Production efficiency and the design of temporary investment incentives

William Jack\textsuperscript{a,\*}, Alan D. Viard\textsuperscript{b}

\textsuperscript{a}International Monetary Fund, European I Department, Room 9-411, 700 19th Street NW, Washington, DC 20431, USA
\textsuperscript{b}Ohio State University, Columbus, OH 43210, USA

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Abstract

The attainment of production efficiency requires that tax incentives equalize pretax rates of return on different assets at each point in time. To achieve this objective, the conventional theory of investment tax credits (ITCs) prescribes significantly lower credit rates on shorter-lived assets. However, this result is valid only for permanent ITCs. We show that the credit rates for temporary ITCs should be much closer to uniform than the conventional theory prescribes. This result is robust to the presence and specification of adjustment costs.

Keywords: Investment incentives; Neutrality; Temporary policies

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1. Introduction

The investment tax credit (ITC) has been frequently employed as an investment incentive in the United States and has been extensively studied by the economics profession. The analyses of economists and policy-makers have often stressed the desirability of designing the ITC in a manner that equalizes pretax rates of return across different types of asset, which is a
requirement for production efficiency. Previous analyses of the problem of designing neutral investment incentives, using Jorgenson's (1963) neoclassical theory, derived the conventional prescription that permanent ITC rates should be positively related to the life of the asset. This analysis has prompted the provision of lower credit rates for short-lived equipment in past US tax legislation and proposals. Economists and policy-makers have generally not examined whether these conclusions are valid for temporary and other time-varying ITCs.

With a permanent ITC, neutrality requires lower credit rates for short-lived assets, because any given credit rate provides a greater stimulus to such assets. This occurs because, when an ITC finances part of a firm's purchase of an asset, the firm not only does not demand its required rate of return on the credit-financed portion but also does not incur depreciation expenses on this component. This second effect is larger for short-lived assets, because they depreciate more rapidly. With a time-varying ITC, however, it is also necessary to consider the change in asset prices induced by future ITC changes. In particular, the phase-out of a temporary ITC induces a capital gain on the undepreciated portion of assets; this gain is greater for assets that depreciate more slowly. Therefore, with a temporary ITC, neutrality requires a smaller differential between short-lived and long-lived assets. Conversely, with an ITC whose rate is being increased over time, neutrality requires a greater differential.

In a model without adjustment costs, for any arbitrary time-varying path of the credit rate on a given asset, we explicitly solve for the path of the credit rate on any other asset that is consistent with production efficiency. We also calculate the output loss that would arise from mistakenly applying the conventional prescriptions to a temporary ITC. We then discuss models with adjustment costs and find that the qualitative results are robust with respect to both their presence and specification. Finally, we discuss incentives based on net investment and the net capital stock and find that their production-efficient design can more easily accommodate time variation.

In Section 2 we review the requirements for production efficiency with a permanent ITC, emphasizing how these results are related to the assumption that the credit is permanent. We then analyze production efficiency with a time-varying credit in Section 3. In Section 4 we discuss the implications of various extensions of the basic model, particularly adjustment costs and incentives based on net investment and the net capital stock. We briefly conclude in Section 5.

2. Production efficiency with a permanent ITC

We examine the simple problem of investment without adjustment costs, as studied by Jorgenson (1963) and Auerbach (1983, pp. 912–914). As
explained below, we impose a number of simplifying assumptions that are common in the existing literature (identical tax treatment of all firms and investors, equity-financed investment, perfect foresight, geometric depreciation, and time-invariant after-tax rates of return, statutory tax rates and depreciation schedules), but we relax the common assumption that the ITC rate is time-invariant. In Section 4 we discuss the implications for our analysis of relaxing some of these other restrictive assumptions.

The representative firm invests in each of \( N \) different assets (types of capital), indexed by \( i \). Gross output is a concave function \( F(\cdot) \) of the stocks of these assets. Each asset has a geometric depreciation rate \( \delta_i \), so that, if \( I_i \) is the level of gross investment in asset \( i \), then the path of the net capital stock \( K_i \) satisfies

\[
I_{it} = \delta_i K_{it} + \dot{K}_{it}, \quad i = 1 \ldots N.
\]  

(1)

The representative firm is taxed at a time-invariant statutory tax rate \( \tau \) on gross output minus its depreciation allowances. Investment is assumed to be equity-financed, so that interest expense deductions need not be considered. The tax law allows a time-invariant depreciation deduction equal to \( D_{i,m} \) for each dollar invested in asset \( i \), \( m \) periods ago. The firm also receives an ITC equal to \( k_i \) for each dollar invested in asset \( i \) at date \( t \). For simplicity, we assume that the basis of depreciation deductions is not reduced by the amount of the ITC. All variables are expressed in real terms. We assume that the firm can engage in negative gross investment (by converting the investment good into the consumption good) and that negative investment is treated symmetrically by the tax code, with the government recapturing a credit equal to \( k_{it} \) of the value of the disinvestment.\(^1\)

Investors demand a time-invariant real after-tax rate of return equal to \( r \), identical across investors. Under perfect foresight, the firm chooses an investment schedule for each asset to maximize the present value of its after-tax profits,

\[
V_0 = \int_0^\infty e^{-rt} \left[ (1 - \tau)F(K_1, \ldots, K_N) - \sum_{i=1}^N (1 - k_{it})I_{it} \right. \\
+ \left. \tau \sum_{i=1}^N \int_i^{t} I_{is} D_{i,t-s} \, ds \right] dt
\]  

(2)

\(^1\) In an economy with multiple firms, this treatment of negative investment, combined with the assumption that all firms face the same tax structure, implies that firms cannot change their combined tax liability by selling assets to each other, since the credit received by the purchasing firm is offset by the selling firm's credit recapture. This justifies our assumption of a representative firm. In Subsection 4.3, we briefly discuss a more realistic specification of the tax treatment of asset sales between firms.
subject to Eq. (1). The pretax relative prices of each capital good and of output are assumed to be exogenous and time-invariant; without loss of generality, each price is normalized to unity at each date.

