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Christopher J. Erceg, Philip R. Israilevich,
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I. Introduction

A common perception of economists and the public at large is that the price of steel sold by domestic integrated producers exhibits pronounced rigidity. Roughly speaking, a product is 'rigidly priced' if its price does not possess substantial covariation with the prices of other products with similar attributes. This perception is accompanied quite predictably by the allegation that the existence of such inflexible pricing is inconsistent with the pricing behavior that would be practiced in a competitive market. Our interest in this study is to assess whether the perception of inflexible pricing by domestic integrated producers is justified.

The first part of our study is devoted to determining if there is really a problem to explain. The domestic price of steel bought in the contract market, dominated by integrated producers, does show considerably less procyclical variation than the price of steel bought in the foreign spot market, so that there are wide and persistent gaps (varying roughly with the business cycle) between the domestic and foreign prices of steel. The behavior of the domestic contract price series is usually construed as sufficient evidence to demonstrate domestic contract price rigidity. We question this interpretation, since it may be possible to rationalize the behavior of these price series simply in terms of variation in an underlying material attribute of steel.

In section two, we consider whether the relative price changes between domestic contract steel and foreign spot steel can be explained in terms of relative variation in the lead time of the two types of steel. We assume that other material attributes, such as quality, do not show appreciable variation over short horizons. We find that a significant amount of variation in relative prices cannot be attributed to changes in relative lead times. Our in-

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ability to explain relative price variation in terms of relative changes in a material characteristic, which is expected to be largely responsible for such variation, lends considerable support to the hypothesis of domestic contract price inflexibility.

If all consumers were accorded equal terms of sale by producers each period, it would be very difficult to interpret rigid pricing as the outcome of an equilibrium in which producers maximized profits and consumers minimized input costs. However, our evidence suggests that some consumers receive preferential treatment. For example, we find that in periods of moderate demand pressure both the average lead time and the price of domestic steel do not appear to rise. However, the spot price rises monotonically with increasing demand. We interpret this to mean that during times of increasing demand pressure domestic producers of contract steel attempt to minimize cost increases to their preferred customers, whether these increases are in the form of longer lead times or actual price hikes. Instead, contract producers quote longer lead times and/or higher prices to transient customers, who consequently turn to the spot market and bid up the price.

The purchasing literature frequently observes that customers can protect themselves against supply uncertainty by establishing a purchasing history with a particular supplier, i.e. by becoming a 'loyal' customer. For example, a recent article in the Cleveland Plain Dealer (July 12, 1988) noted:

"Olympic's decision to cement its ties with domestic mills was part of a long term growth plan... Olympic, which buys about ninety five percent of its steel from U.S. mills, wanted a constant inventory and steady cash flow instead of relying on shipments of imported steel, which can be inconsistent."

Further, when contract producers began allocating their shipments during the 1973-74 steel boom in strict proportion to the quantity a buyer had purchased in 1972, many steel consumers lamented their previous decision to turn to cheaper foreign suppliers.

Our objective in this working paper is to explain the existence of specialized relationships between buyers and sellers, and to offer a hypothesis about how rigid prices may emerge as the outcome of these arrangements. An established literature argues that producers and consumers enter into relationships to bear jointly the risk of certain types of capital assets used for highly specific production processes, i.e. stamping machines for automotive bodies. Our emphasis is somewhat different, since we seek to explain how even consumers or coalitions of consumers who do not have such idiosyncratic requirements may gain from specialized arrangements.

In section three, we examine the determinants of a firm's capital choice given that it must choose capital before it observes the output price, which is a random variable. The absence of a complete market for Arrow-Debreu securities will in general (i.e. if 'spanning' doesn't hold) imply that a firm's capital choice will depend on the preferences of securityholders. It is likely that risk averse producers will choose too little capital. In the aggregate, investing in too little capital is costly, because it shifts the aggregate supply curve inward and increases prices (given any realization of demand) relative to what would be the case in an economy of risk neutral producers. Consumers can induce producers to choose a larger investment in capital by extending long term 'insurance' agreements, in which they agree to transfer wealth to a producer when the producer experiences low returns. In turn, consumers receive rebates during periods when the producer experiences high returns. The mechanism that effects these transfers requires consumers to pay higher-than-market prices during recession states, while they receive lower-than-market prices during boom states. Thus, prices appear 'smoothed.' We demonstrate how this insurance arrangement can lower the expected expenditures of at least some consumers.

