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INTEGRATION UNDER UNCERTAINTY

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I. Introduction

An extensive economic literature has developed concerning
the effects of imperfect information and risk aversion on the
behavior of economic agents. The results which emerge from many
of these models differ from those derived using the perfectly com-
petitive assumptions. This divergence casts doubt on the
relevance of static certainty models as a basis for the formation
of public policy in a dynamic uncertain world. Public utility
regulation and vertical integration are two areas which have been
noticeably affected by the developments in the economics of
uncertainty.

Recent papers by Meyer (9), Peles and Stein (11), and
Perrakis (12), concerning the effects of uncertainty on the
behavior of regulated monopolists raise fundamental questions
about the relevance of the Averch-Johnson (2) over capitalization
effect, the foundation of the theory of rate of return regulation
for almost twenty years. The existence of the A-J effect depends
on the precise manner in which uncertainty enters into the firm's
decision environment. In some cases, it is actually reversed
(11). Even if the effect is operational in the usual direction,
its magnitude may be reduced for a firm that is risk averse (9).
These results should indicate to public utility commissioners

that uncertainty and a firm's attitude toward risk cannot be
ignored in the design of a regulatory constraint.

Uncertainty or lack of perfect information is often dis-
cussed as one of the causes for market failure; that is, a break-
down of the competitive system. It is conceivable that a firm
may respond to uncertainty by attempting to gain more control
over its decision environment. One way to accomplish this goal
is to substitute internal organization for participation in a
market process. Vertical integration is one such structural
response. It has long been acknowledged (8) that the incentive
to integrate vertically is absent in the static certainty setting
of the competitive model. However, rigorous analysis of the
claim that uncertainty provides the incentive for the firm to
integrate vertically has not been attempted to any significant
degree. Arrow (1) and Green (4) are the well known exceptions.
A more recent attempt to model vertical integration under
uncertainty by Carlton (3) considers both input and output firms
facing demand uncertainty; vertical integration upstream occurs
in order to obtain an assured supply of an input. Unfortunately,
the results of this model do not provide unambiguous welfare
implications. Either more of the input is produced or fewer
customers are satisfied than in the nonintegrated case, but
socially desirable technologies are more likely to appear in
vertically integrated structures as a result of the improved
coordination between the stages of production. Another recent

contribution to the vertical integration literature is a paper by Klein, Crawford, and Alchian (6) in which vertical integration is characterized as a means of reducing the costs associated with the risk of appropriation of some part of the quasi rents (=revenue-operating costs-salvage value) associated with certain specialized assets. The oil industry is offered as an example of an industry in which the threat of appropriation exists. Vertical integration of crude exploration and production, transportation (pipeline), refining, and marketing is a way to eliminate this threat of opportunistic behavior.

Vertical integration in the oil industry has concerned policymakers for many years. One stage which has been intensely scrutinized is the transportation of crude and refined products via pipelines. This is a difficult aspect of the industry to analyze since pipelines, in addition to being part of the vertically integrated chain, exhibit natural monopoly characteristics (cost efficiency and economies of scale) and are subject to rate of return regulation. A detailed analysis of the pipeline industry and the current regulatory climate is contained in Mitchell (ed.) (10). The Department of Justice has taken the position that some vertically integrated pipelines firms have the incentive to limit the amount of oil that travels to the downstream market by pipeline forcing some oil to move downstream by alternative (more expensive) modes of transportation. The downstream market price, thus, reflects the cost of the alternative mode. The difference between the downstream price and the cost

of pipeline transportation is profit for the pipeline shippers. If those shippers are also owners of the pipeline company, then the vertically integrated firm has circumvented rate of return regulation. One remedy proposed by the Department for this type of regulatory evasion is divestiture.[1] The economic foundation for the Department's theory appears to be a static certainty model developed by Reynolds (13) designed to explore "the extent to which vertical integration by oil pipelines has allowed the evasion of regulation" (13, p. 73).