Following Auerbach (1983, p. 915), the firm’s objective function (2) can be replaced with

\[
\tilde{V}_0 = \int_0^{\infty} e^{-r} \left[ (1 - \tau)F(K_{t1}, \ldots, K_{tN}) - \sum_{i=1}^{N} (1 - k_{it} - \Gamma_i)I_{it} \right] dt
\]

(3)

where

\[
\Gamma_i = \tau \int_0^{\infty} e^{-rm}D_{i,m} dm
\]

is the present value of the tax savings attributable to the stream of depreciation allowances generated by investing one dollar in asset \( i \). Unlike \( V \), \( \tilde{V} \) does not include the tax savings that result from depreciation allowances attributable to asset purchases prior to date zero; since those purchases are predetermined, this omission has no affect on the firm’s maximization problem. Eq. (3) expresses the after-tax price of each unit of capital as \( 1 - k_{it} - \Gamma_i \), i.e. the purchase price minus the associated ITC minus the present value of the future depreciation allowances.

The Euler equations for this problem are given by

\[
F'(K_{it}) \frac{(1 - \tau) - \delta_i (1 - k_{it} - \Gamma_i) - \dot{k}_{it}}{1 - k_{it} - \Gamma_i} = r, \quad i = 1 \ldots N.
\]

(4)

The Euler equations state that each asset’s after-tax net-of-depreciation return equals the required rate of return \( r \). The after-tax rate of return has three components: the after-tax marginal product \( F'(1 - \tau) \); depreciation \( \delta_i (1 - k_{it} - \Gamma_i) \); and the change in the after-tax asset price, \( -\dot{k}_{it} \). The sum of the three components is then divided by the after-tax price to obtain the after-tax rate of return on each dollar that the firm has invested, and this rate of return is equated to \( r \).

The Euler equations can be rewritten as expressions for the equilibrium pretax marginal product of capital,

\[
F'(K_{it}) = \frac{(r + \delta_i)(1 - k_{it} - \Gamma_i) + \dot{k}_{it}}{1 - \tau}, \quad i = 1 \ldots N.
\]

(5)

Each asset’s social rate of return is its pretax net-of-depreciation rate of return. The equilibrium social rates of return are

\[
F'(K_{it}) - \delta_i = \frac{r - (r + \delta_i)(k_{it} + \Gamma_i) + \delta_i \tau + \dot{k}_{it}}{1 - \tau}, \quad i = 1 \ldots N.
\]

(6)
A number of authors have previously discussed the design of policies that equalize the social rates of return \( F'(K_i) - \delta_i \) across different assets. An equivalent statement of this objective is that effective tax rates be equalized across assets, where the effective tax rate is defined to be the divergence between the pretax and after-tax rates of return divided by the pretax rate of return. Bradford (1980), Harberger (1980), Auerbach (1983, pp. 911–917) and Gravelle (1994, pp. 95–121) are among the most prominent analyses.

The equalization of pretax net rates of return is a requirement for production efficiency in this economic environment. In discussing efficiency in intertemporal models, it is usual to consider output produced at each date to be a separate commodity, in which case an equilibrium is production-inefficient if it is possible to increase output at any date without reducing output at some other date. Therefore, production efficiency requires that the cumulative net-of-depreciation rate of return obtained from holding one asset over any interval equals the rate of return obtained from holding another asset over the same interval; otherwise, shifting investment between the assets would increase output at the end of the interval without reducing output at the beginning of the interval. The cumulative net-of-depreciation rates of return are equalized over all intervals if and only if the instantaneous net-of-depreciation rates of return are equalized at each date.

Throughout this paper we follow previous authors and assume that efficient production is desirable. It is clearly a feature of the first-best optimum. Diamond and Mirrlees (1971) further demonstrated that a second-best optimum, in which lump-sum taxation is restricted and some distortions are required to satisfy the government revenue constraint, continues to feature production efficiency under the assumptions of constant returns to scale and unrestricted taxation of all consumption goods. In the current context, the latter assumption states that the government can freely alter effective tax rates on output at each date by choosing an arbitrarily time-varying path for the ITC rates. When the Diamond–Mirrlees assumptions are relaxed, the complexity of the optimal-tax problem precludes any definitive statements (see Auerbach, 1982, p. 356), but Auerbach (1982, p. 367, 1989a) found that approximate production efficiency generally holds at the optimum and that movements toward production efficiency are usually welfare-improving. Therefore, we assume that efficient production is desirable.

