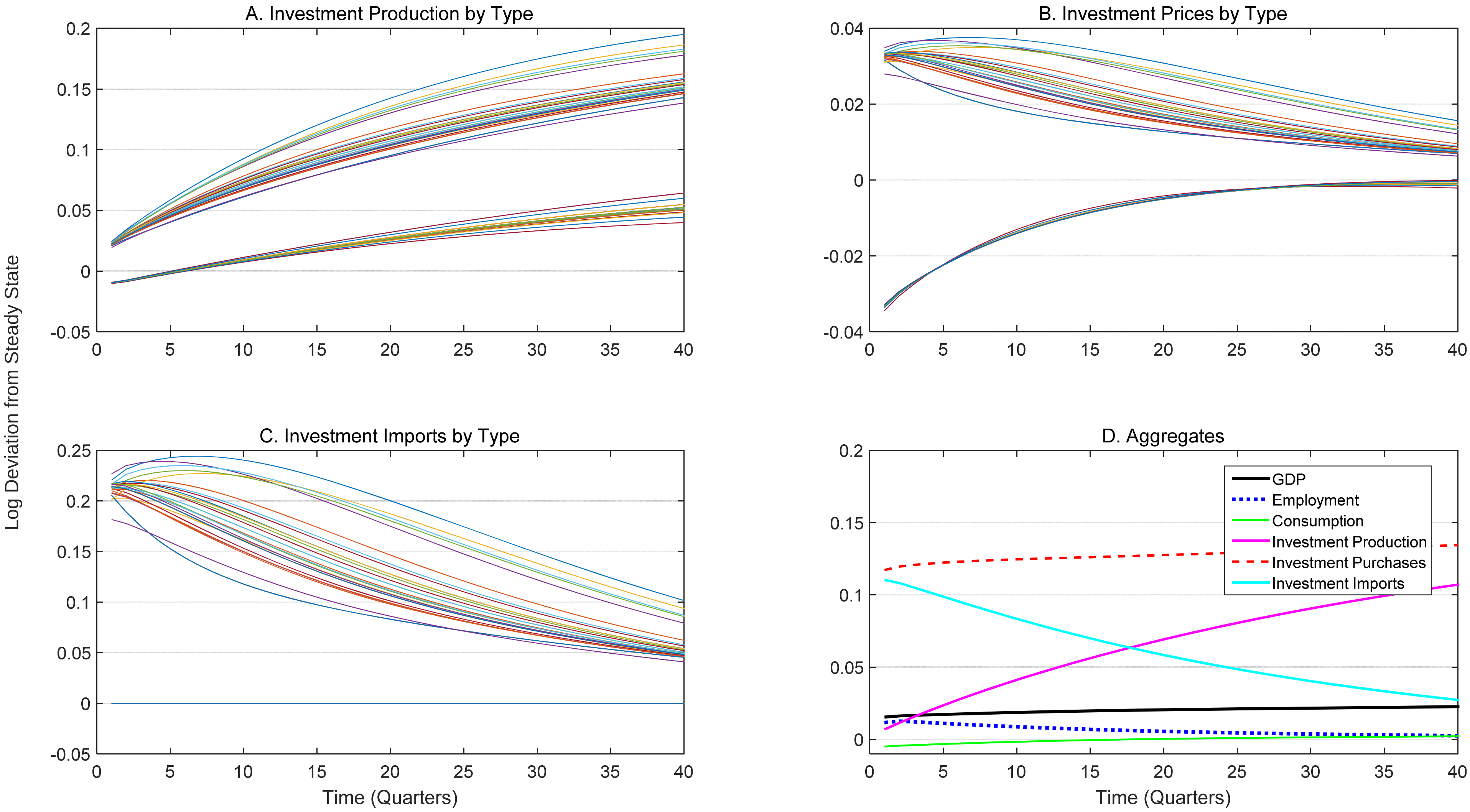
Notes: The figure reports the simulated impulse response functions for the selected variables. The investment subsidy is a 10 percent subsidy for equipment (structures are not eligible) and has an expected horizon of 3 years as described in the text. The figure plots a sample realization in which the policy sunsets in exactly 3 years.

FIGURE 8. TEMPORARY INVESTMENT SUBSIDY FOR EQUIPMENT: KNOWN EXPIRATION



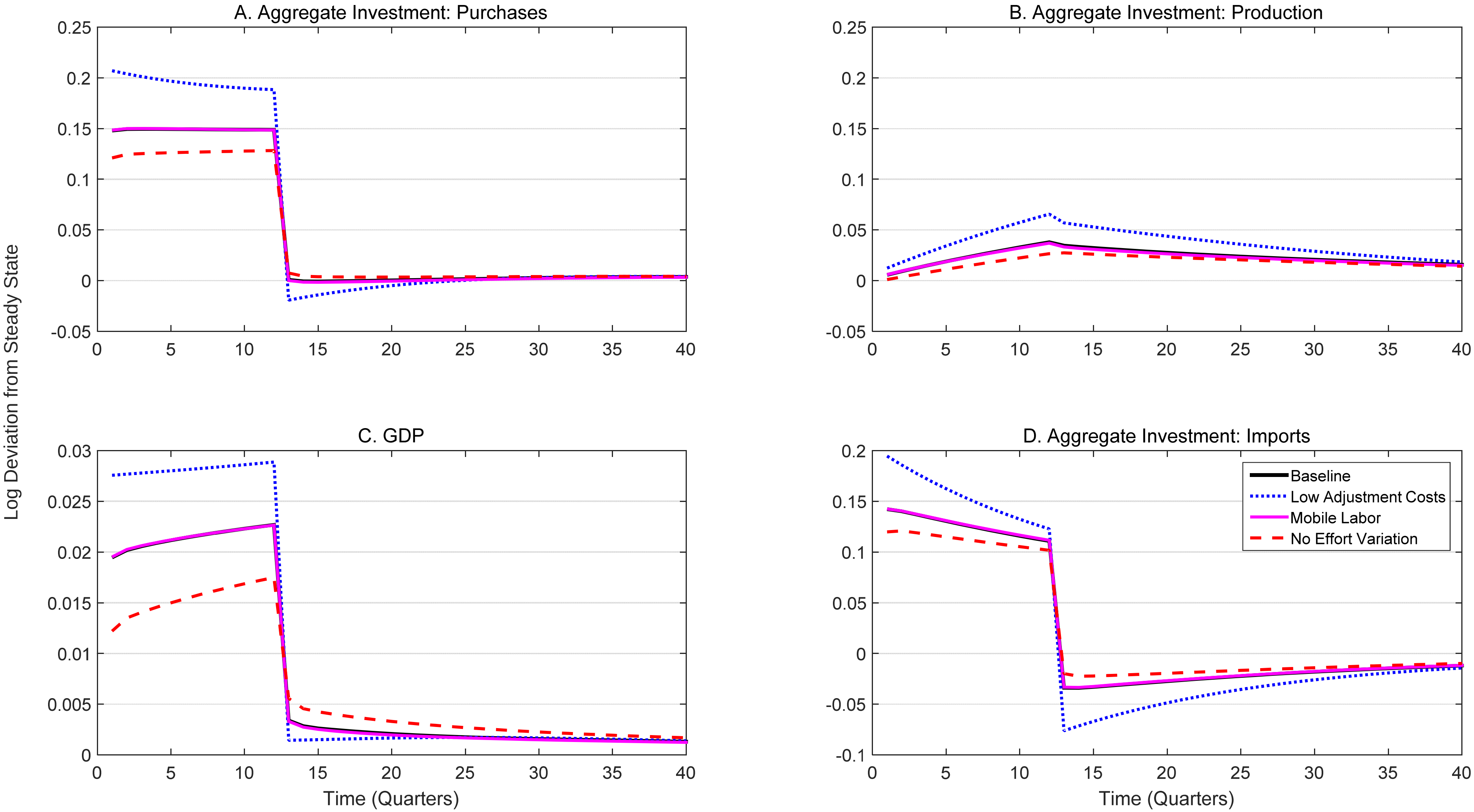
Notes: The figure reports the simulated impulse response functions for the selected variables. The investment subsidy is a 10 percent subsidy for equipment (structures are not eligible) and has an expected horizon of 3 years as described in the text. The figure plots a sample realization in which the policy sunsets in exactly 3 years.

FIGURE 9. PERMANENT INVESTMENT SUBSIDY FOR EQUIPMENT



Notes: The figure reports the simulated impulse response functions for the selected variables. The investment policy is a permanent 10 percent subsidy for equipment (structures are not eligible).

FIGURE 10. TEMPORARY INVESTMENT SUBSIDY FOR EQUIPMENT: UNCERTAIN EXPIRATION, ALTERNATIVE PARAMETER VALUES



Notes: The figure reports the simulated impulse response functions for the selected variables. The investment subsidy is a 10 percent subsidy for equipment (structures are not eligible) and has an expected horizon of 3 years as described in the text. The figure plots a sample realization in which the policy sunsets in exactly 3 years.

TABLE 1A. EQUIPMENT TYPES WITH DEPRECIATION RATES, INVESTMENT SHARES AND AVERAGE SUBSIDIES

	Depreciation (δ)	Investment Share	Average Subsidy
Computers and peripheral equipment	0.30	5.26%	0.40
Software	0.30	9.81%	0.40
Communication equipment	0.15	5.64%	0.38
Electro-medical equipment	0.18	1.10%	0.39
Medical instruments	0.14	1.53%	0.39
Nonmedical instruments	0.14	1.36%	0.39
Photocopy and related equipment	0.18	0.82%	0.40
Office and accounting equipment	0.30	0.43%	0.40
Fabricated metal products	0.09	0.92%	0.39
Steam engines	0.05	0.31%	0.35
Internal combustion engines	0.21	0.14%	0.35
Metalworking machinery	0.12	1.81%	0.39
Special industrial equipment	0.10	2.25%	0.39
General industrial equipment	0.11	3.26%	0.39
Electrical transmission and distribution	0.05	1.51%	0.38
Trucks, buses, and truck trailers	0.19	4.44%	0.40
Autos	0.17	2.84%	0.40
Aircraft	0.07	1.46%	0.40
Ships and boats	0.06	0.23%	0.37
Railroad equipment	0.06	0.41%	0.38
Household furniture	0.13	0.14%	0.40
Other furniture	0.12	2.16%	0.40
Farm tractors	0.15	0.42%	0.39
Other agricultural machinery	0.12	0.82%	0.39
Construction tractors	0.16	0.15%	0.40
Other construction machinery	0.16	1.32%	0.40
Mining and oilfield machinery	0.15	0.40%	0.40
Service industry machinery	0.17	1.29%	0.40
Household appliances	0.17	0.05%	0.40
Miscellaneous electrical	0.18	0.25%	0.39

TABLE 1B. STRUCTURES TYPES WITH DEPRECIATION RATES, INVESTMENT SHARES AND AVERAGE SUBSIDIES

	Depreciation (δ)	Investment Share	Average Subsidy
Hospitals	0.02	1.08%	0.23
Special care	0.02	0.25%	0.23
Medical buildings	0.02	0.39%	0.23
Multi-merchandise shopping	0.03	1.17%	0.30
Food and beverage establishments	0.03	0.55%	0.30
Warehouses	0.02	0.76%	0.23
Other commercial structures	0.03	1.04%	0.30
Warehouses	0.03	2.62%	0.26
Manufacturing	0.02	1.63%	0.31
Electric	0.02	0.58%	0.31
Other power structures	0.02	1.10%	0.32
Communication	0.08	2.38%	0.31
Mining	0.05	0.18%	0.39
Religious structures	0.02	0.44%	0.23
Educational structures	0.02	0.75%	0.23
Railroads	0.02	0.37%	0.25
Farm structures	0.02	0.33%	0.29
Single-family structures	0.01	15.21%	n/a[a]
Multifamily structures	0.01	1.93%	n/a[a]
Other residential structures	0.01	14.75%	n/a[a]

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[a] In the United States, residential structures get either business and household treatment depending on the tenancy. For business treatment, the average business tax subsidy is 0.26; for residential treatment, it is zero.