The oil industry representatives offer a counterargument (10) which questions the wisdom of judging decisions made by risk averse firms in a dynamic uncertain decision environment on the basis of a static certainty model. They point out that there is uncertainty about future demand for pipeline services, and they are reluctant to support independent pipeline companies with shipping guarantees without an opportunity to share in the rewards from a favorable realization of the uncertainty. The industry claims raise some fundamental theoretical issues regarding the behavior of a vertically integrated regulated firm under uncertainty which must be resolved before a clear recommendation for public policy emerges.

This paper attempts to combine the characteristics--rate of return regulation, vertical integration, demand uncertainty, and risk aversion--into a single model. A regulated monopolist vertically integrated downstream is considered. The firm produces an output in the regulated stage which is either used as an input

in the downstream production process or sold in a competitive market. Therefore, this firm faces demand uncertainty in both stages of its operation. In addition, the firm is risk averse which means that there exists a concave utility of profit function for the firm; the firm seeks to maximize expected utility of profit subject to an Averch-Johnson type rate of return constraint involving the expected profit from all production at the regulated stage. It is possible to show, under quite reasonable conditions, that the output of the firm in the regulated stage will be greater than that produced by the corresponding nonintegrated firm. This contrasts sharply with the static certainty result of Reynolds that vertical integration enables the regulated monopolist to evade regulation and, thus, restrict output. If, as the oil industry representatives suggest, the firms under consideration actually face demand uncertainty and are risk averse, the model developed in this paper reinforces the industry claim that social welfare would not necessarily be enhanced by divestiture. On the other hand, it is not possible to conclude that the oil industry is free of competitive problems; this model is merely an illustration of the need for policymakers to exercise caution when using static certainty economic models as the basis for condemning some forms of economic organization. However, the static uncertainty model presented in this paper may not be descriptive of the decision environment in which a pipeline firm operates. Additional research is clearly necessary regarding the applicability of the model to the pipeline industry.

The remainder of this paper is divided into three sections. The model is formulated for both quantity setting and price setting monopolists (Sections II and III), and then the resulting welfare implications and comparisons to the other models are presented (Section IV).

II. Structure of the Problem

The model in this paper is similar to that constructed by Meyer (9) for the regulated, risk averse, nonintegrated monopolist. In this case, the firm is involved in two adjacent stages of the production process. The production technology in the initial stage requires two inputs (capital and labor) which the firm purchases in perfectly competitive markets. Production in the downstream stage also requires two inputs: one is produced in the initial stage and the other input (not capital) is purchased in a perfectly competitive market. The usual assumptions of positive marginal products and diminishing returns apply to both stages. The firm uses a fixed percentage ($\leq$ 100 percent) of the output of the initial stage as an input into the downstream stage. The remaining output is sold in an imperfectly competitive market. The firm is a monopolist in this initial market and, thus, subject to a regulatory constraint. The regulatory environment is such that the constraint applies to the total amount produced in this stage; that is, the firm's downstream operation is regarded as an independent buyer of the product, and it must pay the same price as any other buyer for a unit of the regulated output. The firm faces a simplified rate

of return constraint involving only the expected profit from the regulated stage. Similar to the constraint in the A-J model, the expected net allowable revenue from the regulated stage may not exceed a given percentage of some fixed value of the firm's capital stock.

The incorporation of uncertainty and the firm's risk averse attitude into the decision problem is accomplished in the standard way. This means that the firm faces random inverse demand schedules in the regulated and downstream stages. The corresponding expected revenue functions are increasing at decreasing rates in their respective arguments. Total profit for the firm equals regulated profit plus downstream profit. The firm's risk averse attitude is captured by assuming that there exists a utility of profit function which is increasing at a decreasing rate. The Principle of Increasing Uncertainty is also satisfied; that is, the dispersion (riskiness) of total revenue increases as total expected revenue increases for changes in price or output. Given the random demand, the general form of the monopolist's decision problem is:

maximize E {maximize u(π)}

$\langle \cdot \rangle$ $\langle \cdot \rangle$

subject to technical, market, and institutional constraints, where u(π) is a cardinal utility of profit function and E is the mathematical expectation operator. The effect of demand uncertainty on firm behavior depends on which of the available control variables must be selected before (ex ante) and which can be selected after (ex post) the resolution of the random event.

