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NONNEUTRALITIES OF TAX RULES, INFLATION UNCERTAINTY, AND INVESTMENT BEHAVIOR IN KOREA*

CHUNG MO KOO**

I. INTRODUCTION

The purpose of this paper is to extend the standard neoclassical investment model which has failed to explain the steep decline in business fixed investment in the early 1980s and early 1990s, respectively, in Korea. Modifications are made in this study to analyze the interaction of inflation and tax rules and capital formation; show how inflation uncertainty influences business fixed investment; and to take advantage of recent advances in capital theory to derive a more complete specification and framework for explaining investment behavior in such circumstances in Korea.

In order to explain the steep decline and subsequent slow recovery of nonresidential investment in the early 1990s, we will choose an appropriate investment framework and develop a complete model. In the last couple of decades, the literature on investment has been dominated by two theories of investment --- the standard neoclassical approach originated Dale Jorgenson which has a modification called the adjustment cost approach and the market value approach is the most often used framework to investigate investment behavior. however, the original model is not supplicated enough to explain the steep decline in investment in a world of inflation uncertainty and the interaction of taxation and inflation. Therefore, in this study the standard neoclassical approach will be chosen as a basic theoretical framework to develop a complete model to explain investment behavior in such a world. In the process, advantages of the market value approach will be incorporated into the neoclassical approach.

First, the present study intends to discuss how Korean tax rules and a high rate of inflation interact to affect investment. The nature of the interaction is complex and operates through several different channels. They include: first, use of

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** Associate Professor, Department of Economics, Kangwon National University.

FIFO inventory accounting incurs additional tax liabilities on nominal inventory profits. The size of this effect varies with the rate of inflation. Second, historical cost depreciation causes inflation to raise the effective corporate tax rate. Third, the taxation of nominal corporate income leads to an increase in the before-tax return on equity required by investors, on balance, these effects imply that inflation substantially increased the effective tax rate on corporate equity and therefore discourages investment. This explanation of investment behavior is developed more precisely. Recent literature demonstrates that a standard neoclassical investment model is too imprecise to explain the steep decline in business fixed investment. This is due to its inadequacy in explicitly incorporating the effects of the interaction of inflation and taxation on the user cost of capital. In order to improve the explanatory power of the standard neoclassical investment equation in such circumstances, tax parameters relevant to tax distortions as well as the fraction of FIFO accounting and historical cost depreciation allowances will be explicitly incorporated into the cost of capital. Second, this study tries to show how increased uncertainty about future inflation affects investment. This is due to the fact the fact that high rates of inflation not only make forecasting future inflation rates more difficult, but that uncertainty regarding future inflation increases the risks associated with investment planning and thereby influences the level of investment spending. However, the standard neoclassical approach is inappropriate to explain this because of its dependance upon the assumption of perfect certainty. In order to derive an appropriate investment model under conditions of uncertainty, the capital asset pricing model will be incorporated into a general model of the firm's present value maximization which integrates the market value approach and the standard neoclassical approach.

II. SHORTCOMINGS OF THE STANDARD NEOCLASSICAL INVESTMENT MODEL

In this section, the shortcomings of the original Jorgenson model will be discussed in a manner that a more complete specification and framework would be derived for estimating an investment model when there exist high rates of inflation and uncertainty about future inflation.

1. Nonneutralities of the Tax Rules During Inflationary Period

A standard neoclassical investment model is too explain the steep decline in business fixed investment in the early 1990s in Korea. This is due to its inadequacy to explicitly incorporate the effects of the interaction of inflation and taxation on the user cost of capital.

Three separate nonneutralities of the tax system lead to real effects of inflation. First, firms that use FIFO inventory accounting incur additional tax liabilities on their nominal inventory profits, The size of this effect varies with the rate of inflation, Second, historical cost depreciation causes inflation to raise the effective corporate tax rate. Note that the understatement of depreciation for tax purposes depends on the entire history of the inflation rate, not just on its current level. Third, the taxation of nominal rather than real capital gains leads to an increase in the before-tax return on equity required by investors. This effect is potentially quite large. On balance, these effects imply that inflation substantially increases the effective tax rate on corporate equity under the current Korean tax rules.

The first tax distortion by inflation is its effect on inventory profits. Most corporations use one of two inventory valuation methods, FIFO or LIFO. Under FIFO, the cost of goods sold, which is subtracted from revenues in computing taxable income, is calculated as if the items taken from inventory were the oldest available. Under LIFO, the cost of goods sold is computed as If the items taken from inventory were the ones most recently placed there . In a period of rising prices, the cost of goods sold under the FIFO, and the difference will be less than the cost of goods under FIFO will exceed taxable income under LIFO, and the difference will be greater the greater the greater the rate of inflation. This extra income can be attributed solely to illusory inventory profits which do not represent real economic profits. However, since the tax base for the corporation includes these inventory profits, the real after-tax income of the corporation during inflationary periods will be lower if FIFO is employed than it would be under LIFO. Despite of this fact, the majority of firms still use FIFO for most inventory valuation, but that percentage is narrowing. The impact of excess inventory taxation on capital formation is difficult to judge. Clearly, firms that use FIFO will tend to operate at a lower scale during periods of high inflation. This tax effect will also tend to hurt industries that require small stocks.

The second and most important impact of inflation on the corporate tax base is its impact on the value of depreciation allowances. The use of historic cost as the basis for depreciation deductions implies that the value of the depreciation tax deductions will vary with the rate of inflation. Two distinct effects can be noted here. First, changes in the rate of inflation affect the value of the remaining depreciation allowances on exisoing capital assets. Since depreciation allowances on existing capital are fixed in nominal terms, the present value of those allowances is calculated using a nominal interest rate for discounting. Increases in the rate of inflation will cause the value of these allowances to fall if these increases are associated with changes in nominal interest rates. Thus, only inflation rate changes that were not anticipated at the time the assets were purchased will affect the value of existing depreciation allowances. This particular inflation impact is generally assumed to have no impact whatsoever on the investment decision of firms.

The second effect and the one that has received the majority of attention as the impact of expected inflation on the value of depreciation allowances on new investment. Since the depreciation allowances are based on the original purchase price, the greater the expected rate of inflation throughout the life of that asset, the lower the real value of those allowances. Therefore, the demand for capital assets will be lower, the greater the expected rate of inflation.

The third tax nonneutrality created by inflation is caused by the taxation of nominal rather than real corporate income. This is the aspect of the personal tax system that seems to be the most important in any discussion of the impact of inflation on capital formation. Under the current Korean tax rules, increases in the nominal value of most capital assets are subject to taxation. The greater the rate of inflation, this feature of the tax code places a substantial inflation tax on capital income. Even though capital gains are taxed only upon realization, this inflation-tax interaction can be quite significant.

Considering all the nonneutralities of the tax system during an inflationary period, in this study, a modified neoclassical investment model will be developed which explicitly incorporates the interaction of inflation and taxation into the user cost of capital. The modifications involve the explicit treatment of inventory taxation, depreciation allowances, and capital gains taxation in a manner which incorporates the impact of inflation.

2. Inappropriateness of the Standard Neoclassical Model under Conditions of Inflation Uncertainty

Although other aspects of the standard neoclassical model have also received criticism, its most apparent shortcoming is its dependence upon the assumption of perfect certainty. It is not equipped to handle the problems which arise when decisions are assumed to be made under conditions of uncertainty.

Theoretically, high rates of inflation should not have any direct effect on investment spending, except for effects on the tax structure as discussed in the previous section. There is no intrinsic reason why. for example, a 10 percent rate of inflation should produce a lower level of investment than a 5 percent, if both rates of inflation are perfectly anticipated. However, the investment shortfall particularly in the early 1990s has occurred during a period when inflation had been at high levels. As a rivulet. several economists have suggested this high rates of inflation not only make forecasting future inflation increases the risks associated with investment planning and thereby reduces the level of investment spending.