It is well established (Auerbach, 1983, pp. 911–912; Harberger, 1980, pp. 303–309) that a relatively simple policy induces efficient production in the absence of an ITC (when \( k_i \) is zero for all \( i \) and \( t \)). This policy allows depreciation allowances at each instant equal to true economic depreciation. Under this policy, \( T^*_i = r \delta_i/(r + \delta_i) \) and Eq. (6) implies that \( F'(K_i) - \delta_i \) then equals \( r/(1 - \tau) \) for each asset \( i \) at each date \( t \), and the effective tax rate equals the statutory tax rate \( \tau \). For the remainder of this section we assume
that depreciation allowances match true economic depreciation. Since this assumption implies that production efficiency is attained without an ITC, it simplifies the consideration of how the introduction of an ITC affects production efficiency. Under this assumption, the social rates of return are, from (6),

$$F'(K_u) - \delta_i = \frac{r - (r + \delta_i)k_u + \dot{k}_u}{1 - \tau}, \quad i = 1 \ldots N.$$ \hfill (7)

The question of production efficiency has generally been examined in the context of the steady state associated with a permanent time-invariant ITC. It is apparent from Eq. (7) that production efficiency holds in the steady state if and only if

$$k^*_i = \frac{k^*_j \delta_j + r}{\delta_i + r}, \quad i, j = 1 \ldots N,$$ \hfill (8)

where an asterisk denotes steady-state values. Eq. (8) requires that $k^*_i$ be inversely related to asset $i$'s depreciation rate (positively related to its durability). This finding helped motivate past US tax policy of providing higher credit rates for longer-lived equipment (see the appendix for a brief history of the ITC in the United States).

This result follows from (7), which states that a unit increment in $k^*_i$ reduces by $(r + \delta_i)/(1 - \tau)$ the social rate of return that is compatible with an after-tax return equal to $r$. Therefore, a uniform credit at a rate $k^*$ would produce larger rate-of-return reductions for rapidly depreciating assets and be non-neutral. The reason for this differential effect is straightforward. The asset's net price is lowered by $k^*$, because that portion of the purchase is financed by the government through the ITC. This has two effects. First, the firm does not demand its required rate of return on the credit-financed portion, so the physical product of capital (multiplied by one minus the statutory tax rate) falls by $rk^*$ -- an effect that is uniform across assets. Secondly, the firm does not incur depreciation expense on the credit-financed portion, so the physical product (multiplied by one minus the

Another production-efficient policy allows the cost of capital goods to be immediately deducted (expensed), implying $F_i = \tau$ and $F'(K_u) - \delta_i = r$ for all $i$ at each date $t$. Linear combinations of expensing and economic depreciation are also efficient. We follow previous authors by assuming that depreciation schedules match economic depreciation. Although economic depreciation is difficult to measure, Gravelle (1994, pp. 110–111, 247, 267), using the Hulten–Wykoff estimates, found that, at recent inflation rates, US depreciation schedules generally have similar present values to economic depreciation, since the accelerated lifetimes and the lack of inflation indexing have roughly offsetting effects.

For example, Bradford (1980) noted (pp. 290, 295) that his analysis was confined to the steady state. As discussed below, this qualification has often been overlooked by those applying his results.
statutory tax rate) falls by $\delta k^*$ – an effect that is larger for assets that depreciate more rapidly (short-lived assets).\(^4\)

This can be illustrated by a discrete-time example based on Bradford (1986, p. 221). The statutory tax rate is 50% and depreciation allowances match economic depreciation. The firm’s required rate of return is 5%, one asset has a zero depreciation rate and a second asset has a 100% depreciation rate. The discrete-time counterpart of (8) states that the first type of capital should receive a credit rate 21 times greater than the second type. The above analysis can be used to clarify this result.

Without an ITC, production is efficient, with social rates of return equalized at 10%. In this equilibrium, US$1,000 invested in the first asset yields $100 next period or $50 after tax. Since the firm experiences no depreciation or capital gain on this asset, its net payoff is $50 or 5%. $1,000 invested in the second asset yields $1,100 next period or $1,050 after tax. Since the firm experiences $1,000 depreciation on this asset, its net payoff is $50, yielding a 5% return.

With an ITC, assume the first asset receives a permanent 21% credit, reducing its net price to $790. In the new equilibrium, its pretax payoff is $79 or $39.50 after paying tax. Since the firm continues to experience no depreciation or capital gain on this asset, its after-tax payoff is $39.50, a 5% return on its $790 investment. The second asset receives a permanent 1% credit, lowering its price to $990. In the new equilibrium, its pretax payoff is $1,079 or $1,039.50 after paying tax (recalling that the firm’s depreciable basis is not reduced by the credit). Since the firm’s entire $990 investment depreciates, its net payoff is $49.50 – a 5% return on its investment. Both assets have a 7.9% social rate of return and production is efficient.

A lower credit rate, and hence a smaller price reduction, is necessary for the depreciating asset, because the ITC also lowers its associated depreciation expense (from $1,000 to $990), while no such effect occurs for the non-depreciating asset. To the extent an asset depreciates, the ITC reduces this expense, since the firm incurs no depreciation expense on the credit-financed portion. We have used this example to clarify the conventional result for a permanent ITC; we next use it to examine a time-varying ITC.

3. Production efficiency with a temporary or time-varying ITC

Modifying the previous example, assume now that the ITC is available only in the first period and then expires. We will demonstrate that a uniform 1% ITC is now production-efficient, lowering both social rates of return to

\(^4\) In the regulated-utilities context, this same reasoning implies that both the firm’s required return and its depreciation expense must be reduced for rate-making purposes, in order to normalize an ITC properly (see Kiefer, 1979, pp. 98–99).
7.9% in the first period (after which they revert to 10%). The analysis for the depreciating asset is unchanged; the firm purchases it for $990 and the after-tax payoff is $1,039.50 (from a gross return of $1,079). As before, the entire $990 investment depreciates and the firm receives a net payoff of $39.50, implying a 5% rate of return.