For example, if all control variables can be determined ex post, the monopolist faces a certainty decision problem of the standard form. The choice between price or quantity of output as a control variable in this case is immaterial. However, due to technical, market and institutional factors, some of the firm's decision variables must be selected ex ante. It is known a priori that the firm's expected utility of profit diminishes as more of its decision variables are selected prior to the realization of the random event.

Suppose, for example, the vertically integrated firm is a quantity setter; it must determine the capital stock, the output of the regulated stage, and the output of the downstream stage ex ante. The remaining variables are selected ex post. Given this decision sequence, the firm's objective is to select nonnegative quantities for the ex ante decision variables so as to maximize expected utility of profit subject to a regulatory constraint of the A-J type. Analysis of the first order conditions for this constrained optimization problem yields conditions which can be compared to those previously derived for a nonintegrated firm in both certain and uncertain decision environments. It is possible to demonstrate that an integrated, risk averse firm produces more in the regulated stage than the corresponding nonintegrated monopolist. This result illustrates the differences in the reactions of the integrated and nonintegrated risk averse firms to the presence of demand uncertainty. The integrated firm is concerned that the demand for the output of the regulated stage will be

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greater than expected so that an insufficient amount of this out-put will be available for its own downstream operation. The non-integrated firm, on the other hand, is primarily concerned with avoiding losses if demand is less than expected. This is con-sistent with other analyses of risk averse behavior in which firms forego the possibility of large profits to guard against large losses.

The above discussion is an overview of the model. The next section contains a rigorous exposition of the model for both quantity setting and price setting firms.

III. Model

In order to focus on the output decision in the regulated stage, it is necessary to make some simplifying assumptions about the environment in which the firm operates:

1) Consider a quantity setting firm that is vertically integrated through two stages of a production process.

2) The output of the initial stage Q requires two inputs--capital K and labor L; that is, $Q=Q(K,L)$ with $\frac{\partial Q}{\partial K}, \frac{\partial Q}{\partial L} > 0$ and $\frac{\partial^2 Q}{\partial K^2}, \frac{\partial^2 Q}{\partial L^2} < 0$. The output of the downstream stage W requires two inputs--output from the initial stage Q and another input M; that is, $W=W(Q,M)$ with $\frac{\partial W}{\partial Q}, \frac{\partial W}{\partial M} > 0$ and $\frac{\partial^2 W}{\partial Q^2} \frac{\partial^2 W}{\partial M^2} < 0$. The inputs K, L, and M are purchased in perfectly competitive markets at prices r,w, and w respectively.[2]

3) The firm is a monopolist in the market for Q and thus subject to a rate of return constraint. A unit of Q is either sold or used by the firm to produce W. The price of Q depends on

the total amount produced; that is, the firm faces a random inverse demand schedule $t(Q,\nu)$ such that $\frac{\partial t}{\partial Q} < 0$ and $\frac{\partial t}{\partial \nu} > 0$. ν is a random element with finite moments. The corresponding revenue function is concave. The rate-of-return constraint applies to the revenue generated by the total amount of Q produced. The regulatory commission determines ex ante an allowed rate of return s applicable to the total amount of K used by the firm. The expected profit from the regulated stage operation must be less than or equal to $(s-r)K$.[3]

 4) The price of W is determined in an imperfectly competitive market; that is, $p = p(W,\mu)$ such that $\frac{\partial p}{\partial W} < 0$ and $\frac{\partial p}{\partial \mu} > 0$. μ is a random element with finite moments. The corresponding revenue function is concave.

 5) There exists $\alpha \in [0, 1]$ which represents the fraction of Q production retained by the firm for use in production of W, $(1-\alpha)$ denotes the fraction of Q production that the firm sells.[4] If $\alpha=0$, then $W=0$ and $M=0$ (nonintegrated case).