It is thus hypothesized that the high degreed of uncertainty that has accompanied the high rates of inflation restrains fixed business investment. Therefore. it is more realistic to assume that the future is unknown and that decisions must be made on the basis of forecasts rather than actual knowledge of the future paths of relevant economic variables. To test this hypothesis, it is necessary to incorporate inflation uncertainty into the standard neoclassical investment model.

In the next section, the standard neoclassical model will be modified to incorporate an inflation uncertainty variable to show the effect of the uncertainty on the business fixed investment. And tax parameters relevant to tax distortions will be explicitly incorporated into the cost of capital to explain how the interaction of inflation and tax rules affects investment.

Ⅲ. AN EXTENDED INVESTMENT MODEL

In this section, a consistent model is developed to incorporate the significant issues discussed earlier. First, the model developed here incorporates additional factors into the user cost of capital. The standard neoclassical model originally developed by Jorgenson and his collaborators is the theoretical foundation for an investment equation. However, it is inadequate to explicitly incorporate the effects of interaction of inflation and taxation on capital costs as discussed above. The extended investment model involves the explicit treatment of depreciation allowances, corporate income taxation, and inventory taxation in a manner which incorporates the impact of inflation.

Second, the model is developed to include a variable for inflation uncertainty in order to deal with a world of uncertainty about futursinflation. In the standard neoclassical model, it is assumed that the ultimate objective of the firm is the maximization of the utility of its owners. Under conditions of perfect certainty, the literature has shown that such an objective of the firm is the maximization of the utility of its owners, Under conditions of perfect certainty, the literature has shown that such an objective of the firm is the maximization it the utility of its owners, Under conditions of perfect certainty, the literature has shown that such an objective could be attained without explicit reference to individual preferences if firms were to simply maximize their net wealth or nit income. preferences cannot be so easily ignored under conditions of uncertainty.

One possible method of incorporating individual preferences into the analysis is to assume that each firm's manager or investment planners have a utility function which reflects the preferences of the firm's owners and that production and hence investment decisions are made in the basis of maximizing the expected utility from net income or profits, In this way, firms may be treated as possessing attitudes towards risk reflecting those of their owners. This would, however, appear to be a rather ideal assumption regarding the information-gathering powers of the firm manager.

It is possible instead to incorporate individual preferences into the analysis without assigning firm managers the task of doing so. With regard to actual or expected net wealth, it may be assumed that each firm operates with the objective of maximizing its market value, which is determined by the interaction of the supply of and demand for the shares if ownership in existing firm. In the case of perfect certainty or risk neutralindividuals, market value and actual or expected net wealth will be the same.

However, in the case of risk averse individuals, the market value of the firm will also depend upon the degree of uncertainty and the attitudes toward risk displayed by individual investors and will thus be different than net wealth. The nature of this dependence upon uncertainty and individual preferences may be shown within the context of the capital asset pricing model. In the maximization of the market value of the firm approach to the production decision, it is the market., rather than the firm manager, which is assumed to process information regarding the preferences of individuals and to incorporate it into the planning process. In order to incorporate the level of uncertainty and the degree of risk averse, an investment model under conditions of uncertainty is developed by employing the capital asset pricing model. Thereby, an inflation uncertainty variable will be explicitly incorporated unto the standard neoclassical framework.

1. Incorporation of the Capital Asset Pricing Model

The capital asset pricing model we shall consider is a model of pureexchanged, and there are only two types of assets: bonds, which are issued either by firms or by the investors themselves and pay a known rate of interest r, and company ordinary shares of stock. Firms are assumed to distribute the gross yield of their productive activity among individual investors on the basis of the shares of stocks and bonds these individuals have acquired through the market exchange. The most important assumption we shall make is that the bond market is perfect in the sense that everyone, firms as well as investors, can lend or borrow any amount at a given and certain rate of interest. This is the same as disregarding default risk: all claims will be paid.

If it is assumed that the entire economy as a single large firm, by the method of aggregation, the aggregate market value equation can be written as[1]:

$$(3.1) \quad V = \frac{1}{1+r}\left(\mu_x - \frac{\hat{a}}{2}\sigma_x \right)^2$$

where r = the rate of interst,

μ_x, σ_x = mean and standard deviation of the gross yield respectively,

$\hat{a}$ = a direct measure of the degree of risk aversion,

which may be treated as the overall market price of risk.

The market value of the aggregate firm equals the firm's expected yield adjusted by a risk premium reflecting the level of uncertainty facing the firm and the

[1] The derivation may be referred to Koo(1990).

degree of risk aversion displayed by individual investors in the firm.

In a world of taxation and inflation, equation (3.1) can be rewritten on a time horizon such that the required return by shareholders is the sum of capital gains and yields net of tax. it follows that:

$$(3.2) \quad (\gamma+\pi)V_t = (1-g)\dot{V}_t + (1-\theta)\left[E(D_t) - \frac{\hat{a}}{2}Var(D_t)\right]$$

where γ = a fixed real after-tax return required by equity holders,
π = the expected rate of inflation,
g = the capital gains tax rate on a realization basis,
θ = the marginal personal income tax rate,
D_t = the dividend payment at time period t.

All investors are assumed to have the same tax rates. Now this differential equation can be solved to find the time path of V. The solution to (3.2) becomes:

$$(3.3) \quad V_t = \int_t^{\infty} -\frac{1-\theta}{1-g}\left[E(D_t) - \frac{\hat{a}}{2}Var(D_t)\right]e^{-\frac{\gamma+\pi}{1-g}t}\,dt$$

with the transferability condition that guarantees a unique solution,

$$(3.4) \quad \lim_{t\to\infty} = V_t e^{-\frac{\gamma+\pi}{1-g}} = 0.$$

This condition is necessary to rule out explosive behavior.

In this section, the appropriate expression for the market value of the firm has been derived under conditions of uncertainty. Thereby, in the next section, it will be attempted to integrate the neoclassical investment model under conditions of uncertainty.

2. A Complete Investment Model

Under the conditions of uncertainty, it is assumed that the firm operates with the objective of maximizing its market value. Since th maximization of market value and the maximization of shareholder wealth will yield identical results as shown in equation (3.3), it is assumed that the objective of a firm is to maximize shareholder wealth.

In a world of taxes, shareholder wealth will be maximized when the present value of the after-tax return to shareholders is maximized. In this fashion, the pe-rsonal tax liabilities of shareholders are integrated with the corporate tax liabilit-ies in the determination of the optimal time path of such decision variables as output, employment, and the capital stock.

Each firm is assumed to produce with constant return to scale and to be perfectly competitive in all markets. Another important assumption of this approach is that capital is homogeneous. If capital but raise the return on new investment. These assumption are essential to the deviation of the linkage between market valuation and investment incentives that is discussed below.

The typical firm seeks to choose an investment incentives and equity financing to maximize (3.14) subject to the constraints given by its initial capital stock, by a requirement that the sources of funds equal the uses, and the requirement that the firm maintains debt equal to a fixed fraction, b, of the capital stock. This implies that the debt service of the firm, and its net debt sales can both be both be expressed as functions of the time path of investment expenditures and the capital stock.

A capital feature of the model is that there is a cost to changing the capital stock. Without this cost, the size of the firm would be indeterminate because of constant returns to scale and the assumption of perfect competition. The cost of installing additional capital arises with the rate of capital accumulation, thereby preventing jumps in the demand for capital. The cost function is taken to be convex and homogeneous in investment and capital. Under these conditions, the dividend payment to shareholders will equal revenues minus labor costs, tax payments, debt service, and investment expenditures, plus the proceeds from net debt sales.

In our analysis, the crucial variable is the tax liability of the firm. it can be obtained by multiplying the corporate tax rate, t, by the appropriate corporate tax base. The corporate tax base differs from economic profit in four fundamental ways as discussed in detail in the previous chapter. First, nominal inventory profits are considered part of the tax base. Second, the firm is allowed to deduct depreciation charges based on the historic cost of capital goods before computing its tax liability. Third, the firm is permitted to deduct nominal interest payments for tax purposes. Fourth, nominal rather than real capital gains are taxed at the individual level. Therefore, there is a substantial difference between the corporate tax base and economic profit, and thus the corporate tax rate will be a determinant of the optimal time paths for output, labor demand, and investment.

