House and Shapiro AER 2008 Bonus Depreciation

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Outline

Overview of House and Shapiro (2008)

The Model

Test the model

Take-away

Big picture question: how firms' investments respond to tax increases/decreases

- Literature starts from at least Hall and Jorgenson (1967)
- The direction is quite straightforward: effective tax rate increase reduce investment by increasing the after-tax cost of capital, and vice versa.
- What really matters is the magnitude, which would be determined by demand and supply elasticities of capital-goods investment.
- A temporary reduction in effective tax rate should result in a very large demand response (i.e., close to infinite demand elasticity).
- How the equilibrium market price (and thus quantity) for capital goods will depend on the magnitude of supply elasticity.
- HS builds a model and uses the bonus depreciation setting to obtain the empirical estimate of the supply elasticity as well as equilibrium response of price and quantity.

Outline

Model setup

- Denote $m \in \{1, 2, ..., M\}$ as an index of different types of capital goods. For each type m, denote δ^m be the economic rate of depreciation and K^m be the capital stock.
- Consider a representative firm. The firm's production function at period t is $F(K_t^1, K_t^2, .., K_t^M)$.
- Assume double taxation on capital income: a profit tax with the tax rate denoted by τ_t^π and a dividend and capital gain tax rate denoted by τ_t^d at period t.

Model setup - continued

- Optimization problem of the firm:

$$\max_{\{K^m_{t+1}, I^m_t\}} \sum_{j=0}^{+\infty} \Gamma_{t+j} \{ (1-\tau^d_{t+j})(1-\tau^\pi_{t+j}) F(K^1_{t+j}, K^2_{t+j}, .., K^M_{t+j}) - \sum_{m=1}^{M} \varphi^m_{t+j} I^m_{t+j} (1-\zeta^m_{t+j}) \} \tag{1}$$

s.t.

$$K^m_{t+1} = K^m_t (1-\delta^m) + I^m_t \; \forall m. \tag{2}$$

- φ^m_t is the relative price of type m capital at period t (the output is taken as the numeraire good); I^m_t is the gross investment of type m capital at period t; ζ^m_t is the total subsidy of new purchases of type m capital (so bonus depreciation will temporarily increase ζ^m_t for certain types of capital goods); Γ_{t+j} is the stochastic discount factor, which is equal to $\beta^j \frac{u'(C_{t+j})}{u'(C_t)}$ and normalized to $\beta^j u'(C_{t+j})$, as $u'(C_t)$ is a known constant at time t.

FOCs

- Denote q_t^m as the Lagrangian multipliers for the constraints of equation (2) (one constraint for each type of capital at each period), FOCs with respect to K_{t+1}^m and I_t^m results in, $\forall m$,

$$q_t^m = \beta u'(C_{t+1})[(1-\tau_{t+1}^{\pi})(1-\tau_{t+1}^{d})\frac{\partial F}{\partial K_{t+1}^m}] + \beta(1-\delta^m)q_{t+1}^m, \tag{3}$$

and

$$q_t^m = u'(C_t)\varphi_t^m(1-\zeta_t^m). \tag{4}$$

- Temporary investment tax subsidy such as the bonus depreciation can be modelled as an increase in ζ_t^m for a subset of investment goods.

Making assumptions to solve the model - implication for prices of capital goods

- First, the increase in ζ_t^m is temporary; second, the investment goods affected must have low depreciation (i.e., δ^m close to zero); finally, focus on steady state, i.e., $q_t^m = q^m$, $K_t^m = K^m$ and $C_t = C$.
- From equation (3), one can write the expression of q_t^m as

$$q_t^m = \beta \sum_{j=0}^{+\infty} \{ u'(C_{t+1}) [\beta(1-\delta^m)]^j [(1-\tau_{t+j+1}^{\pi})(1-\tau_{t+j+1}^{d}) \frac{\partial F}{\partial K_{t+1}^m}] \}.$$

  Therefore the steady state assumption holds if the change is temporary (as only the first few terms matter) and δ^m is close to zero (as the difference in the first few terms will be small, provided that β is also sufficiently close to 1).

Making assumptions to solve the model - implication for prices of capital goods, continued

- To determine equilibrium price and quantity, assume the (inverse) supply function of capital to be

$$\varphi_t^m(I_t^m) = (\frac{I_t^m}{I^m})^{\frac{1}{\xi}} \tag{5}$$

  with ξ being the supply elasticity.

- Equation (4) evaluated at the steady state therefore results in (typo in the original paper)

$$\varphi_t^m = \frac{q^m}{u'(C_t)(1-\zeta_t^m)}$$

  which is independent of both ξ and I_t^m. Therefore for temporary tax subsidies, pre-tax prices of long-term investment goods fully reflect the subsidies.