With a uniform 1% ITC, the non-depreciating asset now also costs $990; its equilibrium physical product in the next period is $79, of which $39.50 remains after tax. The firm still incurs no depreciation expense but, unlike before, it now enjoys a capital gain of $10, because the undepreciated asset purchased at a net cost of $990 is worth $1,000 in the next period (when no credit is available). Note that the depreciating asset does not experience a similar capital gain, because it ceases to exist at the end of the period. The capital gain on the non-depreciating asset induced by the expiration of the credit exactly offsets the reduction in depreciation expense on the depreciating asset, so that uniformity is production-efficient.

More generally, an analysis of time-varying ITCs must recognize that asset prices are endogenous to the introduction and removal of investment incentives, and that the importance of these gains depends on asset durability. If the ITC is temporary, then its anticipated reduction or repeal generates capital gains; these gains are greater for more durable assets, so mitigating or negating the conventional conclusion that they must be given higher credit rates to receive the same stimulus. Conversely, an anticipated increase in the ITC generates capital losses; these losses are greater for more durable assets, amplifying their need for higher credit rates.

This logic suggests that the conventional prescription overstates the appropriate rate differentiation for temporary ITCs (whose rates decline over time) and understates the appropriate rate differentiation for ITCs whose rates rise over time. This point is important, because the actual ITC in the United States has exhibited considerable time-variation, much of which may have been anticipated. (The rate changes over time are discussed in the appendix.) However, economists and policy-makers have often applied the conventional results to time-varying credits, without recognizing their invalidity in that context. For example, President Clinton’s 1993 economic proposal, which called for a 2-year ITC for large firms and a permanent ITC for small firms, provided the same degree of differentiation between short-lived and long-lived equipment under each credit (Joint Committee on Taxation 1993, pp. 6–8). We now algebraically examine the conditions for production efficiency with time-varying ITCs.

Eq. (7) implies a general condition for the social rates of return $F'(K_i) - \delta_i$ to be equalized at each date

$$k_{it}(\delta_i + r) - k_{it} = k_{jt}(\delta_j + r) - k_{jt}, \quad i, j = 1 \ldots N.$$  

(9)

As suggested by the above analysis, the impact of the ITC on the
equilibrium pretax rate of return now includes another effect, the change in asset price due to changes in the credit rate. This effect is reflected by the \( \dot{k} \) terms. Since the after-tax asset price is \( 1 - k_{it} - \Lambda_i \), the firm suffers a capital loss if \( k_{it} \) is rising and the equilibrium pretax product of capital must increase to offset this loss. (Equivalently, the rising credit offers an incentive to postpone investment, so current investment must generate a higher pretax product.) Conversely, a falling credit generates a capital gain and lowers the equilibrium pretax profit.

An instructive variation of this condition can be obtained by taking the present value of both sides at the firm's discount rate \( r \). If the present value is finite, integrating by parts yields the equality

\[
 k_{it} + \delta_i \int_t^\infty e^{-r(s-t)}k_{is} \, ds = k_{jt} + \delta_j \int_t^\infty e^{-r(s-t)}k_{js} \, ds .
\] (10)

This equality, which reduces to (8) for a permanent ITC, has a simple interpretation. The equalization of effective tax rates across assets implies that any small perturbation in the mix of capital types that keeps the path of total net investment unchanged at each date cannot change the present value of the firm's taxes (when discounted at \( r \)). Without loss of generality, consider a small perturbation that increases \( \dot{K}_i \) by one unit and lowers \( \dot{K}_j \) by one unit, for any \( i, j \) and \( t \). The associated perturbation in gross investment for asset \( i \) is an increase of one unit at date \( t \) and \( \delta_i \) units at every subsequent date, while the associated perturbation in gross investment for asset \( j \) is a reduction of one unit at date \( t \) and \( \delta_j \) units at every subsequent date. The resulting change in the present value of the firm's credits equals zero if and only if the credit rate paths satisfy (10).

In the numerical example used earlier, consider a perturbation that replaces $1 of net investment in the depreciating asset with $1 of net investment in the non-depreciating asset in the initial period and leaves the subsequent paths of net investment unchanged. This perturbation requires an initial shift in gross investment by these amounts and also reduces gross investment in the depreciating asset by $1 in every subsequent period. Under the permanent ITC, with respective rates of 21% and 1%, this perturbation causes the firm's credits to increase by 20 cents in the initial period and to fall by 1 cent in every subsequent period, yielding a present value of zero. However, when the ITC expires after one period, uniform rates are necessary for neutrality because the subsequent gross investment perturbations do not receive the credit. A shift toward short-lived assets that leaves the path of total net investment unchanged at every date must increase the level of gross investment; with a permanent ITC, the present value of credits is unchanged only if the short-lived assets have a lower credit rate. With a temporary ITC, however, more uniform rates are
appropriate because part of the perturbation to gross investment is not affected by the ITC.