It is assumed that the depreciation allowance per dollar of investment at the period s that can be taken at the period t is given by d_t^s where $t > s$. In addition, it is assumed that there is a one-time investment tax credit at the rate per dollar of investment expenditure.

The extent of nominal inventory profits will vary depending on the particular accounting method employed by the firm. Under FIFO, the act of selling inventory and replacing it with currently produced goods leads to a capital gain on existing inventory stocks if there is a positive rate of inflation. In other words, the FIFO accounting method causes the cost of goods sold to fall short of their replacement cost. This overstates earnings and causes the firm to pay extra taxes.

The alternative inventory accounting method, LIFO, assumes that the most recently produced goods are sold first. Under LIFO, the nominal value of existing inventories will not change, since the accounting cost of goods sold equals replacement cost. Thus, no extra taxes are paid. Therefore, nominal inventory profits will equal the rate of inflation times the nominal value of existing FIFO inventories. Given the simplifying assumption above, this latter figure will be proportioned to total revenues, where the factor of proportion-ability is equal to the percentage of total inventory stocks that are valued using FIFO, f.

Given the discussion above, the dividend payment at the period t can be expressed as:

$$(3.5)\quad D_t = p_t Q_t[1-(1+f\pi)t]-w_t L_t(1-t)-(1-k-b)\mu_t I_t$$
$$-\ b(1-t)\int_0^t r_s\mu_s(I_s-\delta K_s)\,ds-b\,\mu_t K_t + t\int_0^t d_t\,\mu_s I_s\,ds$$

where K_t and L_t = factor inputs at the period t, respectively,

I_t = gross investment at the period t,

Q_t = production function at the period t,

w_t = wage rate at the period t,

μ_t = input price of investment goods at the period t,

r_s = interest rate at the period s,

δ = economic depreciation rate,

k = investment tax credit rate,

f = fraction of total inventory stocks that are valued using FIFO,

t = corporate tax rates,

b = leverage ratio; fixed proportion of net investment expenditures financed with debt,

d_t^s = depreciation allowance per won of investment at the period that can be taken at the period t.

$\int_0^t d_t^s \mu_s I_s d_s$ measures the value of currently allowable depreciation allowances. The calculations of this assumes that the rate of depreciation used for tax purposes reflects accelerated depreciation and that depreciation allowances are based on historical cost.

Substituting equation (3.5) into equation (3.3) yields the market value of equity:

$$(3.6)\quad Vt = \frac{1-\theta}{1-g}\int_t^\infty \{\mathrm{E}(p_t)\,Q_t\,[1-(1+f\pi)t]-\mathrm{E}(w_t)\,L_t(1-t)$$

$$- (1-k-b)\mathrm{E}(\mu_s)\, I_t - b(1-t) \int_0^t r_s \mathrm{E}(\mu_s)\,(I_s - \delta K_s)\, ds$$

$$- b\,\mathrm{E}(\pi_t)\delta K_t + t \int_0^t d_t^s \mathrm{E}(\mu_s)\, I_s ds - \frac{\hat{a}}{2}\, Var(D_t) \} e^{-\frac{\gamma+\pi}{1-g}t}\, dt.$$

Equation (3.6) represents shareholder wealth in an appropriate fashion. Note that in equation (3.6) all cash flows are discounted by the same rate, r, the real after-tax rate of return required by equity holders. However, a fundamental finance principal is that cash flows with different risk attributes should be discounted at different rates. In particular, It is reasonable to argue that the debt payments should be discounted at a rate reflecting the riskiness of bonds rather thanepuity. In addition, the traditional capital budgeting model treats net investment and depreciation allowances as less risky than the cash flows from operations. If we denote the risk premium by φ, then the following condition should hold:

$$(3.7) \quad \tau = \gamma(1-\theta) - \pi + \varphi.$$

But we notice that the variance of dividend payments may be discounted either by τ or by γ. thus, in my study, all cash flows are assumed to be discounted by the same rate for the purpose of simplicity.

Since the equation (3.6) is overly complicated, it is simplified by converting the double integrals to single integrals by reversing the order of integration. this enables us to separate cash flows that are determined by present and future decisions from those that remain from previous decisions. In particular, the following simplication can be made:

$$(3.8) \quad \mathrm{V}_t = \frac{1-\theta}{1-g} \int_t^\infty \{\mathrm{E}(p_t)\mathrm{Q}_t\,[1-(1+f\pi)t] - \mathrm{E}(w_t)\mathrm{L}_t(1-t)$$

$$-[1-k-tz_t-b+\frac{b(1-t)(1-g)}{\tau+\pi}]\mathrm{E}(\mu_t)\mathrm{I}_t$$

$$b\mathrm{E}(\mu_t)\delta\mathrm{K}_t\,[1-\frac{(1-t)\gamma(1-g)}{\tau+\pi}] - \frac{\hat{a}}{2}\, Var(D_t)\}$$

$$e^{-\frac{\tau+\pi}{1-g}t}\, dt - \frac{\mathrm{R}(1-t)}{r} + t\frac{1-\theta}{1-g}\,\mathrm{B}.$$

For the purpose of exposition the following symbols are introduced:

$$(3.9) \quad \mathrm{B} = \int_t^\infty \int_0^t d_t^s\, \mathrm{E}(\mu_s)\mathrm{I}_s\, ds\, e^{-\frac{\tau+\pi}{1-g}t}\, dt.$$

$$(3.10) \quad z_t = \int_t^{\infty} d_s^t e^{-\frac{\tau+\pi}{1-g}t} dt.$$

R is the periodic interest payment on the existing debt. The B variable represents the present value of the remaining depreciation allowances associated with past investments, while z_t is the present value of depreciation allowances on a dollar of new investment. Both B and z_t will depend upon the depreciation schedule applicable to capital goods and the nominal discounting rate.

In maximizing equation (3.8) the firm can ignore R and B because they are independent of any current or future decisions. Also note that a change in the expected rate of inflation impacts upon the market value in two ways. First, it changes the value of two nominal flows, the debt payments on existing bonds and the depreciation tax shields on existing capital assets through its impact on the discounting rate. second, it changes the value of flows from future operations. The latter flows can be influenced by firm decisions. Therefore, it is reasonable to argue that output and input decisions will be changed when the expected rate of inflation changes.

In choosing output and input levels, the manager of the firm will maximize equation (3.8) subject to the following constraints. The first constraint is the production function:

$$(3.11) \quad Q_t = F(K_t, L_t)$$

Capital and labor are assumed to have positive but diminishing marginal products. That is, F_K, $F_L > 0$; F_{KK}, $F_{LL} < 0$. In addition, it is assumed that the two inputs are gross complements that is, $F_{KL} > 0$, if both factors are normal. This in turn implies that an increase in the real factor price of either input will reduce the demand for both inputs.

The second constraint is that capital accumulation equals net investment faced by the firm in maximizing equation (3.8). Given an exponential rate of δ, the capital stock evolves over time according to the following equation:

$$(3.12) \quad \dot{K}_t = I_t - \delta K_t.$$

By dropping the time subscripts and substituting equation (3.31) into equation (3.8), the objective function becomes:

$$(3.\ 13) \quad V = \frac{1-\theta}{1-g} \int_t^{\infty} \{E(p)F(K,\ L)\ [1-(1+f\pi)t]\ E(w)L(1-t)$$

$$-[1-k-tz-b+\frac{b(1-t)\gamma(1-g)}{\tau+\pi}]E(\mu)I$$

$$- b\mathrm{E}(\mu)\delta\mathrm{K}\ [1 - \frac{(1-t)\gamma(1-g)}{\tau+\pi}\ ] - \frac{\hat{\mathrm{a}}}{2}\ Var(\mathrm{D})\}\ e^{-\frac{\tau+\pi}{1-g}t}\ dt.$$

A shadow price, f, is introduced for the constraint given by equation (3.12). It can be interpreted as Tobin's marginal q, the ratio of the market value of an additional unit of capital to its replacement cost. The final two terms in equation (3.8) have not been included in the above equation since they are independent of the time path of the decision variables.