Making assumptions to solve the model - implication for quantities of capital goods

- Assume further the CRRA utility function, $u(C_t) = \frac{1}{-\frac{1}{\sigma}+1}(C_t)^{-\frac{1}{\sigma}+1}$, then $u'(C_t) = C_t^{-\frac{1}{\sigma}}$ where σ is the elasticity of intertemporal substitution for consumption.
- For any variable v_t with steady state value v, denote $dv_t \equiv v_t - v$ be the deviation from the steady-state value and $\widetilde{v}_t \equiv \frac{dv_t}{v}$ be the percent deviation from the steady-state value, then, combining equations (4) and (5) results in

$$\widetilde{I}_t^m = \xi \frac{d\zeta_t^m}{1-\zeta_t^m} + \frac{\xi}{\sigma}\widetilde{C}_t. \tag{6}$$

- From equation (6), if the tax subsidy does not affect aggregate consumption, $\widetilde{C}_t = 0$, then ξ can be inferred from $\widetilde{I}_t^m$ (i.e., the change in investment), given that we know ζ_t^m and $d\zeta_t^m$. In addition, when $d\zeta_t^m = 0$ (i.e., when the subsidy expires), $\widetilde{I}_t^m = 0$, that is, the investment returns to its steady-state value.

Intuition and graphical illustration

- Intuitively, when the tax incentive is temporary and the capital is sufficiently long-term (i.e., making investment now versus a couple of years later matter very little), demand elasticity is infinity.
- This infinite demand elasticity results in quantity change solely determined by supply elasticity and price response one-to-one with tax incentives.

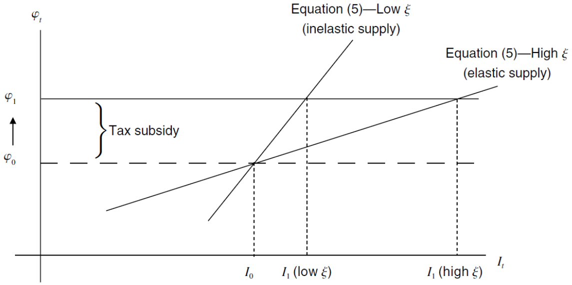

Figure 1. Price and Quantity Responses to Temporary Investment Subsidies

Specifically modelling bonus depreciation

- The model so far is quite general, in the sense that ζ_t^m is not specified.
- The paper then follows Hall and Jorgenson (1967) in calculating ζ_t^m: assuming that the firm immediately recovers the present value of depreciation deductions when it invests, that is, the present value of deductions is

$$z^m = \sum_{j=1}^{R} \frac{D_j^m}{(1+\pi)^j (1+r)^j},$$

where π is the constant inflation rate, r is the constant real interest rate, D_j^m is the schedule of depreciation deductions (e.g., schedule based on MACRS) and R is the estimated useful life.

Specifically modelling bonus depreciation

- Bonus depreciation allows for a proportion to be written off immediately. Therefore, denote λ_t^m as the bonus depreciation allowance for type m capital, the bonus depreciation changes the present value from z^m to $\lambda_t^m + (1 - \lambda_t^m) z^m$. We therefore have
$$\zeta_t^m = (1 - \tau^d)\tau^\pi(\lambda_t^m + (1 - \lambda_t^m) z^m), \tag{7}$$
with steady state $\lambda^m = 0$, resulting in
$$\frac{d\zeta_t^m}{1 - \zeta_t^m} = \frac{(1 - \tau^d)\tau^\pi(1 - z^m)}{1 - (1 - \tau^d)\tau^\pi z^m}\lambda_t^m.$$

Specifically modelling bonus depreciation, continued

- Considering time-varying real interest rate (but still constant inflation) results in

$$z_t^m = \sum_{j=1}^{R} \frac{D_j^m}{\prod_{s=0}^{j-1}(1+\pi)(1+r_{t+s})}. \tag{8}$$

- Basic asset-pricing formula for the risk-free rate results in

$$\frac{1}{\prod_{s=0}^{j-1}(1+r_{t+s})} = \beta^j \left(\frac{C_{t+j}}{C_t}\right)^{-\frac{1}{\sigma}} \tag{9}$$

Specifically modelling bonus depreciation, continued

- Insert equation (9) into equation (8) results in

$$z_t^m (C_t)^{-\frac{1}{\sigma}} = \sum_{j=1}^{R} \frac{D_j^m}{(1+\pi)^j} \beta^j (C_{t+j+1})^{\frac{1}{\sigma}}.$$