TABLE 2. LEGISLATIVE HISTORY OF INVESTMENT TAX INCENTIVES

Law Name	Public Law No.	Stated Duration	Actual Duration	Change to Investment Tax Credit	Change to Depreciation Allowance
Internal Revenue Code of 1954	83-591	Permanent	4 years		Double-declining balance method
Small Business Investment Act of 1958	85-699	Permanent	4 years		First-year depreciation for long-lived assets
Tax Rate Extension Act of 1962	87-507	Permanent	1.6 years	Public utilities eligible for 3% ITC	
Revenue Act of 1962	87-834	Permanent	1.6 years	Introduced 7% ITC; Limited for short-lived assets; Public utilities excluded	Long Amendment (100% basis adjustment for ITC)
Revenue Act of 1964	88-272	Permanent	1.75 years	Simplified ITC	Removed basis adjustment
Suspension of Investment Tax Credit of 1966	89-800	Temporary: 1 year	0.6 years	Suspended ITC	Limited accelerated depreciation
Restoration of Investment Tax Credit	90-26	Permanent	2.5 years	Reinstated ITC and increased ceiling	
Tax Reform Act of 1969	91-172	Permanent	1 year	Repealed ITC	
Reform of Depreciation Rules (1971)	n.a.	Permanent	0.9 years		Shortened the assumed life of equipment and allowed more first year depreciation

Law Name	Public Law No.	Stated Duration	Actual Duration	Change to Investment Tax Credit	Change to Depreciation Allowance
Revenue Act of 1971	92-178	Permanent	3.25 years	Restored ITC at 7%; Limited for short-lived assets; Public utilities eligible for 4%	Introduced ADR system Lowered asset lifetimes
Tax Reduction Act of 1975	94-12	Permanent	1.6 years	Increased to 10%; Extended 10% ITC to public utilities	
Tax Reform Act of 1976	94-455	Temporary: 4.2 years	2.1 years	Extended 10% ITC through 1980	
Revenue Act of 1978	95-600	Permanent	2.75 years	Made 10% ITC permanent	
Economic Recovery Tax Act of 1981	97-34	Permanent	1 year	Extended 10% ITC to short-lived assets	Replaced ADR with ACRS; Simplified asset-life classes; Introduced Accelerated depreciation deductions
Tax Equity and Fiscal Responsibility Act of 1982	97-248	Permanent	1.8 years		Repealed accelerated depreciation
Deficit Reduction Act of 1984	98-369	Permanent	2.3 years		Lengthened asset lives from 15 years to 18 years
Tax Reform Act of 1986	99-514	Permanent	10.8 years	Repealed ITC	Replaced ACRS with MACRS; Reduced depreciation allowances
Taxpayer Relief Act of 1997	105-34	Permanent	4.6 years		Harmonized asset lives for alternative minimum tax with regular tax lives
Job Creation and Worker Assistance Act of 2002	107-147	Temporary: 3 years	1.2 years		Introduced 30% bonus depreciation

Law Name	Public Law No.	Stated Duration	Actual Duration	Change to Investment Tax Credit	Change to Depreciation Allowance
Jobs and Growth Tax Relief Reconciliation Act of 2003	108–27	Temporary: 1.6 years	1.6 years		Increased bonus depreciation to 50% for given asset classes
The Economic Stimulus Act of 2008	110–185	Temporary: 1 year	1 year		Reintroduced 50% bonus depreciation
American Recovery and Reinvestment Act of 2009	111-5	Temporary: 1 year	1 year		Extended 50% bonus depreciation
Small Business Jobs Act of 2010	111-240	Temporary: 1 year	0.2 years		Extended 50% bonus depreciation
Tax Relief, Unemployment Insurance Reauthorization, Job Creation Act of 2010	111-312	Temporary: 3 years	2.1 years		Extended and increased bonus depreciation to 100%
The American Taxpayer Relief Act of 2012	112–240	Temporary: 1 year	1 year		Extended and reduced bonus depreciation to 50%
The Tax Increase Prevention Act of 2014	113-295	Temporary: 1 year	1 year		Extended 50% bonus depreciation

Notes. The legislative history from 1954–2003 comes from Romer and Romer (2009) and Yang (2007). Details on the effects of each law on the ITC and depreciation allowances are based on the author’s calculations using information from Gravelle (1994). Narrative legislative information for investment subsidies from 2002–2015 provided by the authors and also using House and Shapiro (2008). Table A.1 provides Romer and Romer (2009) classification of tax changes according to their stated motivation and whether they were influenced by contemporaneous economic events. The table does not include the passage of the Protecting Americans from Tax Hikes (PATH) act in late 2015 which again extended bonus depreciation. As written, the PATH act is temporary in that it calls for bonus depreciation to be phased-out in 2018—2019.

TABLE 3. EFFECTS OF INVESTMENT SUBSIDIES: EQUIPMENT PRODUCTION AND PURCHASES

	Specification			
Dependent Variable	Constant and linear trend	Macro covariates excluding oil	Macro covariates	Leads and lags of subsidy
Production	1.12	1.14	1.08	1.19
	(0.36)	(0.32)	(0.40)	(0.41)
Purchases	1.94	1.97	1.76	1.97
	(0.44)	(0.36)	(0.43)	(0.43)
Difference of coefficients:	0.82	0.83	0.68	0.77
Purchases - Production	(0.15)	(0.13)	(0.13)	(0.15)

Notes. The dependent variable is the natural logarithm of equipment production or equipment purchases as indicated. The coefficients are semi-elasticities of production or purchases with respect to the comprehensive subsidy ζ_t^m (b_1 in equation 5). The columns report specifications with alternative control variables or lags. The specification in the last column reports the sum of the coefficients on the current and two leads and lags of the subsidy. This last specification also includes the macro covariates. Driscoll-Kraay standard errors are shown in parentheses. The data are a quarterly panel of 28 types of equipment from 1959:1 to 2009:4 from the BEA (types in Table 1A excluding computers and software). See Appendix A for description of data.

Table 4. Effects of Investment Subsidies: Equipment Prices, Inputs, and TFP and Structures Production and Prices

	Specification			
Dependent Variable	Constant and linear trend	Macro covariates excluding oil	Macro covariates	Leads and lags of subsidy
		A. Equipment		
Production Prices[a]	-0.12	-0.02	0.07	0.08
	(0.10)	(0.06)	(0.08)	(0.08)
Production Employees[b]	1.01	1.05	0.76	0.95
	(0.46)	(0.45)	(0.55)	(0S.61)
Production Hours[b]	0.77	0.82	0.65	0.76
	(0.45)	(0.43)	(0.54)	(0.57)
Production Wages[b]	1.28	1.37	0.12	-0.70
	(0.91)	(0.89)	(0.96)	(0.90)
TFP[b]	0.32	0.32	0.28	0.37
	(0.14)	(0.12)	(0.15)	(0.16)
Cost of Materials[b]	0.87	0.93	0.81	1.12
	(0.46)	(0.41)	(0.51)	(0.55)
Cost of Energy[b]	2.22	2.31	0.23	-1.22
	(1.05)	(1.03)	(1.08)	(0.89)
		B. Structures		
Production[c]	0.87	1.06	0.46	0.56
	(0.32)	(0.32)	(0.31)	(0.32)
Prices[c]	0.54	0.39	0.22	0.20
	(0.12)	(0.08)	(0.09)	(0.09)

Notes. See notes to Table 3. Time period is 1959:1 to 2009:4 for all estimates.

[a] Quarterly data on 28 equipment types (BEA data). [b] Annual data on 28 equipment types (NBER productivity database). [c] Quarterly data on 17 structures types (BEA data). See Appendix A for description of data.

TABLE 5.A CALIBRATED PARAMETERS

Parameter	Baseline calibration	Notes
β	0.99	Corresponds to annual discount rate of 4 percent
δ^m	See Tables 1A and 1B	Set according to Fraumeni (1997)
γ_m	See Tables 1A and 1B	Set to imply empirical investment shares.
σ	0.2	Intertemporal elasticity of substitution
η	0.5	Frisch labor supply elasticity
ρ	0.01	Elasticity of substitution for materials
α	0.38	Capital share
τ^N	0.36	Marginal tax rate on labor income
τ^π	0.43	Marginal tax rate on business profits
g	0.333	Steady state ratio of government spending to consumption
μ_x	Implied by Equation (41)	Materials share for investment producers
μ_h	0.75	Capital sub-elasticity for investment producers

TABLE 5.B. BASELINE AND ALTERNATIVE CALIBRATIONS

Parameter	Baseline calibration	Low value	High value	Notes
λ	0. 9167	0.8750	0.9375	Persistence of tax changes (quarterly autocorrelation)
ξ^n	1.00	0.00	4.00	Labor adjustment cost
ξ^h	8.00	2.00	16.00	Capital adjustment cost
θ	0.50	0.01	0.99	Production elasticity of effort
ψ_n	1.00	0.25	1.75	Sectoral labor supply substitution

Notes: The baseline value for the tax persistence parameter corresponds to a 3-year expected duration. The upper and lower values for the persistence parameter imply 4-year and 2-year expected durations. The baseline value for the adjustment cost parameter implies a doubling time for labor of 1 quarter and a doubling time for capital of 2 years. The high adjustment cost calibration implies a doubling time for labor of 1 year and a doubling time for capital of 4 years.

TABLE 6. INDIRECT INFERENCE ESTIMATES AND MODEL COMPARISON

Model Specification	Data	Baseline	Low λ	High λ	Low θ	High θ	Low adj. costs	High adj. costs	Low ψ_n	High ψ_n
Estimated Import Supply Elasticity (χ)		6.53	7.22	5.17	3.06	24.14	13.99	3.13	5.02	16.31
		(1.56)	(1.61)	(1.36)	(0.84)	(11.68)	(2.43)	(0.95)	(1.12)	(5.41)
Targeted Reduced-form coefficients		Reduced-Form Coefficients Implied by Model								
Equipment Production	1.08	1.02	1.03	1.01	1.00	1.13	1.03	0.99	1.03	0.98
	(0.40)									
Equipment Investment	1.76	1.59	1.73	1.45	1.42	1.88	1.73	1.43	1.54	1.74
	(0.43)									
Hours	0.65	0.58	0.59	0.58	0.64	0.57	0.56	0.61	0.45	0.81
	(0.54)									
Material Inputs	0.81	1.02	1.03	1.01	1.00	1.13	1.03	0.99	1.03	0.98
	(0.51)									
Productivity (TFP)	0.28	0.04	0.04	0.04	0.00	0.08	0.04	0.04	0.05	0.02
	(0.15)									

Notes: The first row reports indirect inference estimates of the import supply elasticity under baseline and alternative values of the calibrated parameters. The inferences are based on targeting the reduced-form regression coefficients shown in the first column. The model-implied estimates of these parameters are given in the balance of the table.