 6) The firm selects W,Q, and K ex ante. L and M are ex post decision variables.[5] $L=L(K,Q)$ and $M=M(W,\alpha Q)$ with $\frac{\partial L}{\partial Q}$,

$\frac{\partial^2 L}{\partial Q^2}, \frac{\partial^2 L}{\partial K^2}, \frac{\partial M}{\partial W}, \frac{\partial^2 M}{\partial W^2}, \frac{\partial^2 M}{\partial Q^2} > 0$ and $\frac{\partial L}{\partial K}, \frac{\partial M}{\partial Q} < 0$. Also, L and M are convex in their respective arguments.

 7) Total profit π for the firm is the sum of profit from the downstream operation and that from sales of the regulated stage output. The firm is risk averse; specifically, there exists a von Neuman-Morgenstern utility function u such that u'

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$(\pi) > 0$ and $u''(\pi) < 0$. The firm selects nonnegative values of W, Q and K which maximize the expected utility of profit $Eu(\pi)$ subject to the rate of return constraint that the expected profit from the entire amount of Q produced is less than or equal to $(s-r)K$.[6]

8) The Principle of Increasing Uncertainty is satisfied; that is, the riskiness of total revenue increases as expected total revenue increases for changes in price or output.

Formally, the problem for the firm is

$$\max_{W,Q,K} \quad [Eu(\pi) = Eu(p(W,\mu)W + (1-\alpha)t(Q,\nu)Q - rk - w[L(K,Q) + M(W,\alpha Q)] \tag{1}$$

subject to W, Q, K $\geq$ 0

and

$$E(t(Q,\nu)Q - rK - wL(K,Q)) \leq (s-r)K.$$

If $\pi_1 = t(Q,\nu)Q - rK - wL(K,Q)$, then the Lagrangian function Λ is

$$\Lambda(W,Q,K,\lambda) = Eu(\pi) + \lambda((s-r)K - E(\pi_1))$$

where λ is the Lagrange multiplier. The necessary and sufficient conditions for a maximum are:[7]

$$\frac{\partial \Lambda}{\partial W} = E[u'(\pi)(p + p_W W - wM_W)] = 0 \tag{2}$$

$$\frac{\partial \Lambda}{\partial Q} = E[u'(\pi)((1-\alpha)(t+t_Q Q) - w(L_Q + \alpha M_Q))] -$$
$$\lambda E(t+t_Q Q - wL_Q) = 0 \tag{3}$$

$$\frac{\partial \Lambda}{\partial K} = E[u'(\pi)(-r-wL_K)] + \lambda[(s-r) - E(-r-wL_K)] = 0 \tag{4}$$

$$\frac{\partial \Lambda}{\partial \lambda} = (s-r)K - E(tQ - rK - wL) = 0 \tag{5}$$

where all variables and partial derivatives are evaluated at the equilibrium $(\bar{W}^*, Q^*, K^*, \lambda^*) \geq 0$ and $M_W = \frac{\partial M}{\partial \bar{W}}$, $M_Q = \frac{\partial M}{\partial Q}$

$$P_{\bar{W}} = \frac{\partial p}{\partial \bar{W}}, \quad t_Q = \frac{\partial t}{\partial Q}$$

$$L_Q = \frac{\partial L}{\partial Q} \text{ and } L_K = \frac{\partial L}{\partial K}.$$

From equation (4), the marginal rate of input substitution is

$$-\frac{\partial L}{\partial K} = \frac{r}{w} - \frac{\lambda^*(s-r)}{w[Eu'(\pi^*) - \lambda^*]} \quad . \quad \text{This is obviously}$$

similar to the certainty case analyzed by Averch and Johnson (1).[8] From equation (3)

$$E(u'(\pi^*)) - \lambda^* = -\frac{cov(u'(\pi^*), MR^* - MC^*)}{E(MR^* - MC^*)} +$$

$$\frac{\alpha E(u'(\pi^*)(MR^* + wM^*_Q))}{E(MR^* - MC^*)} \quad (6)$$

where

$$MR^* = t(Q^*, \nu) + Q^* t_Q(Q^*, \nu) \text{ and } MC^* = wL^*_Q.$$

Following the analysis of Holthausen (5), the concavity of u (risk aversion) means that $cov(u'(\pi^*), MR^* - MC^*) < 0$ given $\frac{\partial t}{\partial \nu} > 0$ and the Principle of Increasing Uncertainty.[9] Meyer (9) analyzes the decision problem for a nonintegrated, regulated, and risk averse monopolist $(\alpha = 0)$. He derives the following results for the equilibrium solution $(\hat{Q}, \hat{K}, \hat{\lambda}) \geq 0$:

(i) $Eu'(\hat{\pi}) - \hat{\lambda} = \frac{-cov(u'(\hat{\pi}), \hat{MR} - \hat{MC})}{E(\hat{MR} - \hat{MC})},$ (7)

(ii) $Eu'(\hat{\pi}) - \hat{\lambda} \geq 0$, and

(iii) $E(\hat{MR} - \hat{MC}) > 0$ for a risk averse firm, where $\hat{MR} = t_Q(\hat{Q}, \nu)\hat{Q} + t(\hat{Q}, \nu)$ and $\hat{MC} = w\frac{\partial L}{\partial Q}(\hat{K}, \hat{Q}).$

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He concludes that the output expansion and price reduction effects of the A-J model are preserved under the assumptions of demand uncertainty and risk neutrality. However, risk aversion exerts a moderating influence on these effects. Output is limited by the requirement that $E(\hat{MR} - \hat{MC}) > 0$.

If the regulated monopolist is vertically integrated down-stream ($0 < \alpha \leq 1$), then $Eu'(\pi^*) - \lambda^* \geq 0$. It is apparent from equation (6) that expected marginal revenue greater than marginal cost is no longer necessary for this inequality to hold. The vertically integrated firm may produce a larger output in the regulated stage than the corresponding nonintegrated firm. The exact relationship which must hold in order for $E(MR^* - MC^*) \leq 0$ involves the degree of vertical integration α. Specifically, if

$$\alpha \geq \frac{E(u'(\pi^*)MR^*) - E(u'(\pi))E(MR^*)}{E(u'(\pi^*)MR^*) + wM^*_Q \, Eu'(\pi^*)} > 0,$$ then the vertically integrated firm will select Q^* such that $E(MR^* - MC^*) \leq 0$ and thus $Q^* > \hat{Q}$.

Equations (6) and (7) summarize the difference between the risk averse firm involved only in production of Q and the risk averse firm producing both Q and W. The firms react differently even though both prefer reasonable and secure policies (risk aversion). Intuitively, the nonintegrated firm is primarily concerned with avoiding losses if demand is less than expected, but the vertically integrated firm is concerned that demand for Q will be higher than expected so that an insufficient amount of Q will be available for its own downstream operation. In addition, to the extent that there is substitutability between Q and M in

the production of W and supply of M is uncertain, the risk averse

firm may choose an input mix that favors the input it produces,

thus accentuating the tendency to produce more output in the

regulated stage than the nonintegrated firm. Concern over

unexpected demand and an assured source of supply of an input,

form the underlying rationale for the vertically integrated

firm's production decision in the regulated stage.

If a price setting firm is considered, then t, p, and K are

determined ex ante. This means (i) $Q = Q(t,\nu)$ with $\frac{\partial Q}{\partial t} < 0$ and

$\frac{\partial Q}{\partial \nu} > 0$, (ii) $W = W(p,\mu)$ with $\frac{\partial W}{\partial p} < 0$ and $\frac{\partial W}{\partial \mu} > 0$, (iii) $L =$

$L(Q(t,\nu),K)$ is the labor requirement function for Q production,

and (iv) $M = M(W(p,\mu), \propto Q(t,\nu))$ is the M requirement function for

W production.