The insurance arrangement explains why observed prices appear smoothed relative to market prices. However, only some consumers enter into these relationships. Unless firms distinguish among customers based on their past purchasing history, no customer would be willing to pay the higher-than-market prices during recessions, though all would desire to obtain lower-than-market prices during booms. Thus, a necessary condition for the insurance arrangement to be feasible is that only 'loyal' customers be accorded preferential treatment. 'Loyal' customers are those who have supported the arrangement by paying premiums in the past.

Thus, our hypothesis provides a rationale for specialized relationships between buyers and sellers, which does not require that certain capital assets be consumer-specific. The purpose of these arrangements is to coinsure the risk of a producer's investment in capital. Further, we explain how rigid pricing and preferential treatment to some consumers may proceed as the outcome of such insurance arrangements, since they may be employed together as the mechanism for effecting the insurance premiums and payouts.

II. Can Relative Price Variation be Explained Solely by Variation in Underlying Material Attributes?

Is there evidence to support the claim that the domestic transactions price for steel is rigid? In Figure 1, the transactions price for domestic steel sold on forward contract and the Antwerp spot price are plotted against time over the period 1969-1984 inclusive (both price series are in dollars and are appropriately deflated; the data are described more fully below). The contract price seems to exhibit substantially less variation than the spot price. In particular, the gap between the spot price and the contract price is often very pronounced: it swings from periods in which spot steel sells at roughly a fifty percent premium over contract steel to periods in which spot steel sells at a forty percent discount.

Our introductory remarks lead us to suspect that the contract price may reflect underlying factors related to the nature of the relationship between buyers and sellers, which are not operative in pricing on the spot market. While the spot market accords all customers the same terms of sale, domestic producers may offer terms that provide an intertemporal linkage in the opportunity set of consumers (i.e., they may offer preferred terms to 'loyal' customers). Our interest here is in assessing whether the observed gaps between the contract and spot price reflect fundamental differences in buyer-seller relationships in the two markets, or whether they can be more simply explained in terms of relative changes (over time) in a material attribute of the products.

More formally, our objective is to ascertain whether the observed gaps between the contract price and the spot price:

H1) can largely be explained in terms of variation in an underlying material characteristic of the two types of steel.

H2) are not consistent with what we would predict based on variation on an underlying attribute, and thus such gaps appear attributable to differences in the nature of the buyer-seller relationship in the two markets.

H3) our evidence does not permit us to differentiate between H1) and H2).

Our methodology consists in selecting a particular 'material' quality of steel, its lead time, and testing whether changes in lead time between contract and spot steel can explain relative price variation. Steel consumers emphasize that the three major factors determining their choice of a seller are price, quality, and lead time. Relative lead times show substantial variation, so that if any material attributes can explain the price gap, we expect lead time is an important candidate. We would also like to test whether quality variation is a determinant of relative price changes. However, the absence of data on the quality of contract and spot steel precludes us from studying this effect. We merely presume that variation in the quality of spot relative to contract steel is not substantial enough to rationalize the wide swings in the relative prices of spot and contract steel which occur over fairly short intervals. In other words, quality changes may be responsible for long-term trends in the prices, but they are of second-order importance in explaining the short-term gaps (that are the salient feature of Figure 1).

We first observe that in a market in which all consumers are accorded equal terms of purchase during each trading period, the 'hedonic' price schedule relating the price of steel of a particular lead time to its lead time must be monotonically decreasing. Thus, lower lead-time steel commands a higher price than higher lead-time steel, as depicted in Figure 2.

We can justify the shape of the hedonic price schedule by noting that if the marginal cost of producing a unit of steel with a lower lead time is positive, then an upward sloping schedule would imply that a producer could reduce cost and increase his price on a given quantity of steel by increasing the lead time. Thus, no producer would supply steel with a lead time such that the hedonic price schedule in the neighborhood of that lead time was positive. It follows that in a large market where steel of all possible lead times between w_0 and w_1 is supplied, the hedonic price schedule must be downward sloping over this range.