Appendices

Stimulus Effects of Investment Tax Incentives: Production versus Purchases

C.L.House, A-M.Mocanu and M.D.Shapiro

February 25, 2019

Appendix A: Data

A.1. Production and purchases by type.

This appendix provides further details on the investment data used in our empirical analysis. The purchase data come from the BEA Underlying Detail Tables. For structures we equate purchases and production. For equipment, the production data come from the NBER-CES Manufacturing Productivity Database. Both datasets are available online.

The BEA Underlying Detail Tables (available online at http://www.bea.gov/iTable/index_UD.cfm) provide quarterly figures for the nominal value of capital goods purchases by type and type-specific price indecies. Specifically we used data from Tables 5.5.4U (Price Indexes for Private Fixed Investment in Equipment by Type), 5.5.5U (Private Fixed Investment in Equipment by Type), 5.4.4U (Price Indexes for Private Fixed Investment in Structures by Type), and 5.4.5U (Private Fixed Investment in Structures by Type).

NBER-CES Manufacturing Productivity Database provides annual data for production of capital goods and input usage by industry/product. The production data exist at a much more disaggregated level than the data in the BEA detail files. Product types are identified by six-digit NAICS codes. The dataset includes the dollar value of nominal shipments, nominal product prices, employment, payroll, production worker wages and measured total factor productivity (TFP). Unlike the BEA data, the data in the productivity dataset are available only at an annual frequency. Additional information can be found at the NBER public access data archive (http://users.nber.org/data/nberces.html).

To make the production data comparable with the BEA purchases data we aggregate groups of investment goods in the NBER dataset to match the categories in the BEA detail tables. The BEA provided us with a mapping from the underlying census data in the Productivity Database to the more aggregated investment categories in the BEA detail files. Aggregate nominal production for each category is simply the sum of the disaggregated nominal production levels. The aggregate nominal price is a weighted average of type-specific prices with weights given by the share of nominal production for each category. With the aggregated investment types, we then create quarterly production and price series by distributing the annual aggregates using the Chow-Lin (1971) procedure with the BEA quarterly series as the distributor.

This matching procedure yields a quarterly panel of 30 equipment types (see Table 1A) and 20 structures types (see Table 1B). The sample period is 1959:1 to 2009:4. For the reduced-form estimation, we exclude the computer and software types (because their data is dominated by price changes) and the three residential structures types, so the estimation is based on 28 equipment types and 17 structures types. In the solution to the model, we use all types since the all types must be accounted for in general equilibrium.

Tables 1A and 1B show the economic depreciation rates (see below), the average investment share measured as the ratio of nominal investment to total nominal investment from 1990-2009, and the average comprehensive subsidy. We chose to use recent investment shares to have the simulations match recent investment proportions.

A.2. Tax variables.

We take our series for the corporate tax rate (τ_t^π) from the Office of Tax Policy Research at the University of Michigan.

The type-specific investment tax subsidy measures are computed using the following variables: the investment tax credit ($ITC_{m,t}$), the date-t present value of depreciation allowances ($z_{m,t}^J$). Type-specific data on $z_{m,t}^J$ and the $ITC_{m,t}$ were provided by Dale Jorgenson. We make several adjustments to the standard $z_{m,t}^J$ calculation to account for features of the tax code.

Basis adjustment of ITC. The ITC interacts with depreciation allowances because tax law mandates adjustment of the basis for tax depreciation by the amount of the ITC. Define the *ITC basis adjustment* as λ_t^{ITC}, so the basis for depreciation is reduced by $\lambda_t^{ITC} \cdot ITC_{m,t}$. When the ITC was originally enacted in 1962, the basis for depreciation was adjusted by 100% of the ITC ($\lambda_t^{ITC} = 1$). This provision is called the Long Amendment named after Senator Russell B. Long. In 1964, the Long Amendment was repealed, so the ITC did not reduce depreciation allowances ($\lambda_t^{ITC} = 0$).The Tax Equity and Fiscal Responsibility Act of 1982 changed the basis adjustment, so that only half the ITC was excluded ($\lambda_t^{ITC} = 0.5$) where it remained until the ITC was repealed effective in 1986.

Bonus depreciation. In 2002 the Job Creation and Worker Assistance Act introduced a bonus depreciation allowance, which allowed firms to expense a fraction $\lambda_{m,t}^B$ of qualified investment and depreciate the remaining fraction $1-\lambda_{m,t}^B$ according to existing depreciation schedules. Only certain types of investment goods (those with tax recovery periods less than or equal to 20 years) were eligible for bonus depreciation. The initial bonus rate was 30 percent ($\lambda_{m,t}^B = 0.30$). This was increased by subsequent legislation to 50 percent ($\lambda_{m,t}^B = 0.50$) and then expired in 2005 only to be re-introduced in 2008 at a rate of 50 percent.

Adjusted $z_{m,t}$. Combining the ITC basis adjustment and bonus depreciation allowances, we define the adjusted present discounted value of tax depreciation allowances as $z_{m,t}$. For the years with the ITC (but no bonus depreciation) $z_{m,t}$ is

$$z_{m,t} \equiv z_{m,t}^J \left(1 - \lambda_t^{ITC} ITC_{m,t}\right).$$

For the years with bonus depreciation (but no ITC) $z_{m,t}$ is

$$z_{m,t} \equiv z_{m,t}^J \left(1 - \lambda_{m,t}^B\right) + \lambda_{m,t}^B$$

and for all other years (with neither the ITC nor bonus depreciation) $z_{m,t}$ is simply

$$z_{m,t} = z_{m,t}^J.$$

A general expression is

$$\begin{aligned} z_{m,t} &\equiv \left[z_{m,t}^J \left(1 - \lambda_{m,t}^B\right) + \lambda_{m,t}^B\right]\left[1 - \lambda_t^{ITC} ITC_{m,t}\right] \\ &= z_{m,t}^J \left(1 - \lambda_{m,t}^B\right) + \lambda_{m,t}^B - z_{m,t}^J \lambda_t^{ITC} ITC_{m,t} \\ &\quad + \lambda_{m,t}^B \lambda_t^{ITC} ITC_{m,t} \left(1 - z_{m,t}^J\right) \end{aligned}$$

where we have assumed that the ITC basis adjustment would apply equally to bonus depreciation and regular tax depreciation. In practice there has never been a period with both bonus depreciation and the ITC so the last term in the expression above is always zero in the data.

With the adjustments made above, the expression for the comprehensive subsidy (ζ_t^m) is

$$\zeta_t^m = ITC_{m,t} + z_t^m \tau_t^\pi$$

as given by equation (2) in the text.

A.3. Economic depreciation

The economic rates of depreciation for each type of capital are based primarily on Fraumeni (1997), who has estimated depreciation rates using techniques established by Hulten and Wykoff (1981a, 1981b).

Appendix B: Supplemental Results and Comparison with Goolsbee (1998)

This appendix provides additional empirical results as described in the text and also discusses the relationship between our empirical findings and the earlier findings by Goolsbee (1998).

In the text, we reported empirical estimates for the comprehensive investment tax subsidy ζ_t^m. Table B.1 reports results using the alternative measures of investment subsidies—the investment tax credit ITC_t^m and the user cost tax adjustment Φ_t^m. The ITC is a natural measure because it is likely the most salient form of investment subsidy. For the ITC measure, the results are somewhat more pronounced than for the comprehensive subsidy. Depending on the econometric specification, production increases by between 1.02 and 2.66 percent while purchases rise by between 1.69 and 3.31 percent. The differences between production and purchases are statistically significant. As we saw before, the estimates for price responses are quite close to zero.

The lower panel shows estimates for the user cost tax adjustment Φ_t^m. These estimates show similar patterns though it is worth noting that overall, these estimates are less statistically significant.

As we mentioned in the text, the lack of a price response is at odds with Goolsbee's (1998) findings and deserves some additional discussion. To address this difference, we attempted to replicate his findings using his sample period and the vintage data available when he did his original work. The most prominent finding of Goolsbee's paper is that investment subsidies increase equipment prices and benefit not only firms that invest, but also capital suppliers. This result was robust to alternative specifications, and was present in two distinct datasets—investment price deflators from the BEA, and equipment output deflators from the NBER Manufacturing Industry Database. Furthermore, Goolsbee estimated investment supply elasticities, finding evidence in favor of upward sloping supply curves for equipment goods. If the supply of new capital equipment is price inelastic, economic theory predicts that investment tax incentives have little final effect on investment demand, and instead succeed only in driving up equipment prices.

In contrast, we find that investment tax incentives do not have a clear effect on equipment goods prices, and that investment demand strongly responds to subsidies. Under our preferred specification, a one percent subsidy increases equipment investment by roughly 2 percent, investment production by 1.25 percent, and structures investment by 1.00. The reduced-form analysis in our paper is closely related to Goolsbee's work—we set out to measure many of the same relationships, and our empirical specifications are inspired by those in Goolsbee (1998). Here we attempt to meticulously reconstruct the methodology and data used by Goolsbee at the time when he published his paper. We consider differences in specification, data revisions, and differences in the time period included in each of the two studies. The replication allows us to approximately reproduce Gooslbee's main findings. The main differences are primarily due to differences in sample periods, but also from differences in econometric specification. Tables B.2 and B.3 present the results of our replication / comparison analysis.

Table B.2 presents results for the investment tax credit. Goolsbee's original published estimates are presented in the first column. Goolsbee's specification is run on quasi-differenced data to deal with the first-order serial correlation in the error terms. The next eight columns present results for different specifications, sample periods and data sources. The results are grouped into five different econometric specifications listed as (a) – (e) in the table. For each specification, we report the estimated coefficient on the ITC together with the OLS standard error in parenthesis. The first row in the table presents the pooled estimates (i.e., the results for all types together). Goolsbee's published pooled estimate is 0.390 with an OLS—that is, an increase in the ITC of one percentage point is associated with an increase in the log real price of equipment of 0.390 or roughly 0.4 percentage points.

Specification (a) is closest to Goolsbee's original analysis. This specification uses vintage BEA data on investment prices as well as vintage data for macroeconomic variables included in the regression. The vintage data used were the available data at the time of Goolsbee's earlier paper. The macroeconomic data were published by the U.S. Department of Commerce in *Fixed Reproducible Tangible Wealth in the United States: 1925–1989.* The sample period (1959-1988) and regression specification are both identical to the ones used in Goolsbee's paper. Specifically, the left-hand-side variables include a linear time trend, the growth rate of real GDP, dummy variables for the Nixon price controls, and exchange rates for the German DM and Japanese Yen. For this specification, the OLS regression gives an estimate of 0.551 and a quasi-differenced estimate of 0.177.