- Approximate $z_t^m (C_t)^{-\frac{1}{\sigma}}$ with its steady-state value $z^m (C)^{-\frac{1}{\sigma}}$ results in

$$dz_t^m \simeq z^m \frac{1}{\sigma} \widetilde{C}_t \tag{10}$$

Specifically modelling bonus depreciation, continued

- Totally differentiating equation (7) results in

$$d\zeta_t^m = (1-\tau^d)\tau^\pi((1-z_t^m)\lambda_t^m + dz_t^m) \tag{11}$$

- Substituting equation (10) into equation (11) and then insert into equation (6) results in

$$\widetilde{I}_t^m = \xi(\frac{(1-\tau^d)\tau^\pi(1-z^m)}{1-(1-\tau^d)\tau^\pi z^m})\lambda_t^m + \frac{\xi}{\sigma}\frac{1}{1-(1-\tau^d)\tau^\pi z^m}\widetilde{C}_t, \tag{12}$$

and

$$\widetilde{\varphi}_t^m = (\frac{(1-\tau^d)\tau^\pi(1-z^m)}{1-(1-\tau^d)\tau^\pi z^m})\lambda_t^m + \frac{1}{\sigma}\frac{1}{1-(1-\tau^d)\tau^\pi z^m}\widetilde{C}_t. \tag{13}$$

Outline

Underlying assumptions

- Use data on real investment spending and real investment prices to estimate the parameters of equation (12) and (13).
- Key assumptions: 1. $q_t^m \simeq q^m$ holds; 2. supply of capital function $\varphi_t^m(I_t^m) = (\frac{I_t^m}{I^m})^{\frac{1}{\xi}}$ is valid.

Data and variable construction

- Use BEA data to construct a quarterly panel of investment quantities and prices by type of capital, matched to IRS depreciation schedules.
- Real investment purchases are constructed by dividing nominal purchases by the price index for each type of capital.
- Relative price is defined by the price index divided by the price index for nondurable consumption from NIPA.
- To construct z_m, use actual MACRS depreciation schedules and assume an annual nominal interest rate of 5 percent.
- Set $\tau^{\pi} = 0.3425$, $\tau^{d} = 0.2975$, and HP-filtered real consumption of non-durables for $\widetilde{C}_t$.

Identification

- Equations (12) and (13) theoretically show how investment quantities and prices respond to bonus depreciation.
- Use the pre-bonus depreciation period to estimate investment and prices as functions of observables and thus forecast investment and prices in the absence of such policy in the bonus depreciation period, that is, the steady-state values.
- The deviation from steady-state values serve as dependent variables.
- Identification assumption: other factors that drive the deviation from steady-state values are uncorrelated with the differential impact of bonus depreciation by type of capital.
- However, if bonus depreciation aims at specific types of investment that is affected differentially by the macroeconomy (e.g., the 2001 recession), then the estimates will be biased.

How to estimate steady-state values

- Unfortunately, theory does not provide any guidance about how to determine the steady-state values.
- The paper includes t and $t-1$ values of type-specific investment quantities and prices, the log of aggregate real GDP, the corporate profit rate, the type-specific investment tax credit and a time trend.
- The paper then estimates the linear specifications for steady-state value estimation using the pre-bonus depreciation period.

Regression specification

- Once the specifications are determined, the errors in the post-bonus depreciation period represents firms' responses to bonus depreciation, which serves as dependent variables (similar to using Dechow-Dichev model to calculate earnings quality).
- Define
$$\Psi_1^m = \frac{(1-\tau^d)\tau^\pi(1-z^m)}{1-(1-\tau^d)\tau^\pi z^m}$$
and
$$\Psi_2^m = \frac{1}{1-(1-\tau^d)\tau^\pi z^m},$$
which can be calculated based on τ^π (assumed), τ^d (assumed) and z^m (observable from depreciation schedules) are all constant across time but differ across m.

Regression specification, continued

- We then have

$$\widehat{\varepsilon}_I^{t,m} = \beta_{I0} + \xi \lambda_t^m \Psi_1^m + \frac{\xi}{\sigma} \Psi_1^m \widetilde{C}_t + e_I^{t,m}$$

and

$$\widehat{\varepsilon}_p^{t,m} = \beta_{p0} + \beta_{p1} \lambda_t^m \Psi_1^m + \frac{1}{\sigma} \Psi_1^m \widetilde{C}_t + e_p^{t,m},$$

where $\lambda_t^m = 0.3$ or 0.5 for eligible capital during second quarter of 2002 to first quarter of 2004 and zero otherwise. ξ can then be estimated from the coefficient on $\lambda_t^m \Psi_1^m$ (ranges from 6 to 15).

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Innovative features of the paper

- Belongs to the long literature quantifying the response of investment to changes in tax laws.
- Innovative insight: long-term capital investment demand elasticity is infinite in response to temporary tax changes, implying that one can use the effect of temporary tax changes on the quantity of investment to estimate supply elasticity.