It is useful to solve for the credit rate path on any asset \( i \) that is consistent with production efficiency, for any arbitrary time-varying credit rate path on any preselected asset \( j \). Taking the present value of Eq. (9) with discount rate \((r + \delta_i)\) and integrating by parts yields such a representation,

\[
k_{it} = k_{jt} + (\delta_j - \delta_i) \int_t^\infty e^{(\delta_i + r)(t-s)} k_{js} \, ds.
\]

For a time-invariant ITC, (11) reduces to (8). For any given current credit rate on asset \( j \), (11) states that lower future credit rates on asset \( j \) raise (lower) the appropriate current credit rate on asset \( i \) if asset \( i \) is less (more) durable. In other words, if the credit rate on asset \( j \) is declining, as with a temporary ITC, less rate differentiation is appropriate than the conventional results would imply. Conversely, if the credit rate on asset \( j \) is increasing, greater rate differentiation is appropriate. Eq. (11) has a particularly striking implication for the limiting case of an instantaneous credit; if \( k_j \) is about to become and remain zero, the appropriate credit rates on the two assets are the same.

Additional insights can be obtained by rewriting (11) to express the credit rate on asset \( i \) as a function of future changes in (rather than levels of) the credit rate on asset \( j \),

\[
k_{it} = k_{jt} \frac{\delta_j + r}{\delta_j + r} + \frac{\delta_j - \delta_i}{\delta_j + r} \int_t^\infty e^{(\delta_j + r)(t-s)} k_{js} \, ds.
\]

With a time-invariant ITC, the second term on the right-hand side is zero, while the first term is identical to that in (8). More generally, the appropriate relationship between the credit rate on the two assets depends on the future variation in credit rates. If \( k_j \) will decline in the future (as with a temporary ITC), the credit rates on the two assets are more similar than the steady-state analysis would imply.

In general, (11) and (12) state that the appropriate ratio of the two credits depends on the present discounted value of the future changes, where the discount rate is the after-tax gross-of-depreciation rate of return for the asset whose credit is being calculated. Owing to this high discount rate, changes in \( k_j \) that will occur in the distant future have little effect on the appropriate current value for \( k_i \). However, as will be seen below, changes in the relatively near future can have dramatic implications.

Eqs. (9)–(12) yield a particularly simple result if the credit rate on asset \( j \) is changing geometrically. The following credit rate paths are then compatible with production efficiency,
If $\lambda > 0$, then this parameter measures the extent to which the credit is temporary. Since the credit rate on each asset decays at this same rate, the ratio of the credit rates across assets is constant. However, $k_i$ is inversely proportional to $r + \delta_i + \lambda$, not $r + \delta_i$ as for a permanent credit. Although it is still true that longer-lived assets should receive higher credit rates, the differential is smaller for a temporary credit than for a permanent one, and the extent of the differential varies continuously with the permanence of the credit. As the duration of the credit approaches zero ($\lambda$ approaches infinity), the appropriate credit rates become uniform across assets.

The difference is significant for credits of realistic duration. Consider the case in which asset $j$ has an annualized depreciation rate of 0.075 (roughly the estimated depreciation rate for property assigned a 10-year recovery period under the modified accelerated cost recovery system (MACRS) in the United States) and asset $i$ has an annualized depreciation rate of 0.18 (roughly the estimated rate for property assigned a 3-year recovery period under MACRS). If the annualized after-tax rate of return is 0.08, then, under a permanent ITC, the credit rate on asset $i$ should be 60% of the credit rate on asset $j$. However, if the ITC has a geometric decay rate of 0.693 (implying a half-life of one year), the credit rate on asset $i$ should be 89% of the credit rate on asset $j$. Owing to the temporary nature of the credit, the appropriate credit rates are much closer to uniform than the conventional analysis suggests.

In this example the inefficiency associated with mistakenly employing the standard results for permanent credits can be measured by the loss in output relative to the correct policy. In particular, given the path of capital formation and output obtained under this mistaken policy, we calculate the amount of extra output that could be produced at each date by reallocating the total capital stock at each date efficiently. When, in accordance with (8), the credit rate on asset $i$ is $k_i = \frac{k_j}{(r + \delta_j + \lambda)} e^{-\lambda t}$, the disparity in the rates of return on the two assets at each date is

$$\Delta_t = -\frac{\lambda(\delta_j - \delta_i)}{(1 - \tau)(\delta_j + r)} k_i e^{-\lambda t}.$$

Assuming a Cobb–Douglas production function, and using a Taylor approximation (see Jack and Viard, 1994), the approximate output loss at each date is $-c \frac{\Delta_t^2}{2} K_t$, where $c$ is the amount by which the rate of return disparity is reduced by reallocating one unit of capital and $K_t$ is the total capital stock at date $t$. In the current numerical example, assuming that
$k = 0.1$ and that the ratio of short-lived to long-lived capital is two, the output loss at date $t$ is approximately $0.11 \times e^{-2\lambda t\%}$ of the capital stock. At the time the ITC is introduced, the loss is about $0.11\%$ of the capital stock, which at the assumed required rate of return represents approximately $0.86\%$ of net capital income.

The dependence of the efficiency loss over time on $\lambda$ is instructive. From the expression for $\Delta_t$, it can be seen that a more temporary ITC has a larger initial loss, but that the loss decays more rapidly over time.

The constancy of the ratio of the credit rates arises from the assumption that the ITC is phased out geometrically, in conjunction with the assumption of geometric depreciation. This property is not displayed by any other type of temporary ITC. For example, if the credit rate on asset $j$ is phased out linearly over some interval $T$, a linear phase-out for any other asset is incompatible with production efficiency. Instead, solving (9) reveals that production efficiency is attained with the following paths for the credit rates:

$$k_{jt} = \begin{cases} \frac{\bar{k} T - t}{T}, & 0 \leq t \leq T, \\ 0, & t \geq T \end{cases}$$

$$k_{it} = \begin{cases} \frac{\bar{k} T - t}{T} \frac{\delta_i + r}{\delta_j + r} + \frac{(\delta_i - \delta_j)(1 - e^{(\delta_i + r)(t - T)})}{T(\delta_i + r)^2}, & 0 \leq t \leq T, \\ 0, & t \geq T, \forall i \neq j, \end{cases}$$

where $\bar{k}$ is the initial credit rate on asset $j$.