The analog to equation (1) for the risk averse price setting

firm is:

$$\max_{t,p,k} \lfloor Eu(\pi) = Eu(pW(p,\mu) + (1-\propto)tQ(t,\nu)-rK - w(L(Q(t,\nu),K)$$
$$+ M(W(p,\mu),\propto Q(t,\nu)))\rfloor$$

subject to t, p, $K \geq 0$

    and

$$E(tQ(t,\nu) - rK - wL(Q(t,\nu),K)) \leq (s-r)K.$$

The Lagrangian function Γ is

$\Gamma(t,p,K,\gamma) = Eu[pW(p,\mu) + (1-\propto)tQ(t,\nu)-rK - w(L(Q(t,\nu),K) +$

$M(W(p,\mu), \propto Q(t,\nu)))] + \gamma((s-r)K - E(tQ(t,\nu)-rK -wL(Q(t,\nu),K)))$

where γ is the Lagrange multiplier. The necessary and sufficient

conditions for a maximum are:

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$$\frac{\partial \Gamma}{\partial t} = E[u'(\pi)(t(1-\alpha)Q_t + (1-\alpha)Q(t,v) - w(L_QQ_t +$$

$$\alpha M_QQ_t)] - \gamma E(tQ_t + Q - wL_QQ_t) = 0 \qquad (8)$$

$$\frac{\partial \Gamma}{\partial p} = E[u'(\pi)(pWp + W - wM_WW_p)] = 0 \qquad (9)$$

$$\frac{\partial \Gamma}{\partial K} = E[u'(\pi)(-r -wL_K)] + \gamma(s-r-E(-r - wL_K)) = 0 \qquad (10)$$

$$\frac{\partial \Gamma}{\partial \gamma} = (s-r)K - E(tQ - rK - wL) = 0 \qquad (11)$$

where all variables and partial derivations are evaluated at the

equilibrium $(t^*, p^*, K^*, \gamma^*) \geq 0$

and

$$M_W = \frac{\partial M}{\partial W}, \quad M_Q = \frac{\partial M}{\partial Q},$$

$$Q_t = \frac{\partial Q}{\partial t}, \quad W_p = \frac{\partial W}{\partial p}$$

$$L_Q = \frac{\partial L}{\partial Q} \quad \text{and} \quad L_K = \frac{\partial L}{\partial K}.$$

Similar to the case for the quantity setting firm it is possible

to rewrite equation (10) to obtain[10]

$$E\left(-\frac{\partial L}{\partial K}\right) = \frac{r}{w} - \frac{cov(u'(\pi), -L_K)}{Eu'(\pi) - \gamma} - \frac{\gamma(s-r)}{w(Eu'(\pi)-\gamma)}$$

Again, $Eu'(\pi)- \gamma \geq 0$ and from equation (8),

$$Eu'(\pi)-\gamma = \frac{-cov(u'(\pi), tQ_t + Q - wL_QQ_t)}{E(tQ_t + wL_QQ_t)} +$$

$$\frac{\alpha E[u'(\pi)(tQ_t + Q + wM_QQ_t)]}{E(tQ_t + Q - wL_QQ_t)}$$

According to Holthausen, risk aversion is equivalent to the con-

dition $cov(u'(\pi), -\frac{\partial L}{\partial K}) < 0$; therefore, if $\alpha > 0$, the firm is

not restricted to selection of an output level in the regulated

stage such that expected marginal revenue is greater than

expected marginal cost. Again, depending on the degree of verti-
cal integration, it is possible that the risk averse integrated
firm produces a larger output in the regulated stage than the
corresponding nonintegrated firm.

The comparison between the integrated and nonintegrated
firms is valid given that both firms have the same degree of risk
aversion. It is well known (5) that a firm will reduce its
optimal level of capital stock (one input into the production of
Q) as aversion to risk increases.[11] Therefore, if the
vertically integrated firm is more risk averse than the
nonintegrated firm, it is possible that the integrated firm
selects a level of capital stock (thus output in the regulated
stage) less than or equal to that chosen by the nonintegrated
firm. On the other hand, if the nonintegrated firm is more risk
averse, the output expansion effect of vertical integration is
reinforced. It is impossible to determine in general if the
degrees of risk aversion for integrated and nonintegrated firms
differ.