Specification (b) is nearly identical to the specification in (a) but we use revised data for equipment prices (i.e., we use the same data values for equipment prices that we used in the text but we continue to restrict the sample period to 1959-1988). Under this specification, the estimates change sharply. The simple OLS regression now gives an estimate of -0.164 and a quasi-differenced estimate of -0.271.

Specification (c) is identical to (b) with the exception that the macroeconomic variables included in the regression uses revised data. Using updated data for the macroeconomic aggregates has only a modest impact on the estmates relative to the results for specification (b). The OLS estimate is -0.143 and the quasi-differenced estimate is -0.133.

Specification (d) uses Goolsbee's sample period (1959-1988) and current data but uses the regression specification used in House, Mocanu and Shapiro (2016). Specifically, the regression includes a piecewise-linear time trend, HP-filtered real GDP, dummy variables for the Nixon price controls, and real oil prices. Changing the regression specification in this way actually shifts the estimates back towards the values in Goolsbee (1998). The OLS estimate is 0.298 (we do not run a quasi-differenced specification due to the piece-wise linear time trend).

Finally, the specification in (e) is the same as (d) with the exeption that the sample period is extended to 1959-2009 (i.e., the specification and sample period used in House, Mocanu and Shapiro 2017). The OLS estimate is 0.038 with a standard error of 0.035 which is neither statistically nor economically significant. The reader will notice that this estimate does not exactly match the corresponding estimate in Table 3. In Table 3, the estimate for the macro covariate specification and for the purchases price measure (the BEA measure) is -0.04 with a standard error of 0.08. The reason for the discrepancy is two-fold. First, the point estimate itself is different. This is due to the fact that the estimates in Table 3 are based on the updated set of equipment categories used by the BEA while the estimates in Table B.2 are based on equipment categories used by the BEA in 1988. Thus, when we use the updated data together with the updated sample period in Table B.2, we continue to aggregate the data to match the investment categories used by Goolsbee. Second, the standatd error is much larger in Table 3. This is because we use a HAC estimator for the standard errors while the results in Table B.2 use untreated standard errors.

Table B.3 presents results for the (negative) user cost tax adjustment (i.e., the term Φ_t^m in equation 4). We state the results as negative values to match the reported values in Goolsbee's paper. Additionally, to be comparable with his specification, we do not implement the basis adjustment for the ITC (see Appendix A), so Φ_t^m is calculated using $z_{m,t}^J$ (the unadjusted present value of tax depreciation allowances provided by Jorgenson) rather than the adjusted $z_{m,t}$ used for the estimates in our paper. The specifications and sample periods (a) – (e) are the same as those in Table B.2. Goolsbee's original pooled estimate is -0.17 with a standard error of 0.028. When we adopt his original regression specification and use vintage data we obtain a pooled OLS estimate of -0.26 (standard error 0.075) and a quasi-differenced estimate of -0.133 (standard error 0.042). Shifting to an updated set of data (columns b and c) reduces the magnitude of the estimates sharply. Adopting the specification used in the text and extending the sample period (columns d and e) partially restore the effects though our final estimate is only half of Goolsbee's original estimate. (Again the discrepancy between the estimate in column e and the value reported in Table 3 is due to slight differences in the equipment categories in the updated data and the original data.)

Tables B.2 and B.3 also report regression results for each equipment type. These estimates are much noisier than the pooled estimates and their match to Goolsbee's original estimates is not as consistent.

Although we have replicated the qualitative results in Goolsbee's paper, our estimates are not numerically identical. We note two factors that likely contribute to this difference. First, we were not able to obtain vintage data for investment subsidies, nor for the German and Japanese price indices we used to calculate real exchange rates. Second, our implementation of the AR(2) quasi-differencing procedure used to address serial correlation may differ from that in Goolsbee's paper. The algorithm relies on numerical convergence, and the choice of stopping criteria can affect estimates.

Finally, it should be noted that, unlike the results for quantities, the price results are not particularly robust across econometric specification. Changes in the sample and regression specification have substantial impacts on the estimates. This is not true for the estimates for investment quantities which are much more stable across specifications.

Appendix C: The Non-Stochastic Steady State

In the steady state, all of the endogenous variables are constant. As a result, we can ignore the adjustment cost terms and imports (which are zero in the steady state). We begin by assuming that we can choose the parameters ϕ and ψ to normalize N and e to 1 in the steady state. We will discuss this normalization after the remainder of the system is solved to ensure that this assumption is correct. With $N = e = 1$, the rest of the steady state is given by the following equations:

$$q^m = \frac{C^{-\frac{1}{\sigma}} \left(1-\tau^\pi\right) \left(1-\tau^d\right) R^m}{r+\delta^m} \tag{46}$$

$$q^m = C^{-\frac{1}{\sigma}} \left(1-\tau^d\right) P^m \left[1-\zeta^m\right] \tag{47}$$

$$Q = A \left[h^Q\right]^\alpha \left[(e)^\theta n^Q\right]^{1-\alpha} \tag{48}$$

$$Q = C + X + G \tag{49}$$

$$R = \alpha \frac{Q}{h^Q} \tag{50}$$

$$(1-\alpha) \frac{Q}{n^Q} = W \tag{51}$$

$$I^m = B \left\{ \mu_x \left(x^m\right)^{\frac{\rho-1}{\rho}} + \left(1-\mu_x\right) \left[U^m\right]^{\frac{\rho-1}{\rho}} \right\}^{\frac{\rho}{\rho-1}} \tag{52}$$

$$R = P^m \mu_h \left(1-\mu_x\right) (B)^{\frac{\rho-1}{\rho}} \left[\frac{I^m}{U^m}\right]^{\frac{1}{\rho}} \frac{U^m}{h^m} \tag{53}$$

$$1 = P^m \mu_x (B)^{\frac{\rho-1}{\rho}} \left[\frac{I^m}{x^m}\right]^{\frac{1}{\rho}} \tag{54}$$

$$W = P^m \left(1-\mu_h\right) \left(1-\mu_x\right) (B)^{\frac{\rho-1}{\rho}} \left[\frac{I^m}{U^m}\right]^{\frac{1}{\rho}} \frac{U^m}{n^m} \tag{55}$$

$$U^m = \left(H^m\right)^{\mu_h} \left(e^m\right)^{\theta\left(1-\mu_h\right)} \left(n^m\right)^{\left(1-\mu_h\right)} \tag{56}$$

$$\delta^m K^m = I^m \tag{57}$$

$$N = n^Q + \sum_{m=1}^{M} n^m \tag{58}$$

$$X = \sum_{m=1}^{M} x^m \tag{59}$$

$$H = \left(\prod_{m=1}^{M} \left(\frac{1}{\gamma}\right)^\gamma\right) \left(\prod_{m=1}^{M} \left(K^m\right)^\gamma\right) \tag{60}$$

$$H = h^Q + \sum_{m=1}^{M} h^m \tag{61}$$

$$R\gamma \frac{H}{K^m} = R^m \tag{62}$$

This system has 17 equations (or blocks of equations) in the variables $W, C, Q, X, R, H, H^Q, n^Q, q^m, R^m, P^m$ $, I^m, X^m, H^m, n^m, U^m, K^m$. Eliminating the shadow values q^m with equations (46) and (47) gives

$$\frac{R^m}{P^m} = \left[\frac{1-\zeta^m}{1-\tau^\pi}\right](r+\delta^m)$$

We now eliminate the "duplicate variables" for the separate m-sectors by writing each of the m-variables in terms of the corresponding variable for sector 1. Using the type-specific capital demand equations (62) from the capital aggregating firms we have

$$\frac{R^m}{R^1} = \frac{\gamma_m}{\gamma_1}\frac{K^1}{K^m} = \frac{\gamma_m \delta_m}{\gamma_1 \delta_1}\frac{I^1}{I^m}$$

and so,

$$\frac{R^m}{P^m}\frac{P^1}{R^1} = \frac{\gamma_m \delta_m}{\gamma_1 \delta_1}\frac{P^1 I^1}{P^m I^m}.$$

Using this with our expression for the real rental price $\frac{R^m}{P^m}$ we can write

$$\frac{\frac{R^m}{P^m}}{\frac{R^1}{P^1}} = \frac{\left[\frac{1-\zeta^m}{1-\tau^\pi}\right](r+\delta^m)}{\left[\frac{1-\zeta^1}{1-\tau^\pi}\right]\left(r+\delta^1\right)} = \frac{\gamma_m \delta_m}{\gamma_1 \delta_1}\frac{P^1 I^1}{P^m I^m}$$

and as a result,

$$\frac{P^m I^m}{P^1 I^1} = \frac{\gamma_m \delta_m}{\gamma_1 \delta_1}\frac{\left[1-\zeta^1\right]\left(r+\delta^1\right)}{\left[1-\zeta^m\right](r+\delta^m)} = \Psi_m \tag{63}$$

(equation 39 in the text). Since we have data on the shares $s_m \equiv \frac{P^m I^m}{P^1 I^1}$, depreciation rates δ^m and baseline subsidies ζ^m for all types m, we can construct the implied parameters γ_m as follows. Notice that each γ_m can be expressed in terms of γ_1 as

$$\gamma_m = \Gamma_m \gamma_1$$

where

$$\Gamma_m \equiv s_m \frac{\delta_1}{\delta_m}\frac{\left[1-\zeta^m\right]}{\left[1-\zeta^1\right]}\frac{(r+\delta^m)}{\left(r+\delta^1\right)}.$$

Then, since $\sum_m \gamma_m = 1$ (constant returns to scale) we must have

$$\gamma_1 = \left[\sum_{m=1}^{M}\Gamma_m\right]^{-1}$$

This gives the set of share parameters $\{\gamma_m\}_{m=1}^{M}$ necessary to match the observed investment shares, depreciation rates, and tax subsidies in the data.