Thus, we can approximate the difference in the price of two different types of steel, type L with *low* lead time and type H with *high* lead time, by a first-order Taylor expansion of $p_L(w_L)$ around the price of $p_H(w_H)$. (This decomposition is shown in Figure 2.) We obtain:

$$(1) \qquad p_L(w_L) - p_H(w_H) = \{dp(w_H)/dw\}^*(w_L - w_H) =$$
$$-dp/dw^* w_H + dp/dw^* w_L$$

We will estimate a relation of the form of 1) using monthly observations over the 1969-1984 period inclusive on the following variables:

p_d = the c.i.f. transactions price of composite domestic steel sold on forward contract (i.e., contract price).

p_s = the c.i.f. transactions price of steel sold on the Antwerp spot market (i.e., spot price).

w_d = the lead time on contract steel (in months).

w_s = the lead time on spot steel (in months).

The price of contract steel is a weighted average of the contract prices of the individual steel products composing the aggregate, where the weights on each product are the value of the product as a proportion of the total value of all products in the U.S. shipment mix in 1977. The price data is supplied by Paine-Webber. The price data is adjusted by the producer price index for finished goods. The lead time on spot steel is assumed to be constant, since it is sold directly out of inventory. This assumption is reasonable, as lead time for spot steel depends only on loading and shipping time. Also, since steel is a bulk commodity with a low value per ton shipped even when prices are high, it is basically cost preclusive to substitute between alternative modes of transporting steel across the Atlantic. Domestic steel is sold by forward contract according to specification, so that lead time reflects not only loading and shipping but also waiting in a production queue. The duration of the queue varies with demand conditions. Our measure of average lead time on contract steel is constructed by dividing unfilled orders at the end of each month by shipments of the following month. The unfilled orders and shipments data were taken from various issues of the Commerce Department's *Survey of Current Business.*

Thus, our estimate of 1) using the above data is:

$$(2) \qquad (p_d - p_s) = \underset{(14.6)}{415.07} - \underset{(-11.4)}{132.66^* w_d} \qquad \text{(t-statistics)}$$

$$n = 203 \qquad \text{dep mean} = 97.085$$

$$DW = .210 \qquad FOA = .891 \qquad R^2 = .3925$$

Note that n refers to the sample size, dep mean to the mean value of the dependent variable, FOA to first order autocorrelation in the residuals of the regression, DW to the Durbin-Watson, and R^2 to the coefficient of determination.

The coefficient of w_d is negative, consistent with the negative slope of the hedonic price schedule to which it provides a linear approximation. It is also highly significant. The R^2 of .39 shows this univariate regression exhibits significant power to explain relative price differences. The implied spot lead time of 3.1 months also seems reasonable. Figure 3 graphs how the domestic premium varies inversely with w_d.

However, the evidence of regression 2) does not enable us to make a strong statement about whether changes in lead time largely account for relative price variation. We first observe that the high positive autocorrelation in the residuals of 2) will lead to downward bias in the standard errors, and this bias will be further exacerbated by significant low order positive autocorrelation in w_d. While we could correct for most of the autocorrelation in the residuals by taking first differences (or applying more sophisticated versions of generalized least squares estimation), such procedures tend to eliminate most of the variation in both the independent and dependent variables, since they also exhibit strong positive low-order serial correlation. This leads to poor parameter estimates. Rather than employ such corrections, we will tentatively accept that regression 2) lends support to the hypothesis that lead-time variation has power to explain price changes, though we recognize our statistical inference is biased in favor of the hypothesis. We now seek to determine whether our data can potentially shed more light on the validity of this inference.