As $T$ approaches infinity, the second term in the expression for $k_{it}$ can be ignored and the standard conclusion that the credit rate is inversely proportional to $\delta_i + r$ re-emerges. Conversely, as $T$ approaches zero (or as $t$ approaches $T$), the appropriate credit rates approach uniformity. It can be shown that the ratio of the two credit rates is closer to unity than the permanent credit analysis would suggest, and that the ratio increases throughout the phase-out period, reaching unity as the credits expire.

Consider again the case in which the first (asset $j$) has an annualized depreciation rate of 0.075, the second asset (asset $i$) has an annual depreciation rate of 0.18 and the annual after tax rate of return is 0.08. As noted above, under a permanent ITC, the credit rate on the second asset should be 60% of the credit rate on the first asset. However, if the credit is

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5 As explained in Jack and Viard (1994), this is broadly consistent with Gravelle's (1982) estimate of the stocks of different assets.

6 The policy experiment is asymmetrical, in that the credit rate on one asset is preassigned a particular path and the rates on other assets are then adjusted to maintain production efficiency. Clearly, the roles of these assets could be interchanged and our equations could still be applied.
linearly phased out over a 2-year period, then the initial credit on the second asset should be 91% of the credit rate on the first asset and the credit rates should further approach uniformity as the phase-out proceeds.

It is straightforward to solve for the counterpart to (14) applicable to an ITC on asset $j$, the rate of which is increased linearly from zero to $k$ over an interval $T$. If the credit on the long-lived asset in the above example is linearly phased in over a 2-year period, the appropriate credit rate on the short-lived asset is negative throughout a substantial portion of the phase-in period. At the initial date, when $k_j = 0$, $k_i = -0.31k$, where $k$ is the steady-state credit rate on the long-lived asset. The credit rate on asset $i$ then increases, reaching zero after 0.73 years, and reaching the steady-state level of $0.60k$ at the conclusion of the phase-in period.

These results illustrate the quantitative significance of the divergence between the requirements of production efficiency for permanent and time-varying ITCs. We now examine some extensions of the basic model presented above.

4. Extensions of the simple model

4.1. Adjustment costs

The analysis of Section 3 concentrated on ITCs with continuously varying rates. However, commonly observed temporary investment incentives generally consist of an ITC at a fixed rate for a certain period, that is subsequently removed in a discontinuous fashion. Owing to its assumption of no adjustment costs, the model employed in Sections 2 and 3 is not well-designed to examine such incentives. The Euler equation, Eq. (4), states that, under the maintained assumption of a constant required rate of return, the instantaneous marginal product of capital must equal negative infinity at the instant at which the credit expires. For plausible production functions, however, this marginal product would not be attained even if the capital stock jumped to infinity. Furthermore, the assumption that the firm can engage in infinite investment immediately before the credit expires and infinite disinvestment immediately thereafter, to return the capital stock to a finite level without altering the price of capital, highlights the counterfactual nature of the no-adjustment-cost specification.

In this subsection we report results obtained from a model incorporating a more realistic specification of the investment technology, in which the presence of adjustment costs induces smoothing of investment. In such an economy, we find that, while the specific patterns of production-efficient ITC rates are rather complicated, their qualitative properties conform with the general results obtained in the no-adjustment-cost case. In particular, we
continue to find that credit rates should be closer to uniform for ITCs of short duration. These qualitative results are independent of whether adjustment costs depend on the absolute level of investment or on the ratio of investment to the existing capital stock (the two most common specifications found in the literature).

We discuss a particular problem suggested by the history of the ITC in the United States (the formal analysis of this problem can be found in Jack and Viard, 1994). The tax law has generally specified a 'base' credit rate applicable to long-lived equipment and then specified the credit rates on different types of short-lived equipment as fractions of the base credit rate. To highlight the differences introduced by the temporary nature of the credit, our policy experiment similarly assigns a fixed base credit rate to long-lived equipment, but we assume that the credit rate drops to zero at a certain date $T$ in the future. We then solve for the credit rate paths for different types of short-lived equipment that are consistent with production efficiency.

The results of this experiment (as reported in Jack and Viard, 1994) show that the initial credit rate is lower for the short-lived asset, but that the differential is smaller than for a permanent credit. This is particularly evident for credits of short duration. The optimal credit rate on the short-lived asset generally (but not always) rises during the credit period and generally declines to approximately zero at the expiration date of the long-lived asset's credit. The adjustment-cost-specification yields rich results for the path of the optimal credit rate. In particular, the appropriate credit rate on the short-lived asset is generally not exactly zero after date $T$. This result arises because, in the presence of adjustment costs, firms cannot adjust the capital stock costlessly and instantaneously in response to policy changes.