Because the production functions for the type-specific investment goods have constant returns to scale, the input ratios are common to all sectors m. In particular, dividing the capital first order condition for sector m (53) by the labor first order condition for sector m (55) gives the ratio of labor to capital as

$$\frac{R}{W} = \frac{\mu_h}{1-\mu_h}\frac{n^m}{h^m} \Rightarrow \frac{n^m}{h^m} = \frac{1-\mu_h}{\mu_h}\frac{R}{W}.$$

Similarly the ratio of U^m to h^m is constant across the m-sectors:

$$\frac{U^m}{h^m} = (h^m)^{\mu_h - 1}(n^m)^{(1-\mu_h)} = \left(\frac{n^m}{h^m}\right)^{1-\mu_h} \Rightarrow \frac{U^m}{h^m} = \left(\frac{1-\mu_h}{\mu_h}\right)^{1-\mu_h}\left(\frac{R}{W}\right)^{1-\mu_h}.$$

Dividing the capital first order condition by the materials first order condition (54) gives

$$\frac{U^m}{x^m} = \left(\frac{1-\mu_x}{\mu_x}\right)^{\rho}(\mu_h)^{\rho}\left(\frac{U^m}{h^m}\right)^{\rho}\left(\frac{1}{R}\right)^{\rho} \tag{64}$$

Since the ratio U^m/h^m is the same for all m, the ratio x^m/U^m is also constant for all m sectors. We now use the expressions for U^m/h^m and U^m/x^m together with the production function for type m captial (52) to write the ratio of investment to materials I^m/x^m as

$$\frac{I^m}{x^m} = B^m \mathbb{U}(W,R)$$

where the term $\mathbb{U}(W,R)$ is

$$\mathbb{U}(W,R) \equiv \left\{ \mu_x + \mu_x^{1-\rho}(1-\mu_x)^{\rho} \left[(1-\mu_h)^{1-\mu_h} (\mu_h)^{\mu_h} \left(\frac{1}{W}\right)^{1-\mu_h} \left(\frac{1}{R}\right)^{\mu_h} \right]^{\rho-1} \right\}^{\frac{\rho}{\rho-1}} \tag{65}$$

Given a real wage W and a real rental price for aggregate capital services R, the implied real relative pre-tax price of type m capital (P^m) can be recovered from any of the first order conditions. In particular, using the materials first order condition (54) gives us

$$P^m = \frac{1}{\mu_x}\frac{1}{B^m}\mathbb{U}(W,R)^{-\frac{1}{\rho}} \tag{66}$$

Notice that if the productivity terms B^m are common across the m sectors, then all of the types will have the same price $P^m = P$. We will use the B^m terms to normalize the steady state prices to $P^m = 1$. With this normalization, and $P^m I^m = \Psi_m P^1 I^1$ from (63), we have

$$\begin{aligned} I^m &= \Psi_m I^1 \\ n^m &= \Psi_m n^1 \\ x^m &= \Psi_m x^1 \\ U^m &= \Psi_m U^1 \\ h^m &= \Psi_m h^1 \end{aligned}$$

Using (65), (66) and the definition for MC^U provided in the text gives the expression for μ_x (equation 41).

We can also find expressions for aggregate material usage, aggregate employment in the investment industries and aggregate capital usage by the investment industries as $X \equiv \sum_{m=1}^{M} x^m = \sum_{m=1}^{M} \Psi_m x^1 = \mathbb{B}x^1$ where $\mathbb{B} = \sum_{m=1}^{M} \Psi_m$. Similarly, $\mathbb{B}n^1$ is total employment in the investment industries and total capital usage is $\mathbb{B}h^1$.

We can express the capital stocks similarly as

$$K^m = \Psi_m^k K^1$$

where $\Psi_m^k \equiv \Psi_m \frac{\delta_1}{\delta^m}$. Aggregate capital is then

$$H = K^1 \mathbb{A} \left(\prod_{m=1}^{M} \left(\frac{1}{\gamma_m}\right)^{\gamma_m} \right)$$

with $\mathbb{A} = \prod_{m=1}^{M} \left(\Psi_m^k\right)^{\gamma_m}$.

Since we have normalized $P^m = 1$, we now know the type specific rental prices R^m for each of the m sectors.

$$R^m = \left[\frac{1-\zeta^m}{1-\tau^{\pi}}\right](r+\delta^m).$$

The rental price for the aggregate capital good can be recovered from any of the demand conditions for type m captial (62). For $m = 1$ we have

$$\begin{aligned} R &= R^1 \frac{K^1}{H}\frac{1}{\gamma_1} \\ &= R^1 \frac{\prod_{m=1}^{M} (\gamma_m)^{\gamma_m}}{\mathbb{A}\gamma_1} \end{aligned}$$

Notice that since we know R, we know the capital-to-labor ratio in the numeraire sector $\frac{h^Q}{n^Q}$. Using (50) and (48) we have

$$\frac{h^Q}{n^Q} = \left(\frac{\alpha A}{R}\right)^{\frac{1}{1-\alpha}}$$

which implies that, from (51), we know the steady state wage W

$$W = (1-\alpha)\frac{Q}{n^Q} = (1-\alpha)\, A\left[\frac{n^Q}{h^Q}\right]^{-\alpha}$$

Since we now know R and W, we can solve for the input ratios in the m sector (we previously knew only that were constant across the sectors). In particular, $\frac{n^m}{h^m} = \frac{1-\mu_h}{\mu_h}\frac{R}{W}$ and $\frac{U^m}{n^m} = \left(\frac{h^m}{n^m}\right)^{\mu_h}$. Also, our earlier expression (64) gives us the ratio U^m/x^m. Thus, we now know all of the ratios of the inputs h^m, n^m and x^m (and U^m) for the capital producing sectors.

To find the constant B required to ensure a real relative price of investment goods equal to 1, recall that $\frac{I^m}{x^m} = B \cdot \mathbb{U}(W,R)$ (where we have used the fact that $B^m = B$). From the materials first order condition (54) with $P^m = P = 1$ we need

$$1 = \mu_x\,(B)^{\frac{\rho-1}{\rho}}\left[\frac{I^m}{x^m}\right]^{\frac{1}{\rho}} = \mu_x\,(B)^{\frac{\rho-1}{\rho}}\left[B \cdot \mathbb{U}(W,R)\right]^{\frac{1}{\rho}}$$

so we require

$$B = \frac{1}{\mu_x}\mathbb{U}(W,R)^{-\frac{1}{\rho}}$$

We now have all of the input ratios for the m sectors as well as the ratio of n^Q/h^Q in the numeraire sector. We also know the constant B, the rental prices R^m and R and W.

Notice that the production function for type 1 investment is

$$\begin{aligned}
\delta^1 K^1 &= Bx^1\left\{\mu_x + (1-\mu_x)\left[\frac{U^m}{x^m}\right]^{\frac{\rho-1}{\rho}}\right\}^{\frac{\rho}{\rho-1}} \\
&= Bn^1\left(\frac{x^m}{n^m}\right)\left\{\mu_x + (1-\mu_x)\left[\frac{U^m}{x^m}\right]^{\frac{\rho-1}{\rho}}\right\}^{\frac{\rho}{\rho-1}} \\
&= n^1\mathbb{C}
\end{aligned}$$

where $\mathbb{C} = \left(\frac{x^m}{n^m}\right)\left\{\mu_x + (1-\mu_x)\left[\frac{U^m}{x^m}\right]^{\frac{\rho-1}{\rho}}\right\}^{\frac{\rho}{\rho-1}}$ is a known constant. Using the fact that total capital usage in the investment sectors is $\mathbb{B}h^1$ together with the capital market clearing condition (61) we have

$$\begin{aligned}
\mathbb{A}\left(\prod_{m=1}^{M}\left(\frac{1}{\gamma_m}\right)^{\gamma_m}\right)K^1 &= h^Q + \mathbb{B}h^1 \\
\mathbb{A}\left(\prod_{m=1}^{M}\left(\frac{1}{\gamma_m}\right)^{\gamma_m}\right)\delta^1 K^1 &= \delta^1 n^Q\left(\frac{h^Q}{n^Q}\right) + \delta^1\mathbb{B}n^1\left(\frac{h^1}{n^1}\right)
\end{aligned}$$

where we have used $h^Q = n^Q\left(\frac{h^Q}{n^Q}\right)$ and $h^1 = n^1\left(\frac{h^1}{n^1}\right)$ (recall the ratios $\frac{h^Q}{n^Q}$ and $\frac{h^1}{n^1}$ are known). Using $\delta^1 K^1 = n^1\mathbb{C}$ we have

$$n^1 = n^Q\frac{\delta^1 \cdot \left(\frac{h^Q}{n^Q}\right)}{\left(\prod_{m=1}^{M}\left(\frac{1}{\gamma_m}\right)^{\gamma_m}\right)\mathbb{A}\mathbb{C} - \delta^1\mathbb{B}\cdot\left(\frac{h^1}{n^1}\right)}.$$

Using the fact that total labor used in the investment sectors is $\mathbb{B}n^1$ and total labor has been normalized to 1, the labor market clearing condition is

$$1 = n^Q + \mathbb{B}n^1,$$

which implies that employment in the numeraire sector is

$$n^Q = \frac{\left(\prod_{m=1}^{M}\left(\frac{1}{\gamma_m}\right)^{\gamma_m}\right)\mathbb{AC}{-}\delta^1\mathbb{B}{\cdot}\left(\frac{h^1}{n^1}\right)}{\left(\prod_{m=1}^{M}\left(\frac{1}{\gamma_m}\right)^{\gamma_m}\right)\mathbb{AC}{-}\delta^1\mathbb{B}{\cdot}\left(\frac{h^1}{n^1}\right)+\delta^1\mathbb{B}\cdot\left(\frac{h^Q}{n^Q}\right)}$$

and $n^1 = \frac{1-n^Q}{\mathbb{B}}$. With n^1 and n^Q, we can compute h^1, x^1, U^1, and h^Q. We now also have n^m,h^m, x^m,U^m, I^m and K^m. With the set $\{K^m\}_{m=1}^{M}$ we have the aggregate capital stock H. Total production of the numeraire good is $Q = An^Q\left[\frac{n^Q}{h^Q}\right]^{-\alpha}$ and the resource constraint for the numeraire good requires

$$Q = C + \mathbb{B}x^1 + G.$$

Given a level of government purchases G we can compute C as the residual. Our procedure is to calibrate the ratio $g = \frac{G}{C}$ and then solve for consumption as

$$C = \frac{Q - \mathbb{B}x^1}{1+g}$$

Finally, steady state real GDP in the model is (by definition)

$$GDP = C + \sum_{m=1}^{M} I^m + G$$

To make sure that the initial normalization $N = e = 1$ is consistent with our proposed steady state solution we must satisfy the labor supply condition

$$W = \frac{C^{\frac{1}{\sigma}}}{1-\tau^N}\frac{\phi}{1-\theta}[1]$$

which will require the parameter ϕ to be

$$\phi = W\frac{\left(1-\tau^N\right)(1-\theta)}{C^{\frac{1}{\sigma}}}.$$

Similarly, to ensure $e = 1$ we will require the steady state effort supply condition to be

$$e = \frac{\theta}{1-\theta}\frac{\phi}{\psi}[1] = 1$$

which requires

$$\psi = \frac{\theta}{1-\theta}\phi$$

Appendix D: Non-targeted Moments

In this appendix, we report simulated moments that were not targeted by the indirect inference procedure. The indirect inference estimator of the supply elasticity χ was chosen to match the empirical moments in Table 6—equipment production, equipment investment, hours worked at equipment firms, material inputs used at equipment firms, and measured TFP at equipment firms. The model also produces moments that we did not target but for which we have reduced-form estimates. Table D.1 reports non-targeted moments for each of the model specifications considered in Table 6. Specifically, the table reports the model implied moments for structures production, wage payments at equipment firms, equipment prices and structures prices. The left-hand side column displays the reduced-form estimates of these parameters from the data. The columns to the right report the model-implied moments.