In the absence of the risk premium, this dynamic optimization problem can be written as:

$$(3.14)\quad \max_{\mathrm{L,I,K}} \Omega = \frac{1-\theta}{1-g} \int_t^{\infty} \{[\mathrm{E}(p)\mathrm{F}(\mathrm{K},\ \mathrm{L})\mathrm{A} - \mathrm{E}(w)\mathrm{LB} - \mathrm{E}(\mu)(\mathrm{I}\Gamma + \mathrm{K}\Delta)$$
$$- \frac{\hat{\mathrm{a}}}{2}\ Var(\mathrm{D})]\ e^{-\frac{\gamma+\pi}{1-g}t} + f(\mathrm{I} - \delta\mathrm{K} - \dot{\mathrm{K}})\}dt.$$

where $\mathrm{A} = 1-(1+\mathrm{f}\pi)\mathrm{t}$,
$\mathrm{B} = 1-\mathrm{t}$,
$\Gamma = 1-\mathrm{k}-\mathrm{tz}-\mathrm{b}[1-(1-\mathrm{t})(1-\mathrm{g})/(1-\theta)]$ and
$\Delta = \delta\mathrm{b}[1-(1-\mathrm{t})(1-\mathrm{g})/(1-\theta)]$.

Nothing that the variance of dividend payments is given by the follpwing:

$$(3.15)\quad Var(\mathrm{D}) = Var(p)\mathrm{F}^2\mathrm{A}^2 + Var(w)\mathrm{L}^2\mathrm{B}^2 + Var(\mu)(\mathrm{I}\Gamma + \mathrm{K}\Delta)^2$$
$$+2\ [\mathrm{Cov}(w,\ \mu)\mathrm{LB}(\mathrm{I}\Gamma + \mathrm{K}\Delta) - \mathrm{Cov}(\mu,\ p)\mathrm{FA}(\mathrm{I}\Gamma + \mathrm{K}\Delta)$$
$$- \mathrm{Cov}(p,\ w)\mathrm{LFAB}],$$

the optimality condition for capital demand can be given by:

$$(3.16)\quad F_k = \{\mathrm{E(c)} + \hat{\mathrm{a}}\ [Var(\mu)(\mathrm{I}\Gamma + \mathrm{K}\Delta) + \mathrm{Cov}(w,\ \mu)\mathrm{LB} - \mathrm{Cov}(\mu,\ p)\mathrm{QA}]$$
$$(\Delta + \Gamma\mathrm{H})(1/\mathrm{A})\}/\{\mathrm{E}(p) - \hat{\mathrm{a}}\ [Var(p)\mathrm{QA} - \mathrm{Cov}(\mu,\ p)(\mathrm{I}\Gamma + \mathrm{K}\Delta)$$
$$- \mathrm{Cov}(p,\ w)\mathrm{LB}]\}$$

where

$$(3.17a)\quad \mathrm{E(c)} = \mathrm{E}(\mu)(\Delta + \Gamma\mathrm{H})/\mathrm{A}$$

or

$$(3.17b)\quad E(c) = \frac{E(\mu)}{1-(1+f\pi)t}\{(1-k-tz)\left(\delta+\frac{r+\pi}{1-g}\right)$$
$$-b\left[1-\frac{(1-t)(1-g)}{1-\theta}\right]\left(\frac{r+\pi}{1-g}\right)\}$$

which is the expected implicit rental price, or, expected nominal user cost, of capital. This represents the expected price a firm should charge itself for the use of its non-capital.

The first order condition (3. 16), along with the production function (3. 31), may be solved for capital demand equation which describes the firm's equilibrium position:

$$(3.18)\quad K_t^* = f[E(p_t), E(w_t), E(c_t), Var(p_t), Var(w_t), Var(\mu_t), Cov(p_t, w_t)\; Cov(w_t, \mu_t), Cov(\mu_t, p_t)]$$

$$(3.19)\quad Q_t^* = h[E(p_t), E(w_t), E(c_t), Var(p_t), Var(w_t), Var(\mu_t), Cov(p_t, w_t)\; Cov(w_t, \mu_t), Cov(\mu_t, p_t)]$$

where asterisk denotes desired or optimal quantities. As these conditions were derived within a dynamic context, it is assumed that they will be met at each point in time.

Explicit parametric expressions for the factor demands may not be derived until assumptions are made concerning the specific form of the production function. The standard neoclassical investment model is based upon the assumption that a Cobb-Douglas production function with constant returns to scale is appropriate:

$$(3.20)\quad Q_t = \Omega K_t^{\alpha} L_t^{1-\alpha}$$

represents Hick-neutral technological progress, α and $1-\alpha$ rate elasticities of output with respect to capital and labor, respectively, and $0 \langle \alpha \langle 1$.

When combined with the marginal productivity conditions given in (3. 16), the following expression is produced:

$$(3.21)\quad K_t^* = \alpha Q_t^*\{E(p_t) - \hat{a}[Var(p_t)Q_t^*A - Cov(\mu_t, p_t)(I_t^*\Gamma+K_t^*\Delta) -$$
$$Cov(p_t, w_t)L_t^*B]\}/[E(c_t)+\hat{a}[Var(\mu_t)(I_t^*\Gamma+K_t^*\Delta) +$$
$$Cov(w_t, \mu_t)L_t^*B - Cov(\mu_t, p_t)Q_t^*A](\Delta+\Gamma H)(1/A)\}$$

In general terms, it may be expressed as[2]:

$$(3.22)\quad K_t^* = f[E(w_t), E(c_t), Var(w_t), Var(\mu_t), Cov(p_t, w_t), Cov(\mu_t, p_t), Q_t, I_t, \Omega, \alpha, \hat{a}, f, \pi, t, g, \theta, k, \tau, z, b, \delta, \gamma].$$

Equation (3.22) shows that the optimal demand for capital by the firm owned by risk averse individuals depends upon expectations regarding prices, the degree of uncertainty associated with those expectations, and tax parameters. It also shows that the inclusion the variance and covariance components of the dividend payments in the firm's objective function severely complicates the task of deriving explicit capital demand relationship. In order to carry out the desired empirical research to analyze the impact of inflation, price uncertainty, and tax rules upon business fixed investment, simplifying assumptions must be imposed in order to derive easily manageable expressions.

If it is assumed that the variances of wages and of input prices of investment goods, and the covariances between output prices, wages and input prices are strictly proportional to the variance of output prices, and that capital and labor can be approximated as a fixed proportion of output, we may rewrite as a rough approximation of (3.15):

$$(3.23)\quad Var(D_t) \approx Var(p_t)Q_t^2A^2 + \varepsilon_1 Var(p_t)(\tau_1 Q_t)^2B^2 + \varepsilon_2 Var(p_t)(\tau_3 Q_t \Gamma + \tau_2 Q_t\Delta)^2 + 2(\varepsilon_{12} Var(p_t)\tau_1 Q_t B(\tau_3 Q_t \Gamma + \tau_2 Q_t \Delta) - \varepsilon_{20} Var(p_t) Q_t A (\tau_3 Q_t \Gamma + \tau_2 Q_t \Delta) - \varepsilon_{01} Var(p_t)\tau_1 Q_t^2 AB$$

where $Var(w_t) = \varepsilon_1 Var(p_t)$, $Var(\mu_t) = \varepsilon_2 Var(p_t)$,
$Cov(p_t, w_t) = \varepsilon_{01} Var(p_t)$, $Cov(w_t, \mu_t) = \varepsilon_{12} Var(p_t)$,
$Cov(\mu_t, p_t) = \varepsilon_{20} Var(p_t)$, $L_t = \tau_1 Q_t$, $K_t = \tau_2 Q_t$, and $I_t = \tau_3 Q_t$.