In the no-adjustment-cost case, Eqs. (11) and (12) state that the appropriate credit rate on the second asset would be zero at time $T$ if the credit rate on the first asset is then zero. Without adjustment costs, the capital stock can adjust instantaneously to its steady-state value, so when the credit rate on the first asset becomes zero, its capital stock immediately adjusts to restore its pretax rate of return to the steady-state level. Setting the credit rate on the second asset to zero also drives its pretax rate of return immediately to the steady-state level, thereby equalizing rates of return across the two assets from date $T$ onward. With adjustment costs, however, starting from a position away from the steady state, asset prices change to equate net-of-depreciation marginal after-tax returns (including after-tax capital gains) with the interest rate, yielding particular paths of capital formation and prices. When the credit rate on the long-lived asset becomes zero at $T$, its pretax rate of return does not immediately revert to the steady-state level. Production efficiency requires that the pretax rate of
return on the short-lived asset must similarly diverge from the steady-state level. In general, a zero credit rate on the short-lived asset will not achieve the same divergence. Of course, the credit rate on the short-lived asset converges towards zero in the long run.

Similarly, there is no simple relationship between the two credit rates before the expiration date. In the presence of adjustment costs, the past matters because, as described above, its affects cannot be undone through immediate and costless adjustment. The effects of current tax policy therefore depend upon past policies and the design of production-efficient tax policies today requires information on past policy. This is in contrast to the case without adjustment costs, for which Eq. (9) states that a linear combination of \( k \) and \( k' \) is equated across assets at each date. As indicated by (11) and (12), this condition was satisfied by forward-looking equations in which the current credit rates are simple functions of only the future credit rates. In the adjustment cost model, however, a function of \( k, k', F', \) and \( q \) is equalized across assets, where \( F' \) and \( q \) depend in a complicated manner on both past and future credit rates. As a result it is difficult to distinguish the specific determinants of the appropriate credit rate paths. Owing to these problems of interpretation, numerical simulations are necessary, and reveal qualitatively similar properties to the no-adjustment-cost case (as shown in Jack and Viard, 1994).

4.2. Alternative investment incentives

One policy implication of our analysis is the potential superiority of investment incentives other than credits for gross investment. Bradford (1986, pp. 221–222, 238) proposed a simple investment incentive that is neutral across different types of capital – a credit paid at a uniform rate on the net stock of each asset. This incentive attains production efficiency without the administrative complication of specifying differential rates, although depreciation rates must still be known to measure the net capital stocks. Our analysis highlights an additional advantage of this incentive. If the credit rate is uniform across different types of capital at each date, production is efficient, regardless of how the credit rate varies over time. This can be seen most easily by noting that, under such a credit, a perturbation to the capital mix that leaves total net investment unchanged at every date necessarily leaves the present value (indeed, the time-path) of the firm's credits unchanged. Alternatively, letting \( z_{it} \) denote the net-capital-stock credit rate on asset \( i \) at date \( t \), the Euler equations (4) now take the form

\[
\frac{F'(K_i)(1 - \tau) + z_{it} - \delta_i + \delta_i \Gamma_i}{1 - \Gamma_i} = r, \quad i = 1 \ldots N.
\]
The equilibrium social rates of return are then

\[ F'(K_{it}) - \delta_i = \frac{r - (r + \delta_i)\Gamma_i + \delta_i \tau - z_{it}}{1 - \tau}, \quad i = 1 \ldots N. \]  

(16)

When depreciation allowances follow economic depreciation, it can be seen that these rates of return are equalized if and only if \( z_{it} \) is equalized across \( i \), at any \( t \). With this credit, unlike the gross-investment credits actually employed in the United States, it is not necessary to provide separate analytical frameworks for permanent and temporary credits.

An investment incentive based on net additions to the capital stock would clearly have similar properties to one based on the net stock. In fact, Gravelle (1994, p. 112) noted that a permanent credit paid at a uniform rate on net investment at each date is production efficient. This result can also be extended to the time-varying case; if the credit rate is uniform across different assets at each date, production will be efficient, regardless of how the credit rate varies over time. The enactment of either of these investment incentives would provide an administratively simple way to ensure production efficiency, without the need to distinguish whether the incentive is permanent or temporary.

4.3. Other extensions

Throughout this paper we have simplified the problem by imposing a number of assumptions common to the ITC literature. Here, we briefly examine the possible implications of relaxing some of these assumptions.

We have assumed that the investors' required rate of return is exogenous and constant. As noted by Auerbach (1989b, p. 947, n.6) and Summers (1981, pp. 113–115), since the US corporate sector is a small component of world financial markets, the interest rate is approximately exogenous, and the assumption of constancy is relatively benign. Also, it is likely that similar conclusions would arise with a time-varying or endogenous rate of return.

In this paper, following previous authors who examined permanent ITCs, we argued that production efficiency was likely to be an (exact or approximate) characteristic of the second-best tax optimum and identified a class of tax policies that satisfied this criterion. One possible extension would be to specify an objective function for the government, which would make it possible to determine whether production efficiency is indeed desirable and, if it is, to choose a particular policy within the class that we have identified.

It would also be of interest to modify certain aspects of the economic environment that we (and previous authors) have assumed. In particular, the assumption of perfect foresight is clearly restrictive and it would be valuable
to examine the appropriate design of an ITC when future tax policy is uncertain. In the presence of such uncertainty, it seems clear that any ITC, even one labelled ‘permanent’ by the legislature, is inherently temporary to some extent, since firms must consider the possibility of future legislative action. Investment under an uncertain ITC has been analyzed by Hassett and Metcalf (1994), although they did not consider the question of neutrality across different assets. Auerbach and Hines (1988) have performed a similar analysis. If investment is irreversible, then the work of Dixit and Pindyck (1994) could be used to further analyze the impact of uncertain policy environments. We also assumed that firms received the ITC on purchases of used assets, but that firms selling assets experienced an offsetting credit recapture, so that sales of assets between firms had no net tax consequences. During most of the intervals in which the United States used the ITC, the actual recapture rules on asset sale were more generous than those implied by our assumption, but the eligibility of used asset purchases for the credit was strictly limited, implying that sales of assets between firms could be either subsidized or penalized by the tax code. A more realistic treatment of such transactions might have implications for the welfare effects of temporary ITCs.