Perhaps surprisingly, the model does a fairly good job of replicating the price estimates. The equipment price coefficients are all close to zero while the structures price estimates are roughly 0.2—again close to their empirical counterparts. The moments where the model fit is worst is with wage changes and structures investment. The structural model was constructed to match data on equipment production and purchases. Structures seem to react substantially more strongly to investment subsidies and are likely described by a different supply specification. Thus, it is perhaps not surprising that the structures production moments fail to match.

The wage response in the data is quite muted (0.12 in our preferred econometric specification) while it is more pronounced in the model. This discrepancy could reflect several possibilities. First, the model assumes that wages are allocative while in the real world there is evidence that wage payments are not purely allocative. Second, the baseline calibration for the model features an intermediate value for the long-run substitutability of labor across sectors (determined by the parameter ψ_n). It is possible that the relatively low estimate of the wage reaction to investment subsidies is indicative of greater substitutability than we have in the baseline specification (e.g., see the last column of Table D.1). Finally, the reader will note that the wage estimates themselves are not consistent from one reduced-form specification to another (see Table 4 in the text).

Appendix E: Allowing for International Borrowing and Lending

In this appendix, we consider the consequences of modifying the model to allow for international borrowing and lending of the numeraire good in addition to allowing trade in equipment goods.

To allow for international borrowing and lending we introduce another "country" which we simply refer to as the "Rest of the World" or the ROW. This country seeks to maximize

$$\sum_{t=0}^{\infty} \beta^t \frac{\left(C_t^{\text{row}}\right)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}$$

subject to

$$Q^{\text{row}} + S_{t-1}^{\text{row}} \left(1 + r_{t-1}\right) = C_t^{\text{row}} + S_t^{\text{row}}.$$

Where Q^{row} is a constant real endowment of the numeraire good. S^{row} is real savings and C^{row} is real consumption of the numeraire good by the ROW. The solution to this optimization problem requires

$$\left(C_t^{\text{row}}\right)^{-\frac{1}{\sigma}} = \left(1 + r_t\right) \beta E_t \left[\left(C_{t+1}^{\text{row}}\right)^{-\frac{1}{\sigma}}\right].$$

We now require a bond market clearing condition $S_t^{\text{row}} + S_t = 0$. We modify the domestic economy's resource constraint to include savings so

$$Q_t + S_{t-1} \left(1 + r_{t-1}\right) = C_t + X_t + \sum_{m=1}^{M} P_t^m IMP_t^m + G_t + S_t.$$

We also modify the domestic definition of real GDP (Y_t) to allow for non-zero net exports

$$Y_t = C_t + \sum_{m=1}^{M} P^m \cdot \left[I_t^m + IMP_t^m\right] + G_t + \left\{S_t - S_{t-1}\left(1 + r_{t-1}\right)\right\}$$

Note that if we let $\tilde{S}_t^{\text{row}} \equiv \frac{dS_t^{\text{row}}}{Q^{\text{row}}}$ and $\tilde{S}_t \equiv \frac{dS_t}{Q}$ then the linearized version of the bond market clearing condition $S_t^{\text{row}} + S_t = 0$ is

$$\left(\frac{Q^{\text{row}}}{Q^{\text{row}} + Q}\right) \tilde{S}_t^{\text{row}} + \left(1 - \frac{Q^{\text{row}}}{Q^{\text{row}} + Q}\right) \tilde{S}_t = 0$$

where $\omega \equiv \left(\frac{Q^{\text{row}}}{Q^{\text{row}} + Q}\right)$ is the ratio of the "size" of the ROW relative to the total market for the numeraire good. If $\omega = 0$ then the ROW is so small that it has no influence on the domestic equilibrium. This corresponds with the case of period by period balanced trade with the foreign suppliers of tradeable equipment. If $\omega = 1$ then the ROW is so much larger than the domestic economy that the domestic market effectively faces a fixed real interest rate for the numeraire good. This corresponds to a case of a small open economy. Intermediate cases are associated with an upward sloping supply of savings.

Tables E.1 and E.2 show the consequences of allowing for an elastic supply of lendable funds. Table E.1 reproduces the estimates in Table 6 in the text under the assumption that $\omega = 1/2$. This implies that the "size" of the ROW is equal to the size of the domestic economy (the U.S.). Comparing the estimates of χ in Table E.1 to the estimates in Table 6 we see that the estimated supply of foreign equipment rises modestly across all specifications. Table E.2 considers the case in which $\omega = 3/4$ which implies that the ROW is three times as large as the U.S. Again, the estimates increase modestly for all of the specifications. The results in these tables suggest that the estimates of χ are, for the most part, robust to whether the U.S. borrows to finance purchases of foreign equipment.

Figure E.1 shows the aggregate consequences of allowing for international borrowing and lending of the numeraire. In the figure, we report aggregate investment purchases, aggregate investment production, aggregate GDP and aggregate imports. Each line corresponds to a different value for ω. The dark thin lines are for lower values of ω while the light thick lines are for high values of ω (approaching 1.00). The baseline model considered in the text corresponds to $\omega = 0$.

The reader will notice that variations in ω have relatively little impact on aggregate investment purchases, production or imports. On the other hand, as we change ω aggregate GDP does change noticeably. In particular, for $\omega = 0$, GDP rises moderately with the onset of the subsidy. The reason for this is twofold: first the subsidy encourages domestic production of investment goods; Second the subsidy encourages purchases of investment goods from foreign suppliers. Given our baseline assumption of balanced trade, the import of foreign investment goods necessitates the contemporaneous production and export of the numeraire good. Both forces work to increase GDP in the short run. For $\omega = 1$, there is no immediate increase in GDP. Instead, while domestic production of investment goods increases, importing investment goods from abroad can be financed over time. Thus, while the overall stimulus to GDP is roughly the same, it is spread out over time when we allow for borrowing and lending from abroad.

TABLE A.1. ROMER AND ROMER (2009) CLASSIFICATION OF CHANGES IN TAX LAWS

Law Name	Public Law No.	Romer and Romer (2009) Classification	Motivation
Internal Revenue Code of 1954	83-591	Exogenous	Long-run
Small Business Tax Revision Act of 1958	85-699	Exogenous	Long-run
Revenue Act of 1962	87-834	Exogenous	Long-run
Tax Rate Extension Act of 1962	87-507	Exogenous	Long-run
Revenue Act of 1964	88-272	Exogenous	Long-run
Suspension of Investment Tax Credit of 1966	89-800	Endogenous	Countercyclical
Restoration of Investment Tax Credit	90-26	Exogenous	Long-run
Tax Reform Act of 1969	91-172	Exogenous Endogenous	Long-run Countercyclical
Reform of Depreciation Rules of 1971	n.a.	Exogenous	Long-run
Revenue Act of 1971	92-178	Exogenous	Long-run
Tax Reduction Act of 1975	94-12	Endogenous	Countercyclical
Tax Reform Act of 1976	94-455	Exogenous	Long-run
Revenue Act of 1978	95-600	Exogenous	Long-run
Economic Recovery Tax Act of 1981	97-34	Exogenous	Long-run
Tax Equity and Fiscal Responsibility Act of 1982	97-248	Exogenous	Deficit-driven

Law Name	Public Law No.	Romer and Romer (2009) Classification	Motivation
Deficit Reduction Act of 1984	98-369	Exogenous	Deficit-driven
Tax Reform Act of 1986	99-514	Exogenous	Long-run
Tax Relief Act of 1997	105-34	Exogenous	Deficit-driven
Job Creation and Worker Assistance Act of 2002	107-147	Endogenous	Countercyclical
Jobs and Growth Tax Relief Reconciliation Act of 2003	108–27	Endogenous	Countercyclical
The Economic Stimulus Act of 2008	110–185	Endogenous	Countercyclical
American Recovery and Reinvestment Act of 2009	111-5	Endogenous	Countercyclical
Small Business Jobs Act of 2010	111-240	Endogenous	Countercyclical
Tax Relief, Unemployment Insurance Reauthorization, Job Creation Act of 2010	111-312	Endogenous	Countercyclical
The American Taxpayer Relief Act of 2012	112–240	Endogenous	Countercyclical
The Tax Increase Prevention Act of 2014	113-295	Endogenous	Countercyclical

TABLE B.1: EFFECTS OF INVESTMENT SUBSIDIES ON EQUIPMENT PRODUCTION, PURCHASES AND PRICES USING ALTERNATIVE MEASURES OF INVESTMENT SUBSIDIES

	Specification			
Dependent Variable	Constant and linear trend	Macro covariates excluding oil	Macro covariates	Leads and lags of subsidy
		A. Investment Tax Credit		
Production	2.09	2.12	2.66	2.91
	(0.50)	(0.45)	(0.52)	(0.53)
Purchases	2.94	2.97	3.02	3.31
	(0.64)	(0.56)	(0.65)	(0.63)
Diff.: Prod. – Purch	0.85	0.85	0.37	0.39
	(0.20)	(0.18)	(0.21)	(0.22)
Production Prices	0.02	-0.11	0.14	0.18
	(0.13)	(0.09)	(0.13)	(0.15)
Purchases Prices	-0.20	-0.24	-0.08	-0.08
	(0.14)	(0.09)	(0.14)	(0.15)
		B. User Cost Tax Adjustment		
Production	1.28	1.28	1.28	1.41
	(0.33)	(0.31)	(0.36)	(0.38)
Purchases	1.73	1.73	1.44	1.60
	(0.44)	(0.41)	(0.47)	(0.49)
Diff.: Prod. – Purch	0.45	0.44	0.16	-0.19
	(0.14)	(0.14)	(0.15)	(0.16)
Production Prices	0.00	-0.08	-0.01	0.02
	(0.07)	(0.06)	(0.07)	(0.07)
Purchases Prices	-0.09	-0.09	-0.01	0.01
	(0.08)	(0.06)	(0.08)	(0.09)

Notes. The dependent variable is the natural logarithm of equipment production or equipment purchases as indicated. The independent variable is either the investment tax credit, ITC^m (Panel A) or the user cost tax adjustment, Φ^m (Panel B). The coefficients are semi-elasticities of production or purchases with respect to the subsidy (b_1 in equation 5). The columns report specifications with alternative control variables or lags. The specification in the last column reports the sum of the coefficients on the current and two leads and lags of the subsidy. This last specification also includes the macro covariates. Driscoll-Kraay standard errors are shown in parentheses. As described in Section III in the text, the sample is a quarterly panel of 28 types of equipment from 1959:1 to 2009:4.