Thus (3. 23) can be written:

$$(3.24)\quad Var(D_t) \approx \Phi\, Var(p_t)Q_t^2$$

where

$$(3.\ 25)\quad \Phi = A^2 + \varepsilon_1\tau_{12}B^2 + \varepsilon_2(\tau_3\Gamma + \tau_2\Delta)^2 + 2\varepsilon_{12}\tau_1 B(\tau_3\Gamma + \tau_2\Delta) - 2\varepsilon_{20}A(\tau_3\Gamma + \tau 2\Delta) - 2\varepsilon 01\ \tau 1\ AB.$$

(3.24) is not intended to suggest that only the variance of output prices co-

[2] Similar derivation can be obtained from Koo(1990).

ntributes to the uncertainty faced by the firm. Rather it is suggested that the variance of all prices, input and output alike, tend to move together so that changes in the relative uncertainty associated with the different prices are roughly the same and that overall level of output price.

Replacing (3.15) with (3.24) in the firm's objective function produces the following Lagrangian instead of that in (3.14):

$$(3.26)\quad \max_{L_t, I_t, K_t} \Omega = \frac{1-\theta}{1-g} \int_t^{\infty} \{[E(p_t)F(K_t, L_t)A - E(w_t)L_tB - E(\mu_t)$$

$$(I_t\Gamma + K_t\Delta) - \frac{\hat{a}}{2} Var(p_t)[F(K_t, L_t)]^2\} e^{-\frac{\tau+\pi}{1-g}t}$$

$$+ f(I_t - \delta K_t - \dot{K}_t)\}d_t.$$

The first order condition for a maximum of this simplified version of the objective function is:

$$(3.27)\quad \frac{\delta\Omega}{\delta K_t} - \frac{d}{d_t}\frac{\delta\Omega}{\delta K_t} = \frac{1-\theta}{1-g}[E(p_t)F_K A - E(\mu_t)\Delta - \hat{a}\Phi\, Var(p_t)$$

$$F(K_t, L_t)F_K]\, e^{-\frac{\tau+\pi}{1-g}t} - f\delta + f = 0$$

(3.27) may be solved for the following marginal productivity conditions:

$$(3.28a)\quad F_K = \frac{E(\mu_t)(\Delta + \Gamma H)}{E(p_t)A - \hat{a}\Phi Var(p_t)Q_t}$$

or

$$(3.28b)\quad F_K = E(\mu t)\{(1-k-tz)(\delta + \frac{\tau+\pi}{1-g}) - b[1 - \frac{(1-t)(1-g)}{1-\theta}]$$

$$(\frac{\tau+\pi}{1-g})\}/\{E(p_t)[1-(1+f\pi)t] - \hat{a}\Phi Var(p_t)Q_t\}$$

These marginal productivity conditions lead to the same general information as did those in the more general case, namely that the marginal productivities are higher, and hence factor demands lower, the greater the degree of uncertainty, given in this case by the variance of output prices, the greater the degree of risk aversion displayed by investors in the firn, and the larder the proportion of total inventory stocks that are valued using FIFO.

Employing the Cobb-Douglas production function, it is possible to transform (3.28) into the following capital demand expression:

$$\text{(3.29a)} \quad K_t^* = \frac{\alpha Q_t^*[E(p_t)A - \hat{a}\Phi Var(p_t)Q_t^*]}{E(\mu_t)(\Delta + \Gamma H)}$$

or

$$\text{(3.29b)} \quad K_t^* = \frac{\alpha Q_t^*[E(p_t)A - \hat{a}\Phi(1/A)Var(p_t)Q_t^*]}{E(c_t)}$$

recalling $E(ct) = E(\mu t)(\Delta + \Gamma H)/A$.

In the standard neoclassical model, it is assumed that the desired stock of capital is not capable of being immediately acquired, but rather that the actual stock of capital can only be brought gradually towards the desired stock by means of an adjustment process. the standard neoclassical model is thus given by:

$$\text{(3.30)} \quad I_t = I(K_t^*, K_t)$$

where K_t^* denotes the desired stock if capital as given in (3.29), K_t is the stock of capital existing at the time of the investment decision, and the function I_t describes the adjustment process relating actual to desired capital stock.

Following Jorgenson, the standard neoclassical investment equation will be derived for an empirical study as follows:

$$\text{(3.31)} \quad I_t = \beta(L)\, \Delta K_t^* + \delta Kt_{t-1}$$

which, by substituting (3.29b) for K_t^* becomes:

$$\text{(3.32)} \quad I_t = \alpha\beta_1(L)\Delta\left[\frac{O_t^*}{c_t^*}\right] - \alpha\hat{a}\left[\frac{\Phi}{A}\right]\beta_2(L)\Delta\left[\frac{\Phi Var(p_t)Q_t^{*2}}{p_t c_t}\right] + \delta K_{t-1}$$

where c is the real cost of capital (hereafter c denotes areal variable). Because it includes as an explanatory variable the unobservable desired output, (3.31) would not appear capable of empirical study. In order to solve this problem, Jorqenson (1963) assumes that output and employment on the one hand and capital stock on the other are determined by a kind of iterative process. In each period, production and employment are determined are set at the levels given by the first marginal productivity condition and the production function with actual capital stock fixed at its current level; demand for capital is set at the level given by the second marginal productivity condition, that is, by means of solving the capital demand equation (3.29), given output and employment with stationary market conditions, such a process is easily seen to converge to the desired maximum of market value of the firm.

The advantage of assuming firms to employ such a procedure is that it allows the substitution of actual output for desired output in (3.29) and hence (3.32). Thus equation (3.32) may be rewritten as:

$$(3.33)\quad I_t = \alpha\beta_1(L)\Delta\left[\frac{O_t}{c_t}\right] - \alpha\hat{a}\left[\frac{\Phi}{A}\right]\beta_2(L)\,\Delta\left[\frac{Var(p_t)O_t^2}{p_t\,c_t}\right] + \delta K_{t-1}$$

where $\beta_1(L)$ and $\beta_2(L)$ are polynomials in the lag operator and reflect elements of both the adjustment and expectations forming processes. Note that this modification was made under the assumptions of putty-putty technology and the Cobb-Douglas production function with constant returns to scale as conventionally used in a standard neoclassical model.

The standard neoclassical model developed by Jorgenson and collaborators is but a special case of (3.33) in which either $\hat{a}$ or Var(p) is assumed equal to zero such that:

$$(3.34)\quad I_t = \alpha\beta(L)\,\Delta\left[\frac{O_t}{c_t}\right] + \delta K_{t-1}$$

However, recent studies show that the specification of the underlying production technology and the choice of a particular production function crucially influence the explanatory power of aggregate investment equations. Equation (3. 33) is current only if technology is putty-putty (that is existing capital can be modified when the user cost of capital changes) and there are no lags in adjusting the capital stock to its new optimal level when anticipated sales or the cost of capital changes.

In the next section, the model developed in this study will be empirically tested for its appropriateness in such a world discussed above and compared with the empirical results of alternative versions of investment of equations.

IV. EMPIRICAL RESULTS

The theoretical model developed above indicates that inflation uncertainty and the interaction between inflation and taxation play important roles in the determination of investment. Changes in the degree of inflation uncertainty measured by the variance of output price can have an adverse effect on the rate of investment. Due to the nonneutralities of the tax system, the demand for capital stocks is reduced by an increase in the expected rate of inflation. In this chapter, we estimate empirical investment demand equations to determine the sensitivity of investment demand to changes in the degree of inflation uncertainty and to changes in the user cost of capital.

Alternative versions of investment equations to be empirically tested are presented as:

$$(4.1)\quad \Delta(I_t - \delta K_{t-1}) = w(L)\,\Delta\left[\frac{Q_t}{c_t}\right]$$

$$(4.2)\quad \Delta(I_t - \delta K_{t-1}) = w_1(L)\,\Delta\left[\frac{Q_t}{c_t}\right] + w_2(L)\,\Delta\left[\frac{Var(p)Q_t}{p_t c_t}\right]$$

where $w_1(L)$ and $w_2(L)$ are polynominals in the lag operator and reflect elements of both the adjustment and expectations forming processes. Version 1 of the investment equation is given by (4.1) which is a standard neoclassical model under the assumptions of certainty and putty-putty technology specification. The final form of the distributed lag function of the standard neoclassical model used in our empirical work involves the specification of first differences in the dependent variable, net investment. Version 2 is given by (4.2) which assumes uncertainty and putty-putty technology. This is an complete version of the standard neoclassical model, developed in this study, in which the concept of inflation uncertainty is incorporated and additional factors are incorporated into the user cost of capital to address the effects of the interaction of inflation and taxation.