Policy-makers who advocate temporary ITCs often argue that the economy is suffering from imperfections, such as underutilized resources, of the type featured in Keynesian macroeconomic models and that a temporary ITC is an effective remedy. In such a model, it is unclear whether production efficiency would be desirable or whether, for example, the incentive should favor assets typically used by small firms that are more likely to face financing constraints. The solution of such a model would raise many issues not considered here or in the previous literature.

We have also assumed that all firms are taxed at the same rate. The tax status of actual firms is clearly more complex, since some firms are not subject to the corporate income tax, while others are subject to the corporate alternative minimum tax and others have loss carryforwards, and since firms incorporated or operating in different countries are subject to different tax regimes. Recognition of these differences would imply that the tax structure has already induced a certain degree of production inefficiency and would complicate the welfare analysis of an ITC’s effect on production efficiency. We further assume that all investment is equity-financed; an extension to allow the possibility of debt finance would be useful. Allowing the statutory tax rate and the depreciation schedules, as well as the ITC, to vary over time would also be of interest.

In general, it seems likely that these extensions would cast further doubt on various aspects of the conventional prescriptions but would probably not alter the conclusion that greater uniformity of rates is appropriate for temporary ITCs than for permanent ITCs.
5. Conclusions

The basic intuition behind the orthodox prescription that shorter-lived assets should have lower investment tax credit rates is that, at any given credit rate, such assets receive a greater benefit from the reduction in depreciation expense caused by the ITC. However, when the ITC is temporary, it is necessary to also consider the capital gain induced by anticipated ITC reductions. Such gains are smaller for short-lived assets. Therefore, the credit rates should be closer to uniform than the orthodox prescription suggests. We have shown that this result is robust to the presence and the specification of adjustment costs.

Our primary contribution in this paper has been to show that temporary and permanent investment incentives raise significantly different issues and that some important results derived in the literature on permanent incentives are inapplicable to the empirically relevant case of temporary incentives. Only when the incentives are based on net capital stocks, or additions thereto, are the rules for setting production efficient credit rates the same in both cases (when uniformity is always appropriate).

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Appendix: A brief history of the ITC in the United States

The ITC was introduced by the Revenue Act of 1962 (16 October 1962), effective for tangible personal property placed in service on or after 1 January 1962. The credit rates were 7% for property with a useful life of 8 years or more, 4.67% for property with a useful life of 6 years or more but less than 8 years and 2.33% for property with a useful life of 4 years or more but less than 6 years. No credit was provided for property with a useful life less than 4 years. Firms were required to reduce depreciation basis by the amount of the credit. The Revenue Act of 1964 (26 February 1964) repealed the basis reduction requirement (and increased the basis of assets already placed in service), effective 1 January 1964.

The Act to Suspend the Investment Credit (8 November 1966) suspended
the ITC, subject to certain transition rules, for property acquired from 10 October 1966 to 31 December 1967. The Act to Restore the Investment Credit (13 June 1967) reinstated the ITC, generally for property acquired on or after 10 March 1967. The Tax Reform Act of 1969 (30 December 1969) repealed the ITC, subject to certain transition rules, for property acquired on or after 19 April 1969.

The Revenue Act of 1971 (10 December 1971) reinstated the ITC, generally effective for property acquired on or after 16 August 1971, with a 7% rate for property with a class life of 7 years or more, 4.67% for property with a class life of 5 years or more but less than 7 years and 2.33% for property with a class life of 3 years or more but less than 5 years. No credit was provided for property with a class life of less than 3 years.

The Tax Reduction Act of 1975 (29 March 1975) temporarily increased the credit rates for property acquired from 22 January 1975 to 31 December 1976. The three credit rates were increased, respectively, from 7% to 10%, 4.67% to 6.67% and 2.33% to 3.33%. The Tax Reform Act of 1976 (4 October 1976) extended the higher rates to 31 December 1980, and the Revenue Act of 1978 (6 November 1978) made them permanent.

The Economic Recovery Tax Act of 1981 (13 August 1981) altered the credit rates, effective for property placed in service on or after 1 January 1981. This law provided for a 6% credit rate for property assigned a 3-year recovery period under the new depreciation system (generally, property with a class life of 4 years or less) and a 10% rate for all other eligible property. The Tax Equity and Fiscal Responsibility Act of 1982 (3 September 1982) required firms to reduce their depreciation basis by half of the credit amount, effective, subject to certain transition rules, for property placed in service on or after 1 January, 1983.

The Tax Reform Act of 1986 (22 October 1986) repealed the ITC, effective, subject to certain transition rules, for property placed in service on or after 1 January 1986.

Some of these laws also modified the definition of eligible property, particularly provisions concerning the eligibility of public utility structures, horticultural structures and elevators. Many of these laws also modified the limit on the amount of used property on which the ITC could be claimed, the recapture of credits when property was disposed of shortly after acquisition, the extent to which the ITC could offset current-year tax liability, the number of years that excess credits could be carried back or forward, the treatment of the ITC when property was leased from one firm to another and the treatment of the ITC for utility rate-making purposes.

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