Table B.2: Investment Tax Credit (ITC)

		Specification / Sample Period							
Investment Type	Goolsbee (1998)	(a) 1959-1988 Vintage Data		(b) (a) + revised eqp price data		(c) (b) + revised macro data		(d) 1959-1988 Current data /specification	(e) 1959-2009 Current data /specification
	Quasi Diff	OLS	Quasi Diff	OLS	Quasi Diff	OLS	Quasi Diff	OLS	OLS
Pooled	0.390	0.551	0.177	-0.164	-0.271	-0.143	-0.133	0.298	0.038
	(0.036)	(0.129)	(0.074)	(0.090)	(0.062)	(0.089)	(0.057)	(0.075)	(0.035)
Furniture	0.024	-0.098	-0.051	-0.496	-0.270	-0.483	-0.302	0.105	-0.300
	(0.137)	(0.159)	(0.159)	(0.119)	(0.132)	(0.121)	(0.128)	(0.175)	(0.066)
Fabricated metals	0.745	1.159	0.223	0.548	0.449	0.706	0.443	0.449	-0.264
	(0.170)	(0.321)	(0.288)	(0.299)	(0.278)	(0.270)	(0.281)	(0.262)	(0.149)
Engines	0.664	0.853	-0.020	0.650	0.205	0.774	0.145	0.689	-0.299
	(0.248)	(0.320)	(0.284)	(0.378)	(0.370)	(0.355)	(0.372)	(0.529)	(0.186)
Tractors	0.710	0.331	0.378	-0.013	-0.181	0.058	0.215	0.401	-0.004
	(0.133)	(0.175)	(0.173)	(0.196)	(0.265)	(0.187)	(0.129)	(0.193)	(0.110)
Agricutural machinery	0.976	0.660	0.513	0.097	-0.149	0.178	0.312	0.635	0.065
	(0.195)	(0.263)	(0.326)	(0.169)	(0.224)	(0.161)	(0.131)	(0.159)	(0.101)
Construction machinery	0.481	0.435	-0.035	0.324	0.168	0.329	0.275	-0.055	0.156
	(0.145)	(0.474)	(0.649)	(0.234)	(0.285)	(0.228)	(0.210)	(0.384)	(0.131)
Mining machinery	1.674	1.221	0.104	0.885	0.021	1.079	0.078	0.476	0.032
	(0.243)	(0.406)	(0.307)	(0.397)	(0.385)	(0.379)	(0.386)	(0.369)	(0.163)
Metalworking machinery	0.432	0.283	0.069	-0.237	-0.141	-0.157	-0.158	0.192	-0.301
	(0.183)	(0.172)	(0.198)	(0.221)	(0.269)	(0.222)	(0.268)	(0.235)	(0.104)
Special ind. machinery	0.150	0.057	0.023	-0.268	-0.199	-0.214	-0.246	-0.015	-0.294
	(0.139)	(0.125)	(0.147)	(0.174)	(0.217)	(0.173)	(0.153)	(0.222)	(0.089)
General industrial	0.206	0.307	0.305	-0.229	-0.272	-0.221	-0.278	-0.020	-0.191
	(0.162)	(0.158)	(0.146)	(0.174)	(0.171)	(0.184)	(0.172)	(0.265)	(0.085)
Office/computers	-0.761	2.958	-0.378	-1.608	-0.415	-2.272	-0.015	0.210	1.458
	(0.492)	(2.176)	(0.881)	(1.393)	(0.932)	(1.350)	(0.936)	(1.001)	(0.424)
Service ind. machinery	0.125	0.001	0.015	-0.477	-0.433	-0.434	-0.431	0.211	0.162
	(0.112)	(0.092)	(0.109)	(0.142)	(0.110)	(0.142)	(0.103)	(0.149)	(0.067)

Table B.2 (cont.): Investment Tax Credit (ITC)

Investment Type	Goolsbee (1998)	Specification / Sample Period							
		(a) 1959-1988 Vintage Data		(b) (a) + revised eqp price data		(c) (b) + revised macro data		(d) 1959-1988 Current data /specification	(e) 1959-2009 Current data /specification
	Quasi Diff	OLS	Quasi Diff	OLS	Quasi Diff	OLS	Quasi Diff	OLS	OLS
Electrical distribution	0.260	-0.035	0.140	-0.313	-0.249	-0.246	-0.264	0.843	0.355
	(0.183)	(0.206)	(0.210)	(0.210)	(0.194)	(0.205)	(0.161)	(0.315)	(0.124)
Communication equip.	-0.603	-0.424	-0.186	-0.452	-0.259	-0.552	-0.265	-0.055	0.734
	(0.210)	(0.221)	(0.136)	(0.251)	(0.204)	(0.249)	(0.200)	(0.239)	(0.121)
Electrical equipment	0.894	0.471	0.197	-0.530	-0.534	-0.513	-0.532	0.175	-0.373
	(0.181)	(0.306)	(0.192)	(0.134)	(0.091)	(0.138)	(0.119)	(0.205)	(0.085)
Trucks and buses	0.787	0.176	-0.081	-0.249	-0.505	-0.087	-0.525	0.363	-0.118
	(0.230)	(0.408)	(0.290)	(0.423)	(0.428)	(0.375)	(0.426)	(0.334)	(0.245)
Autos	-0.583	1.971	1.698	-2.393	-1.652	-2.371	-1.684	-1.867	-1.552
	(0.194)	(1.130)	(1.234)	(0.397)	(0.363)	(0.393)	(0.351)	(0.426)	(0.209)
Aircraft	1.010	0.380	0.445	-0.244	-0.456	-0.189	-0.389	0.713	0.538
	(0.184)	(0.390)	(0.408)	(0.192)	(0.208)	(0.189)	(0.193)	(0.220)	(0.094)
Ships and boats	0.591	0.470	-0.282	-0.346	-0.275	-0.276	-0.275	0.384	-0.262
	(0.120)	(0.310)	(0.202)	(0.156)	(0.180)	(0.152)	(0.176)	(0.135)	(0.084)
Railroad equipment	1.091	1.159	1.031	0.838	0.335	0.982	0.257	0.908	0.089
	(0.170)	(0.367)	(0.275)	(0.359)	(0.376)	(0.346)	(0.378)	(0.399)	(0.152)
Instruments	-0.349	-0.049	-0.079	-0.524	-0.537	-0.585	-0.520	0.560	0.081
	(0.172)	(0.111)	(0.101)	(0.178)	(0.163)	(0.190)	(0.169)	(0.181)	(0.057)

Notes: The table reports the estimated coefficient on the type specific investment tax credit. The left hand side variable is the log of real equipment prices as described in Appendix B. Columns (a) – (e) indicate different econometric specifications. Specification (a) limits the sample to 1959-1988 and uses vintage data as described in Appendix B. Regressors include linear time trend, growth rate of real GDP, Nixon price controls, and exchange rates for the German DM and Japanese Yen. Specification (b) is the same as (a) but uses revised (current) data for equipment prices; (c) is the same as (b) but uses revised data for macroeconomic covariates; (d) is the same as (c) but changes the regression specification to include a piecewise-linear time trend, HP-filtered real GDP, Nixon price controls, and real oil prices; (e) is the same as (d) but extends the sample period to 1959-2009.

Table B.3: User Cost Tax Adjustment (negative)

		Specification / Sample Period							
Investment Type	Goolsbee (1998)	(a) 1959-1988 Vintage Data		(b) (a) + revised eqp price data		(c) (b) + revised macro data		(d) 1959-1988 Current data /specification	(e) 1959-2009 Current data /specification
	Quasi Diff	OLS	Quasi Diff	OLS	Quasi Diff	OLS	Quasi Diff	OLS	OLS
Pooled	-0.170	-0.263	-0.133	0.030	0.010	0.007	-0.017	-0.180	-0.088
	(0.028)	(0.075)	(0.042)	(0.052)	(0.039)	(0.051)	(0.033)	(0.033)	(0.018)
Furniture	-0.024	0.069	0.024	0.276	0.043	0.259	0.052	-0.060	0.146
	(0.077)	(0.093)	(0.088)	(0.073)	(0.083)	(0.074)	(0.083)	(0.075)	(0.036)
Fabricated metals	-0.413	-0.678	-0.096	-0.381	-0.320	-0.443	-0.322	-0.143	-0.573
	(0.073)	(0.176)	(0.155)	(0.162)	(0.138)	(0.142)	(0.140)	(0.109)	(0.081)
Engines	-0.345	-0.397	-0.167	-0.301	-0.187	-0.373	-0.164	-0.385	0.136
	(0.145)	(0.192)	(0.161)	(0.220)	(0.210)	(0.209)	(0.213)	(0.219)	(0.089)
Tractors	-0.498	-0.136	-0.183	-0.034	-0.001	-0.097	-0.170	-0.198	0.014
	(0.112)	(0.108)	(0.113)	(0.115)	(0.151)	(0.110)	(0.071)	(0.088)	(0.057)
Agricutural machinery	-0.485	-0.386	-0.371	-0.112	-0.067	-0.164	-0.233	-0.245	-0.055
	(0.112)	(0.145)	(0.167)	(0.092)	(0.116)	(0.085)	(0.059)	(0.074)	(0.051)
Construction machinery	-0.288	-0.293	-0.163	-0.168	-0.138	-0.227	-0.188	-0.457	-0.017
	(0.078)	(0.324)	(0.399)	(0.162)	(0.192)	(0.163)	(0.154)	(0.264)	(0.077)
Mining machinery	-0.882	-0.767	-0.122	-0.591	-0.158	-0.681	-0.181	-0.232	-0.134
	(0.127)	(0.234)	(0.170)	(0.228)	(0.214)	(0.215)	(0.215)	(0.171)	(0.089)
Metalworking machinery	-0.169	-0.226	-0.067	-0.029	-0.018	-0.063	-0.012	-0.069	-0.028
	(0.095)	(0.094)	(0.103)	(0.131)	(0.139)	(0.125)	(0.140)	(0.098)	(0.057)
Special ind. machinery	-0.085	-0.091	-0.086	0.057	-0.008	0.028	0.060	-0.150	0.039
	(0.066)	(0.067)	(0.078)	(0.101)	(0.125)	(0.097)	(0.082)	(0.100)	(0.047)
General industrial	-0.130	-0.193	-0.202	0.069	0.115	0.064	0.129	-0.162	0.031
	(0.083)	(0.088)	(0.086)	(0.101)	(0.101)	(0.104)	(0.100)	(0.134)	(0.046)
Office/computers	0.483	-0.468	0.072	0.799	-0.182	1.036	-0.449	-0.203	-0.655
	(0.266)	(1.400)	(0.467)	(0.873)	(0.527)	(0.839)	(0.522)	(0.429)	(0.254)
Service ind. machinery	-0.071	-0.052	-0.065	0.167	0.028	0.136	0.192	-0.072	-0.079
	(0.060)	(0.055)	(0.061)	(0.100)	(0.124)	(0.097)	(0.075)	(0.071)	(0.034)

Table B.3 (cont.): User Cost Tax Adjustment (negative)