1. Data and Parameters

To test the theory of investment behavior summarized above, the corresponding stochastic investment equations have been to quarterly data for Korean non-residential business sector for the period 1970-92. The data used in this study came from a variety of sources. All variables are measured quarterly and all flow variables are expressed in real terms at annual rates.

The empirical model developed above explicitly recognizes that capital is not a homogeneous entity. Following current practice, capital is disagreated into two components, capital equipment and capital structures. This distinction is important for at least two reasons. First, the Korean tax laws treat equipment and structures differently. Tax rules allow different depreciation schedules and applies the investment tax credit only to expenditures on equipment and not to structures. Second, order and delivery lags should vary substantially for two categories. Imposing the same lag structure by estimating a single-investment equation would seriously reduce the explanatory power of the model.

The dependent variable in estimating (4.1) and (4.2) is chosen to be net investment in producer durable equipment by the nonresidential business sector.

Even though data for a more aggregate sector is available, it is chosen because it is the most highly aggregated set of data consistent with available data for use in conjunction with the explanatory variables, that is, data for investment expenditures, capital stock, output price deflators are consistently available only at the aggregate level of the nonresidential business sector.

Data for nonresidential net investment in equipment, I_t^N, is available from the National Accounts of the Bank of Korea. Output, Q_t, is measured as the gross domestic product of the nonresidential business sector which is also available from the National Accounts of the Bank of Korea. The output price, p_t, is the implicit price deflator for the gross domestic product of nonresidential business sector obtained from the Price Statistics Summary of the Bank of Korea. The purchase price for new investment in equipment, μ_t, is the implicit price deflator for the gross private domestic investment in equipment by the nonresidential business sector in the Price Statistics Summary. The expected rate of inflation, π_t, is estimated using the economically rational expectations model. The proxy for the variance of output price, $Var(p_t)$, used in this study is estimated based upon the ARCH model.

The real user cost of capital, c_t, is calculated using the following expression:

$$(4.3)\quad c_t = \frac{\mu_t}{p_t[1-(1+f\pi_t)t]}\{(1-k-tz_t+k'tz_t)$$

$$[\delta + \frac{r_t(1-\theta)}{1-g}] - b[1-\frac{(1-t)(1-g)}{1-\theta}]\frac{r_t(1-\theta)}{1-g}\}$$

The personal income tax, θ, is the average tax rate calculated by the author. The corporate tax rate, t, and the investment tax credit rate for equipment, k, are obtained from J. Y. Kim(1991). k' is a constant parameter which is set to zero if the investment tax credit is not deductible from depreciation allowances, and k if it is. The capital gains tax rate, g, is derived from the average marginal tax rate. The leverage ratio, b, may be also calculated by the author. The epreciation rate, δ, is obtained by using the gross investment series to reproduce the corresponding capital stock series using the following formula: $K_t = (1-\delta)K_{t-1} + I_t$.

Because the depreciation rate is assumed a constant, it is necessary to treat the annual variation in the calculated depreciation rates as random fluctuations about the true rate. The fraction of total inventory stocks that are valued using FIFO accounting methods, f, is taken to be 0.63. This figure can be obtained by regressing the inventory valuation adjustment against the inventory stock series multiplied by the change in output price.

The coefficient from this regression will equal the value of f. Determining an appropriate value for z_t, the present value of the depreciation allowance on new investment in equipment, is slightly more complicated. The formula for z_t is given by:

$$(4.4) \quad z_t = \int_0^T D_s \exp\left[-\frac{r(1-\theta)}{1-g}s\right]ds$$

where D_s is the depreciation allowance per won of investment taken for tax purposes, while T is the tax life of that asset. The discount rate used in this study to calculate the present value of tax depreciation differs substantially from the standard calculation. It is the corporate bond rate net of personal taxes. The theoretical model in the previous section discusses why this is the appropriate discount rate for depreciation allowances. The value of z_t, is thus dependant upon the formula used to determine the depreciation allowance, D_s.

2. Estimation Technique

To estimation the parameters of the distributed lag function for alternative versions of investment behavior, an appropriate distributed lag estimation technique should be employed. Studies suggest that conclusions drawn from the estimation of the distributed lag equation may be influenced significantly by the choice of lag length and polynominal restrictions employed. Unless the correct lag length and degree of polynominal are specified, estimates of the individual lag weights, however, will be biased generally. Therefore, it is important that the appropriate specification should be determined.

There are numerous procedures and criteria for determining the appropriate lag length and polynominal degree. We choose procedure outlined recently by Pagano and Hartley because it is a computationally efficient procedure, that is, it yields lower standard error than the conventional F-test procedure. Batton and Thornton(1983) show that PH techniques substantially improves the explanatory power of the estimated equation and are superior to alternative specifications techniques. When Almon first introduced the polynominal distributed lag models, she suggested that end point constraints should always be employed. Even if end point constraints have little basis in either economic or econometric theory, we employ the end point constraints in this study for the purpose of improving the efficiency of estimation.

3. Estimates of Investment Equations

The results from empirically estimating alternative versions of investment equations, (4.1) and (4.2), using quarterly data for nonresidential investment in equipment are contained in tables in the Appendix.

The standard neoclassical model of investment equation, (4.1), under the assumptions of perfect certainty is estimated with the original specification of the user cost of capitol. This specification does not explicitly incorporate the impact of inflation-tax interactions. As discussed earlier the standard neoclassical model does not appropriately explain the steep decline and slow recovery in investment which occurred in 1970's and in early 1990's in Korea. This is due to its assumption of perfect certainty and its failure to explicitly incorporate the effects of the interaction of inflation and taxation on the user cost of capital.

Estimation results of equation (4.1) under the conventional specification of capital costs are presented in Table 5. The ordinary least squares are applied to estimate the equation. The Durbin-Watson statistic rejects the null hypothesis at a 1% level. Thus, there is no need for a correction for autocorrelation. The lag pattern for the variable is reasonably humped over the period and most individual coefficients are highly significant. More weight is concentrated in the early states of the lag for net investment. After the midpoint, the weight of the lag decreases. However, the coefficient on the longest lag length and polynominal degree are appropriate. The results in Table 1 indicate that equation (4.1) has a low degree of explanatory power. The R^2 statistic for this equation, 0.334, is lower than the R^2 for alternative versions of investment equation. The standard error, 1.741, is the highest among the four versions of investment equation. These results indicate that the standard neoclassical framework is not appropriate to explain the steep decline and weak recovery of investment in a world of uncertainty associated with future inflation and tax distortions in conjunction with inflation.

The inflation-tax interactions have been considered as a primary cause for the low rate of capital formation during 1970's and early 1990's. In this study a modified standard neoclassical investment model is developed which explicitly incorporates the interaction of inflation and taxation into the user cost of capital. The indications involve the explicit treatment of depreciation allowances, capital gains taxation, and inventory taxation in a manner which incorporates the impact of inflation. Equation (4.1) is then regressed with the modified specification of cost of capital. The results are presented in Table 2. The R^2 statistic increased from 0.334 to 0.358. The standard error, 1.709, is lower than that of the estimation of (4.1) with the original specification of capital cost, 1.741. These results indicate that the explanatory power of the investment equation evidently improves with a respecification of the user cost of capital in a manner that incorporates the impact of inflation. The lag distributions associated with $\Delta[Q_t/C_t]$ are very similar regardless of the specifications of user cost of capital. The ordinary least squares estimation is still appropriate since the Durbin-Watson statistic shows 1.698 which rejects the null hypothesis at a 1% level.