IV. Welfare Implications and Comparisons to Other Models

The welfare implications of many results in the economics of
uncertainty have not been resolved. In the present context, the
crucial question for public policy is whether or not vertical
integration and rate of return regulation cause resources to be
allocated inefficiently. It is well known that when all other
industries are perfectly competitive, and a monopolist hires
factors in perfectly competitive markets, resources will not be

efficiently allocated since the monopolist will charge a price in excess of marginal cost. This is the standard antitrust rationale for restricting market power. Yet, the A-J thesis asserts that the regulated monopolist also misallocates resources by choosing to utilize too much capital in order to enhance its rate base. In the presence of uncertainty and risk aversion, as incorporated into the above model, vertical integration increases output and decreases price compared to the nonintegrated case. However, since neither the model of an unregulated monopolist nor the A-J model of regulation provides an efficient allocation of resources, equivalent to the competitive model, any result of this model relative to these two is not open to evaluation. Such a welfare judgement must be deferred until a second best criterion capable of assessing the regulated environment is developed.

The model constructed by Reynolds (13) utilizes a static certainty setting for a profit maximizing firm integrated into a downstream market and faced with a binding rate of return constraint in its initial stage of operation. The production technology at the regulated stage involves only one input (capital). Total profits for the firm are obviously the sum of its profits from the regulated and unregulated stages. The firm is a monopolist in the regulated stage but not necessarily in the unregulated stage. The model allows for the possibility that the regulated entity has many owners who may act as competitors in the other stage. The owners of the regulated entity have a share of total industry profits which is less than or equal to

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100 percent. Reynolds concludes that if the vertically integrated firm's share of industry profits is sufficiently large, then the firm is able to evade regulation by using at the regulated stage less capital and, thus, producing a smaller output than the corresponding nonintegrated, regulated firm.

This contrasts sharply with the model presented in Section III wherein the integrated, regulated, risk averse firm selects a larger output than an equivalent nonintegrated firm. This result has profound implications regarding divestiture as a remedy for competitive problems. Divestiture would create an industry composed of regulated, nonintegrated firms. If the real world is characterized by uncertainty and risk averse firms, this model would predict that regulated output would be less than in the case that diverstiture did not occur--the opposite effect intended by such a remedy.

As discussed above, one application of the notion of regulatory evasion through vertical integration has been to the pipeline industry.[12] Therefore, if K_m, K_r, K_{A-J} denote the pipeline sizes for the unregulated, Reynolds, and Averch-Johnson monopolists, respectively, then we know that $K_m < K_r < K_{A-J}$.[13] Given regulation and risk aversion, $K_u < K_{A-J}$, $K_{uv} < K_{A-J}$, and $K_u < K_{uv}$ where K_u and K_{uv} denote the pipeline sizes selected by the nonintegrated and integrated firms respectively, and K_{A-J} corresponds to the pipeline size chosen by both risk neutral integrated and nonintegrated firms. Further comparisons

are impossible. Because only a limited amount of comparability

exists among the models, some issues are not resolved by the-

oretical analysis alone. For example, even knowing the above

inequalities, no determination of the relationship of K_{uv}

with K_m and K_r is possible. Therefore, undersizing, if

it actually occurs, is a phenomenon which must be investigated

empirically.

To determine the appropriate public policy regarding oil

pipelines, it is important to question which model is the better

approximation of a pipeline firm's decision environment. If it

is Reynolds' static certainty model, then divestiture could be an

appropriate remedy for the abuses which exist as a result of ver-

tically integrated firms evading regulation. If it is the static

uncertainty model, divestiture may have adverse economic conse-

quences. On the other hand, neither model may be an accurate

description of a firm in the pipeline industry, requiring addi-

tional research to develop a model which is more descriptive of

the decision environment in which a pipeline firm operates.

In assessing the relevance of the model presented in Section

III for use in analyzing the pipeline industry, a number of

issues must be addressed. First, vertical integration is exoge-

nous in the model. This prohibits consideration of the firm's

decisions regarding the optimal degree of vertical integration.

Second, there is a lack of empirical support for the model. The

availability of information to verify the assumptions of the mod-

el must be investigated. Third, the intense antitrust scrutiny

given to the oil industry in the past may add constraints to the firm's decision environment which are not captured in the model. Fourth, the firm in the model is vertically integrated into only two stages of the production process. Many firms in the oil industry, on the other hand, are integrated throughout the entire production process from crude exploration to product marketing. This multistage aspect of integration may introduce factors into the firms' decision environments which significantly alter behavior from that described in the model. Finally, the model is static. A dynamic model must ultimately be constructed in order to understand the pipeline decision process with regard to such questions as the optimal time for entry into a given market and alternative means of (i) attaining a given capacity as well as (ii) expanding capacity. If these or other factors not explicitly taken into account in constructing the model of a vertically integrated, regulated, risk averse firm are significant determinants of pipeline firm behavior, then this model will have only limited use in the formation of public policy regarding the pipeline industry.