Investment Type	Goolsbee (1998)	Specification / Sample Period							
		(a) 1959-1988 Vintage Data		(b) (a) + revised eqp price data		(c) (b) + revised macro data		(d) 1959-1988 Current data /specification	(e) 1959-2009 Current data /specification
	Quasi Diff	OLS	Quasi Diff	OLS	Quasi Diff	OLS	Quasi Diff	OLS	OLS
Electrical distribution	-0.130	-0.037	-0.157	0.131	0.023	0.095	0.150	-0.401	-0.242
	(0.073)	(0.121)	(0.114)	(0.126)	(0.135)	(0.121)	(0.090)	(0.138)	(0.062)
Communication equip.	0.183	0.251	0.047	0.314	0.191	0.361	0.200	0.079	-0.145
	(0.092)	(0.129)	(0.085)	(0.143)	(0.120)	(0.140)	(0.119)	(0.102)	(0.068)
Electrical equipment	-0.429	-0.424	-0.174	0.214	0.060	0.202	0.108	-0.149	0.078
	(0.092)	(0.168)	(0.094)	(0.093)	(0.104)	(0.091)	(0.097)	(0.087)	(0.048)
Trucks and buses	-0.419	-0.025	0.004	0.221	0.109	0.048	0.123	-0.101	0.414
	(0.174)	(0.265)	(0.159)	(0.272)	(0.246)	(0.249)	(0.246)	(0.184)	(0.134)
Autos	0.341	-0.512	-0.643	1.093	0.935	1.103	0.933	0.352	0.632
	(0.129)	(0.598)	(0.693)	(0.227)	(0.203)	(0.244)	(0.203)	(0.307)	(0.107)
Aircraft	-0.539	-0.254	-0.291	0.099	0.258	0.045	0.213	-0.351	-0.235
	(0.134)	(0.235)	(0.253)	(0.119)	(0.129)	(0.119)	(0.124)	(0.118)	(0.053)
Shipts and boats	-0.206	-0.237	0.166	0.031	-0.004	0.010	-0.012	-0.190	-0.290
	(0.055)	(0.149)	(0.093)	(0.083)	(0.094)	(0.075)	(0.094)	(0.043)	(0.037)
Railroad equipment	-0.486	-0.546	-0.502	-0.420	-0.202	-0.469	-0.175	-0.322	-0.129
	(0.081)	(0.199)	(0.152)	(0.189)	(0.190)	(0.180)	(0.192)	(0.148)	(0.072)
Instruments	0.164	0.005	0.041	0.233	0.239	0.247	0.229	-0.210	-0.068
	(0.090)	(0.071)	(0.063)	(0.123)	(0.112)	(0.131)	(0.114)	(0.084)	(0.032)

Notes: The table reports the estimated coefficient on the type specific user cost tax adjustment (see equation 4 in the text). The left hand side variable is the log of real equipment prices as described in Appendix B. Columns (a) – (e) indicate different econometric specifications. Specification (a) limits the sample to 1959-1988 and uses vintage data as described in Appendix B. Regressors include linear time trend, growth rate of real GDP, Nixon price controls, and exchange rates for the German DM and Japanese Yen. Specification (b) is the same as (a) but uses revised (current) data for equipment prices; (c) is the same as (b) but uses revised data for macroeconomic covariates; (d) is the same as (c) but changes the regression specification to include a piecewise-linear time trend, HP-filtered real GDP, Nixon price controls, and real oil prices; (e) is the same as (d) but extends the sample period to 1959-2009.

TABLE D.1. INDIRECT INFERENCE ESTIMATES: NON-TARGETED MOMENTS

Model Specification	Data	Baseline	Low λ	High λ	Low θ	High θ	Low adj. costs	High adj. costs	Low ψ_n	High ψ_n
Estimated Import Supply Elasticity (χ)		6.53 (1.56)	7.22 (1.61)	5.17 (1.36)	3.06 (0.84)	24.14 (11.68)	13.99 (2.43)	3.13 (0.95)	5.02 (1.12)	16.31 (5.41)
Reduced-form coefficients		Reduced-Form Coefficients Implied by Model								
Structures Investment	0.46 (0.31)	1.78	1.81	1.70	1.53	2.11	2.02	1.55	1.73	1.90
Wage Bill	0.12 (0.96)	0.60	0.61	0.59	0.61	0.62	0.56	0.64	0.77	0.26
Equipment Prices	0.07 (0.08)	0.09	0.10	0.09	0.14	0.03	0.05	0.14	0.10	0.05
Structures Prices	0.22 (0.09)	0.27	0.29	0.25	0.33	0.22	0.20	0.33	0.29	0.24

Notes: The first row reports indirect inference estimates of the import supply elasticity under baseline and alternative values of the calibrated parameters. The inferences are based on targeting the reduced-form regression coefficients shown in the first column. The model-implied estimates of these parameters are given in the balance of the table.

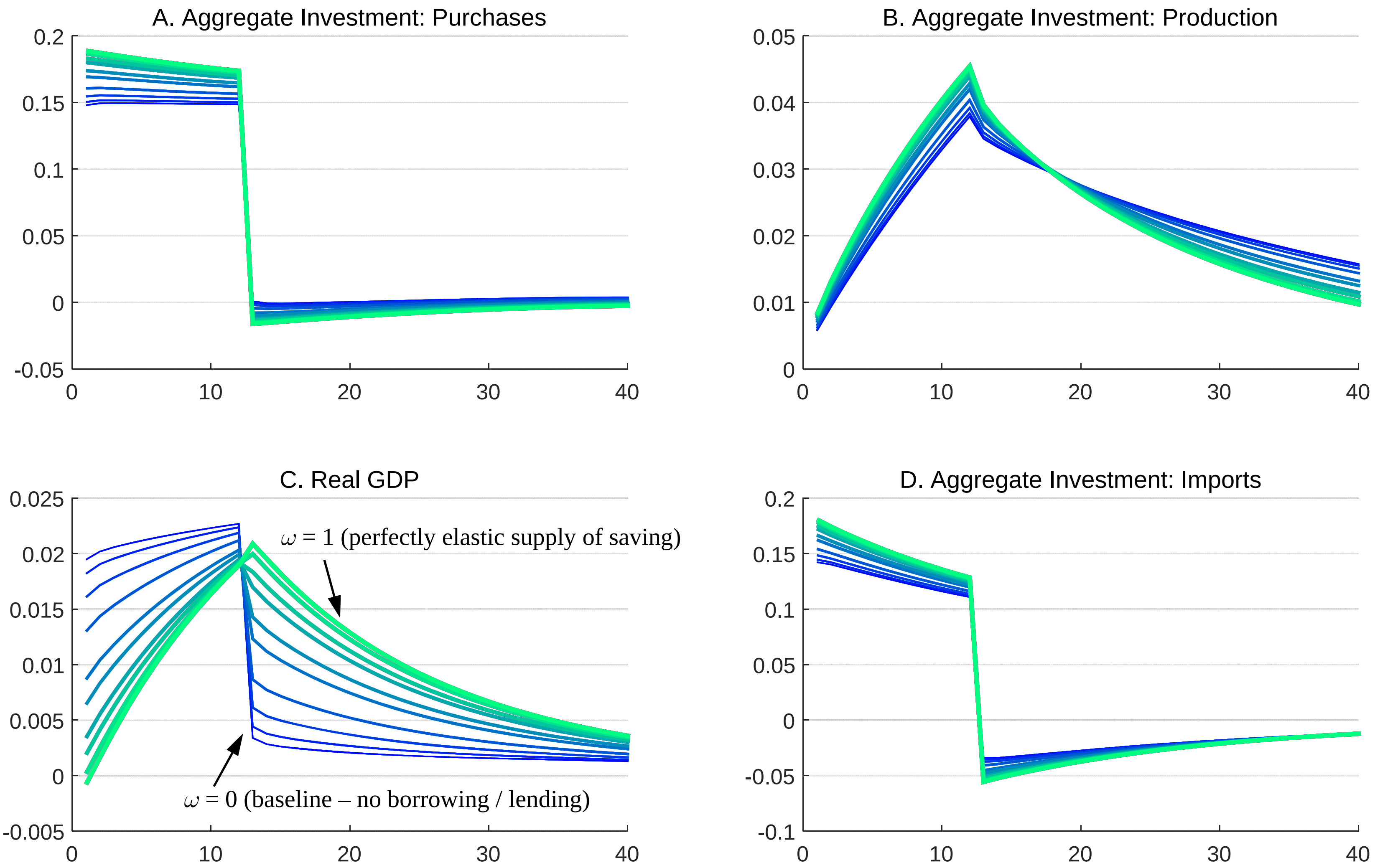
TABLE E.1. INDIRECT INFERENCE ESTIMATES AND INTERNATIONAL BORROWING ($\omega = 1/2$, ROW IS SAME SIZE AS U.S.)

Model Specification	Data	Baseline	Low λ	High λ	Low θ	High θ	Low adj. costs	High adj. costs	Low ψ_n	High ψ_n
Estimated Import Supply Elasticity (χ)		7.47 (1.78)	8.17 (1.82)	5.94 (1.55)	3.59 (0.93)	24.57 (12.81)	17.06 (2.04)	3.72 (0.00)	5.65 (1.24)	21.61 (8.05)
Targeted Reduced-form coefficients		Reduced-Form Coefficients Implied by Model								
Equipment Production	1.08 (0.40)	1.02	1.04	1.01	1.00	1.17	1.04	0.98	1.03	0.99
Equipment Investment	1.76 (0.43)	1.63	1.78	1.49	1.47	1.90	1.77	1.47	1.58	1.80
Hours	0.65 (0.54)	0.57	0.58	0.57	0.62	0.59	0.55	0.59	0.44	0.80
Material Inputs	0.81 (0.51)	1.02	1.04	1.01	1.00	1.17	1.04	0.98	1.03	0.99
Productivity (TFP)	0.28 (0.15)	0.04	0.04	0.04	0.00	0.09	0.04	0.04	0.05	0.02

Table E.2. Indirect Inference Estimates and International Borrowing ($\omega = 3/4$, ROW is 3x size U.S.)

Model Specification	Data	Baseline	Low λ	High λ	Low θ	High θ	Low adj. costs	High adj. costs	Low ψ_n	High ψ_n
Estimated Import Supply Elasticity (χ)		9.13 (2.2)	9.81 (2.21)	7.29 (1.89)	4.24 (1.06)	23.77 (13.41)	24.01 (4.65)	3.92 (1.13)	6.69 (1.46)	30.00 (13.68)
Targeted Reduced-form coefficients	Reduced-Form Coefficients Implied by Model									
Equipment Production	1.08 (0.40)	1.03	1.05	1.02	1.01	1.25	1.04	1.00	1.04	1.04
Equipment Investment	1.76 (0.43)	1.68	1.84	1.54	1.53	1.91	1.85	1.50	1.63	1.88
Hours	0.65 (0.54)	0.56	0.57	0.55	0.59	0.63	0.54	0.59	0.42	0.82
Material Inputs	0.81 (0.51)	1.03	1.05	1.02	1.01	1.25	1.04	1.00	1.04	1.04
Productivity (TFP)	0.28 (0.15)	0.04	0.04	0.04	0.00	0.09	0.04	0.04	0.05	0.02

FIGURE E.1. TEMPORARY INVESTMENT SUBSIDY FOR EQUIPMENT WITH INTERNATIONAL BORROWING



Notes: The figure reports the simulated impulse response functions for the selected variables. The investment subsidy is a 10 percent subsidy for equipment (structures are not eligible) and has an expected horizon of 3 years as described in the text. The figure plots a sample realization in which the policy sunsets in exactly 3 years. Each line corresponds to a different value of the parameter ω as described in Appendix E.