The low performance of the standard neoclassical model is also attributed to its assumptions of certainty. It is not equipped to deal with the problems which arise when decisions are assumed to be made under conditions of uncertainty. As discussed before, high rates of inflation not only make forecasting future inflation increases the risks associated with investment planning and thereby reduces the level of investment spending. Considering all these arguments the standard neo-classical model is modified in a manner that incorporates uncertainty regarding future inflation.

If an inflation uncertainty variable is incorporated with the standard neo-classical model the model is significantly improved. The estimation results of equation (4.2) are shown in Table 7. Modification of the model substantially increases the R^2 statistic, 0.505 and reduces the standard error to 1.562 which is approximately 8.6 percent less than that of (4.1), 1.709. The ordinary least squares estimation is again applied since there is no evidence of auto-correlation as the Durbin-Watson statistic indicates 1.856. The lag distribution associated with $\Delta[Q_t/C_t]$ in (4.1) and (4.2) are very similar. In both distribution, most of the first eight coefficients are statistically significant at the 10% level. Equation (4.2) suggests that the level of investment spending is affected by the degree of uncertainty regarding the price of output. Its first seven coefficients on $\Delta[Var(p_t)Q_t^2/p_tc_t]$ are significant and account for approximately 90% of the total impact. The sum of coefficients of the uncertainty variable has a negative sign as expected from the theoretical arguments given in the previous chapter. These coefficients therefore not only are statistically significant but also may have a substantial adverse effect on the level of net investment in the economy. These results also indicate that the explanatory power of the investment equation substantially improves by incorporating an inflation uncertainty variable into the investment equation.

It is interesting to note that the results obtained here contradict the ones suggested by recent literature on investment under price uncertainty within the context of the theory of investment. As discussed earlier, the q approach shows that, given the current output price, higher price uncertainty tends to increase the expected value of future marginal value of products of capital and hence increase q and the rate of investment. However, in this study, it is shown that higher uncertainty regarding future price of output restrain the rate of investment both theoretically and empirically by incorporating an inflation uncertainty variable into the standard neoclassical approach.

V. CONCLUSIONS

This study has examined three testable hypothese by deriving a more complete specification and framework for estimating an investment model. The testable hypotheses are: 1) Increased uncertainty about future inflation adversely affects bus iness fixed investment; and 2) The interaction of taxation and inflation discourages business fixed investment.

An extended investment model is developed by incorporating an inflation uncertainty variable with the standard neoclassical. The modification also involves the explicit treatment of depreciation allowances, capital gains taxation, and inventory taxation in a manner which incorporates the impact of inflation.

In order to test the three hypotheses, the extended model is compared with three alternative versions of investment equation by using the aggregate quarterly data over the period 1970:I to 1992:IV. Comparisons of the estimate of the two equations prove the extended model, equation (4.2), under the assumptions of uncertainty and putty-clay technology to be statistically superior of uncertainty version. The coefficients associated with the uncertainty variable are statistically significant. The R^2 statistic associated with the extended model is highest and the standard error significantly less inflation-tax interaction in the specification of the user cost of capital substantially improves the explanatory power of the investment model.

The estimation results show that : 1)Changes in the degree of inflation uncertainty can have significant negative effects on the rate of business fixed investment ; and 2)The interaction of the high rates of inflation in Korea throughout the 1970s and early 1980s, and early 1990's with our non-indexed tax system has had a particularly damaging impact upon capital accumulation.

APPENDIX

[Table 1] Pagano-Hartley t-statistics for Lag Length Selection of Equation (4.1) $\Delta I_t^N = w(L)\,\Delta(Q_t/c_t)$

Lag	L = 20	L = 18	L = 16
0	2.068	2.224	1.919
1	0.555	0.743	0.864
2	1.657	1.565	1.644
3	2.228	2.277	2.308
4	1.175	1.148	0.225
5	−0.747	−0.446	0.270
6	2.374	1.924	2.016
7	1.025	1.558	1.640
8	−0.211	−0.563	−0.474
9	−0.584	−0.528	−1.375
10	−0.941	−0.452	−0.291
11	0.436	−0.059	0.102
12	0.304	0.431	−0.300
13	−0.119	−0.101	0.563
14	−0.186	−0.430	−0.601
15	−3.111*	−3.008*	−2.843*
16	0.472	0.497	1.064
17	0.357	0.241	
18	0.929	1.400	
19	0.051		
20	1.176		

* First significant t-statistic

[Table 2] Pagano-Hartley t-statistics for Lag Length Selection of Equation (4.2) $\Delta I_t^N = w_1(L)\,\Delta(Q_t/c_t) + w_2(L)\,\Delta[\mathrm{Var}(p_t)Q_t^2/p_t c_t]$

	First variable with lag on second variable equal to			Second variable with lag on first variable equal to		
Lag	20	16	12	20	16	15
0	0.260	0.614	0.778	0.101	0.603	0.489
1	0.351	0.535	0.363	−1.427	−0.738	−0.694
2	1.175	1.726	1.279	−1.090	−1.991	−2.104
3	1.005	0.912	1.441	−0.068	0.626	0.743
4	1.283	0.742	−0.004	−2.962	−4.042	−4.112
5	−0.880	−0.034	0.487	−0.996	−1.528	−1.512
6	2.671	2.076	2.610	−2.113	−0.821	−0.713
7	1.257	2.599	2.347	0.098	−0.969	−0.991
8	0.803	0.296	0.348	−0.811	0.385	0.398
9	0.522	−0.271	−0.327	−1.236	−1.026	−0.979
10	−0.808	0.262	0.229	1.505	0.046	0.050
11	1.776	0.020	0.037	0.002	1.499	1.586
12	1.083	0.566	−0.303	−2.305*	−1.992*	−1.850*
13	−0.235	0.295	0.161	0.763	1.135	1.125
14	0.232	−0.449	−0.538	−0.619	0.130	0.240
15	−2.580*	−2.347*	−2.320*	−0.123	−0.810	−0.863
16	0.731	0.657	1.265	0.645	1.073	1.088
17	1.164			0.709		
18	0.747			1.266		
19	0.071			−0.527		
20	−1.188			1.276		

* First significant t-statistic

[Table 3] Pagano-Hartley t-statistics for Polynominal Degree Selection of Equation (4.1) $\Delta I_t^N = w_1(L)\,\Delta(Q_t/c_t)$

Polynominal Degree		P = 15	
0	2.178	8	1.193
1	−6.781	9	0.563
2	−1.234	10	−0.725
3	2.217	11	1.508
4	−1.550	12	−0.103
5	0.967	13	−1.289
6	0.964	14	0.051
7	2.256*	15	−0.641

* First significant t-statistic

[Table 4] Pagano-Hartley t-statistics for Polynominal Degree Selection of Equation (4.2) $\Delta I_t^N = w_1(L)\,\Delta(Q_t/c_t) + w_2(L)\,\Delta[\mathrm{Var}(p_t)Q_t^2/p_t c_t]$

Polynominal Degree	First variable with polynomial degree on second variable equal to 12	Second variable with polynomial degree on first variable equal to 15
0	2.369	−1.858
1	−3.677	1.718
2	−2.461	2.096
3	1.311	−4.002
4	0.446	−1.459
5	0.498	1.987
6	0.311	0.452
7	1.645*	1.038
8	1.334	0.683
9	0.025	2.762*
10	−0.414	−0.024
11	1.455	0.762
12	−0.269	0.595
13	−0.997	
14	0.158	
15	−0.409	

* First significant t-statistic

[Table 5] Ordinary Least Squares Estimates of Equation (4.1) $\Delta I_t^N = w(L)\,\Delta(Q_t/c_t)$ with the Standard Neoclassical Specification of the Cost of Capital

Lag	Estimated Coefficients	
0	0.00246*	(2.493)
1	0.00221*	(3.194)
2	0.00181*	(2.581)
3	0.00184*	(2.672)
4	0.00201*	(3.379)
5	0.00191*	(3.103)
6	0.00137*	(2.162)
7	0.00050	(0.860)
8	−0.00034	(0.588)
9	−0.00078	(1.232)
10	−0.00062	(1.032)
11	−0.00006	(0.095)
12	0.00040	(0.566)
13	0.00009	(0.124)
14	−0.00126	(1.745)
15	−0.00256*	(2.446)
$\sum w_i$	0.00967*	(2.795)
SE = 1.741		
R^2 = 0.334		
DW = 1.666		

* Indicates significance at the 5 percent level.
Absolute value of t-statistics in parenthesis.