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(11) Yoram Peles and Jerome Stein, "The Effect of Rate of Return
     Regulation is Highly Sensitive to the Nature of the
     Uncertainty," American Economic Review, 66 (June 1976)
     pp. 278-89.

(12) Stylianos Perrakis, "On the Regulated Price Setting Monopoly
     Firm with a Random Demand Curve," American Economic Review,
     66 (June 1976) pp. 410-416.

(13) Robert Reynolds, "The Effects of Regulation of Oil
     Pipelines: A Preliminary Analysis," American Statistical
     Association 1979 Proceedings of the Business and Economic
     Statistics Section (August 1979) pp. 73-81.

<u>FOOTNOTES</u>

*The views expressed in this paper are those of the author. They
are not intended to reflect views or policies of the Federal
Trade Commission or individual Commissioners. I wish to thank
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the paper.

1. Another remedy suggested by the Department of Justice
involves a set of competitive rules for joint venture pipeline
systems. These rules preserve the vertically integrated
structure of firms in the oil industry but alter the incentives
of those firms that participate in joint ventures. The specific
rules which have been proposed (See (10)) are: (i) open and
nondiscriminatory access to the pipeline for all shippers, (ii)
any pipeline owner or shipper can request and obtain expansion of
pipeline capacity, (iii) the pipeline company must provide open
ownership to all shippers at a price equal to replacement cost
less economic depreciation, and (iv) annual adjustment of
ownership shares to reflect each owner's share of average
throughout.

2. The name of the input and/or output and its quantity are
denoted by the same symbol.

3. The regulatory constraint applies to the total profit the
firm expects to earn from the regulated stage. The firm must
regard its own downstream operation as a separate entity when
computing the revenue subject to the regulatory constraint.

4. Vertical integration is exogenous.

5. Since the firm determines Q, K, and W <u>ex ante</u>, the amount of
L and M required is known before the realization of μ and ν.
This means that L(Q,K) and M(W, αQ) are not stochastic.

6. This is a rate of return which may be earned on average.

7. Since the revenue functions are concave and L and M are
convex, π is a concave function. Since u is concave, a point
that satisfies the first order conditions is a maximum for the
problem.

8. Averch and Johnson derive $-\frac{dL}{dK} = \frac{r}{w} - \frac{\rho^*}{1-\rho^*} \cdot \frac{(s-r)}{w}$ where
ρ^* is the Lagrange multiplier for the A-J constrained optimiza-
tion problem: $\max_{K,L} (\pi = p(Q)Q(K,L) -wL -rK)$ subject to $\pi \leq$
$(s-r)K$.

9. The Principle of Increasing Uncertainty is equivalent to the
requirement that $\frac{\partial MR(Q,\mu)}{\partial \mu}$ and $E(MR(Q,\mu))$ have the same sign.

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10. In order to rule out the possibility that the firm does not produce Q, assume that price is greater than the marginal cost of production.

11. Increasing risk aversion means that the firm would be willing to pay an increasing amount to insure against a given risk. Using the Arrow-Pratt Index, $r_i(\pi) = \dfrac{-u''_i(\pi)}{u'_i(\pi)}$,

$u_1(\pi)$ more risk averse than $u_2(\pi)$ means that $r_1(\pi) \geq r_2(\pi)$ for all π and $>$ for at least one π.

12. See Mitchell (10) for a discussion.

13. Since Reynolds assumes that only one input is used in the production process of the regulated entity, it is not possible for him to analyze the A-J effect. In the version of the paper presented at the ASA Meeting in August 1979, he asserted (without proof) that the distortion in capital-labor choice diminishes as the extent of vertical integration increases.