[Table 6] Ordinary Least Squares Estimates of Equation (4.1) $\Delta I_t^N = w(L)\,\Delta(Q_t/c_t)$ with the Modified Specification of the Cost of Capital, (4.3)

Lag	Estimated Coefficients	
0	0.00236*	(2.777)
1	0.00203*	(2.518)
2	0.00156*	(2.617)
3	0.00152*	(2.606)
4	0.00168*	(3.388)
5	0.00163*	(3.166)
6	0.00119*	(2.219)
7	0.00043	(0.887)
8	−0.00030	(0.623)
9	−0.00069	(1.297)
10	−0.00055	(1.087)
11	−0.00004	(0.088)
12	0.00035	(0.588)
13	0.00003	(0.051)
14	−0.00124*	(2.056)
15	−0.00245*	(2.732)
$\sum w_i$	0.00751*	(2.503)
SE = 1.709		
R^2 = 0.358		
DW = 1.698		

* Indicates significance at the 5 percent level.
Absolute value of t-statistics in parenthesis.

[Table 7] Ordinary Least Squares Estimates of Equation (4.2)
$\Delta I_t^N = w_1(L)\,\Delta(Q_t/c_t) + w_2(L)\,\Delta[Var(p_t)Q_t^2/p_t c_t]$

	Estimated Coefficients			
Lag	w_1		w_2	
0	0.00142	(1.713)	0.00455	(0.716)
1	0.00101	(1.698)	−0.01044*	(2.143)
2	0.00069	(1.157)	−0.00659	(1.620)
3	0.00087	(1.478)	−0.00848	(1.882)
4	0.00131*	(2.479)	−0.01645*	(3.856)
5	0.00163*	(2.990)	−0.01753*	(4.005)
6	0.00158*	(2.989)	−0.00859*	(2.080)
7	0.00119*	(2.361)	0.00051	(0.123)
8	0.00065	(1.262)	0.00129	(0.363)
9	0.00021	(0.391)	−0.00099	(0.268)
10	0.00006	(0.113)	0.00519	(1.473)
11	0.00014	(0.268)	0.01214*	(2.712)
12	0.00020	(0.312)	−0.01037	(1.884)
13	−0.00015	(2.241)		
14	−0.00104	(1.690)		
15	−0.00180*	(2.033)		
$\sum w_i$	0.00797*	(2.599)	−0.05576*	(2.163)
SE=1.562				
R^2 = 0.505				
DW= 1.856				

* Indicates significance at the 5 percent level.
Absolute value of t-statistics in parenthesis.

REFERENCES

Abel, Andrew B., "Empirical Investment Equations: An Integrative Framework," Karl Brunner and Allan Meltzer, eds., *On the State of Macro-Economics*, Carnegie-Rochester Conference Series on Public Policy, 1980, pp. 39-91.

_______, "Taxes, Inflation and the Durability of Capital," *Journal of Political Economy*, 89(1981), pp. 548-60.

_______, "Optimal Investment under Uncertainty," American Economic Review, 73(1983), pp. 228-233.

Auerbauch, Alan, "Inflation and the Tax Treatment of Firm Behavior," *American Economic Review*, 71(1981), pp. 419-23.

Batten, Dallas S. and Daniel L. Thornton, "Polynominal Distributed Lags and the Estimation of the St. Louis Equation," *Review*, 65(1983), pp. 13-25.

Bertola, Giuseppe, "Irreversible Investment," unpublished working paper, Princeton University, 1989.

Bischoff, Charles, "Business Investment in the 1970's: A Comparison of Models," *Brooking Papers on Economic Activity 1*, 1971, pp. 13-58.

Bosworth, Barry P., "Taxes and the Investment Recovery," *Brooking Papers on Economic Activity 1*, 1985, pp. 1-45.

Caballero, Richard J., "On the dynamics of Aggregate Investment," Columbia University, discussion paper No. 541, May 1991.

_______ and Robert S. Pindyck, " Uncertainty, Investment, and Industry Evolution," NBER Working Paper No. 4160, September 1992.

Ciccolo, John and Gary Fromm, "'q' and the Theory of Investment," *Journal of Finance*, 34(1979), pp. 535-47.

Dixit, Avinash and Robert S. Pindyck, *Investment under Uncertainty*, Princeton, NJ: Princeton University Press, 1993.

Eisner, Robert and M. I. Nadiri, "Investment Behavior and the Neo-Classical Theory," *Review of Economics and Statistics*, 50(1968), pp. 625-47.

Feldstein, Martin, "Inflation, Tax Rules and Investment: Some Econometric Evidence," *Econometrica*, 50(1982) , pp. 825-62.

_______ and Lawrence Summers, "Inflation and the Taxation of Capital Income in the Corporate Sector," *National Tax Journal*, 32(1979), pp. 445-70.

Hall, Robert E. and Dale W. Jorgenson, "Tax Policy and Investment Behavior," *American Economic Review*, 57(1967), pp. 391-414.

Hendershott, Patric and Sheng-Cheng Hu, "Investment in Producer's Equipment," in *How Taxes Affect Economic Behavior*, H. Aaron and J. Pechman, eds., Washington, D. C. : Brookings Institution, 1981, pp. 85-129.

Ingersoll, Jonathan E., Jr., and Stephen A. Ross, "Waiting to Invest: Investment and Uncertainty," *Journal of Business*, 65(1992), PP. 1-29.

Jorgenson, Dale W., "Capital Theory and Investment Behavior," *American Econ-*

omic Review, 53(1963), pp. 247-59.

_______, "The Theory of Investment Behavior," in *Determinants of Investment Behavior*, New York: National Bureau of Economic Research, 1967, pp. 129-55.

_______ and C. D. Siebert, "A Comparison of Alternative Theories of Corporate Investment Behavior," *American Economic Review*, 58 (1968), pp. 681-712.

Kim, Jun Young, *Cost of Capital and Effective Corporate Income Tax Rate in Korea*, Korea Development Institute, 1991.

Koo, Chung Mo, "The Neoclassical Investment Model: Revisited," *The Management Science*, 14(1990), pp. 91-140.

Kopcke, Richard, "Inflation, Corporate Income Taxation, and the Demand for Capital Assets," *Journal of Political Economy*, 89(1981).

Kwack, Tae Won, "Tax-Incentive Investment Policy in Korea and Its Economic Effect," *Selected Policy Issues in Korea's Tax Rules*, Korea Development Institute, 1984.

Lintner, John, "Security Prices Risk and Maximal Gains from Diversification," *Journal of Finance*, December 1965.

Modigliani, Franco, "Debt, Dividend Policy, Taxes, Inflation, and Market Valuation," *Journal of Finance*, 37(1982).

Mossin, Jan, "Equilibrium in a Capital Asset Market," *Econometrica*, October 1966.

Nickell, Stephen J. *The Investment Decisions of Firm*, Cambridge; Cambridge University Press, 1978.

Pagano, Marcello and Michael J. Hartley, "On Fitting Distributed Lag Models subject to Polynomial Restrictions," *Journal of Econometrics*, 16(1981), pp. 171-98.

Pindyck, Robert S., "Irresponsibility, Uncertainty, and Investment," *Journal of Economic Literature*, 29(1991), pp. 1110-1152.

_______ and Andres Solimano, " Economic Instability and Aggregate Investment," *NBER Macroeconomics Annual*, NBER, 1993, pp. 259-303.

Summers, Lawrence H., "Taxation and Corporate Investment: A q-Theory Approach," *Brookings Papers on Economic Activity* 1, 1981.

Yoshikawa, H., "On the 'q' Theory of Investment," *American Economic Review*, 70 (1980), pp. 739-43.