The statistical power of regression 2) obviously depends on the observations in the lower right hand corner of Figure 3, where contract lead time is high and the contract premium over spot very low. We find that these observations occurred in the 1973-74 period almost exclusively, when there was a severe steel shortage and domestic lead times rose markedly. If we delete the 1973-74 period, we lose a large amount of variation in our independent variable, and we expect to obtain much poorer regression results. The range of the independent variable wd is from about 1.6 to 4.1 months over the entire sample period 1973-74 inclusive, while it drops from about 1.6 to 3.1 if that period is omitted. The regression over the same sample as in 2) excluding the 1973-74 period yields:

$$(3) \qquad (p_d - p_s) = \underset{(4.6)}{127.06} - \underset{(-.1)}{1.3427^* w_d}$$

$$n = 167 \qquad \text{dep mean} = 124.004$$

$$DW = .048 \qquad FOA = .968 \qquad R^2 = .0001$$

We expected the regression would show markedly less power to explain the contract price premium—regression 3) demonstrates no power to do so (note that the absolute value of our t-statistic would even be lower, if we corrected for bias in the standard error). How can we reconcile this result (3) with our earlier finding (2) that the premium is quite responsive to lead time variation? It may be the case that the wd range between 1.6 and 3.1 is the range of 'normal variation' for lead time. In other words, while we expect the premium to increase as the *ex ante* lead-time difference stretches, it should not necessarily respond to changes in *ex post* realizations of lead time differences. Thus, a domestic producer may offer to deliver a product at a price that is higher, and lead-time that is on average lower, than the price and lead time the consumer expects to obtain on the spot market.

During 'normal' times, the producer's actual lead time may vary considerably around this average value without affecting the previously contracted price for the steel (although we expect that variance in the lead time would affect the price that is set *ex ante*). Thus, regression 3) seems consistent with the interpretation that the premium does not vary with lead-time changes, so long as those changes reflect random variation around a constant mean. On the other hand, regression 2) indicates that the premium does appear to respond to changes in expected lead time. Thus, when the period in which average lead times increased markedly (1973-74) is included in the sample, the premium does respond to lead-time variation.

However, even when the 1973-74 period is excluded, the dependent variable shows substantial variation. Over this subsample, the domestic premium ranges from a low of six dollars to a high of two hundred and seven dollars, or roughly between one and thirty-five percent of its average value (over the entire sample). This is interesting, because it allows us to get an idea of the magnitude of the premium not explained by lead-time differences. Regression 2) of itself did not impart a good picture of whether lead-time differences were large enough to justify the observed magnitude of the domestic premium. Regression 3) clearly says that there are large price swings that remain even after we account for variation in lead time. Thus, while we have evidence saying that at least some of the premium can be explained by lead-time differences, we have found strong support for H2: there seems to be large variation in the price premium that cannot be rationalized in terms of variation in a material characteristic.

Interestingly, the contract premium, $p_d - p_s$, exhibits substantial covariation with the business cycle even when the premium does not systematically vary with lead time. Figure 4 plots $p_d - p_s$ against capacity utilization for steel over the subsample (i.e., excludes 1973-74). When business activity is relatively strong (as proxied by capacity utilization), the spot price rises relative to the contract price. When business activity is relatively weak, the spot price falls relative to the contract price. In other words, contract steel seems to be 'overpriced' during recessions and 'underpriced' during booms.

Figure 1 also shows that the premium varies countercyclically. However, the objection to using this as support for price rigidity is that such variation could possibly reflect covariation with an underlying material attribute, such as lead time, which also varies with the business cycle. If so, the premium's observed correlation with the business cycle could be incidental. However, Figure 4 depicts variation in the premium not explained by lead-time variation, and it is clear that this 'residual' variation still exhibits strong comovement with the business cycle. Thus, Figure 4 provides considerably stronger support for the hypothesis of rigid pricing.

As observed in the introduction, rigid prices may be rationalized as the outcome of long-term arrangements between buyer and seller, rather than reflecting anti-competitive practices. The basic model can be reformulated to show how the opportunities of some consumers appear to worsen as aggregate demand increases, while others experience no increase in price and/or lead time. Specifically, in the range of low to moderate demand pressure, i.e. over the subsample excluding the 1973-74 period, neither the domestic price nor the lead time rises with increasing capacity utilization (caput). In fact, both variables appear to be close to constant, as the results below indicate:

(4) $p_d = 525.62 + 22.660 * caput$

(27.3) (0.9)

n = 167 dep mean = 558.65

DW = .043 FOA = .968 R^2 = .0052

(5) $w_d = 2.180 + .1224 * caput$

(14.6) (0.7)

n = 167 dep mean = 2.28

DW = .582 FOA = .703 R^2 = .0029

However, the regression of p_s on *caput* yields:

(6) $p_s = 225.577 + 236.427 * caput$

(9.1) (8.0)

n = 167 dep mean = 420.28

DW = .093 FOA = .943 R^2 = .2788

Regressions 4) and 6) are obviously poor models for explaining price variation. However, 4-6) afford further insight into the behavior of the domestic premium $(p_d - p_s)$. Namely, one component of the premium, the spot price, exhibits substantial covariation with demand (as proxied by capacity utilization). On the other hand, neither the domestic price nor lead time appear related to demand conditions (over this truncated sample covering moderate levels of demand).

The results of regressions 4-6), together with Figure 4, provide considerable evidence that all consumers do not receive equal treatment. In equal access markets, relative price variation should only depend on variation in underlying material characteristics. If all consumers were quoted a constant lead time and price for contract steel as capacity utilization rates increased within this range, no consumer would be willing to pay *increasing* premiums for spot steel as demand pressure increased. Although spot steel does not offer more appealing characteristics relative to contract steel as demand increases in this range (since the lead time difference is roughly constant), the amount by which the spot price increases with demand pressure is substantial. (However, we caution against placing too much weight on the parameter estimates of 4) and 6), since they are probably biased. If 3) holds, then it is easy to determine if the coefficient estimates of 4-6) are biased, since these coefficients bear a simple relation to those of 3)).

Thus, our regression results indicate that as demand increases over moderate levels, consumers purchasing in the contract market do not incur any significant price increases or longer lead times. On the other hand, the monotonic rise of the spot price with capacity utilization means that consumers buying spot experience a progressively poorer opportunity set as demand rises. Taken together, this evidence strongly suggests that some consumers receive preferential treatment from producers of contract steel, and those who do not are forced to pay substantial premiums on the spot market during periods of high demand.

Finally, we observe that lead time tends to increase with capacity utilization when we run regression 5) over the entire sample:

$$(7) \qquad w_d = \underset{(8.5)}{1.5361} + \underset{(4.8)}{1.0268} * caput$$

$$n = 203 \qquad \text{dep mean} = 2.3970$$

$$DW = .369 \qquad FOA = .810 \qquad R^2 = .1047$$

This result is expected. When demand increases over moderate levels, contract producers act so as to minimize the potentially adverse effects of such demand increases on the opportunity sets of their most preferred customers, i.e. they quote longer lead times to transients to reserve space in the production queue for regular customers. However, when aggregate demand becomes sufficiently high, firms must use lead time and/or price increases to allocate production capacity even among their preferred customers.

To summarize this section, lead time variation does seem to explain part of the variation in the contract premium. However, there are large and persistent swings in the premium that cannot be explained by lead-time variation, although they are (inversely) related to the business cycle.

III. Rigid Prices as a Means of Implementing Insurance Transfers Between Buyers and Sellers

In the previous section, we observed that a substantial amount of variation in the contract premium could not be attributed to lead-time variation. However, the premium exhibits substantial negative correlation with business activity, so that domestic steel seems 'overpriced' during recessions and 'underpriced' during booms. Further, we find that some consumers appear to receive preferential treatment during booms. Given our first result, the second result is to be expected: in markets in which all producers accorded consumers equal terms of sale each period irrespective of their past purchasing history, no producer selling steel at a price exceeding that of other producers' steel of comparable quality could find customers.

Thus, rigid pricing seems to imply that producers systematically discriminate in the terms of sale they offer different customers. The challenge of this section is to explain the motivation for maintaining rigid pricing policies. In this section, we argue that rigid prices emerge as the outcome of particular vertical 'insurance' arrangements between buyers and sellers, and are merely the mechanism through which such insurance transfers are made.

III.A. Why the Capital Decision is a 'Gamble.'

As a prelude to our analysis, we make the following assumptions about the nature of the economic environment in which producers and consumers operate:

a) the product market is competitive in the sense that there is free entry and exit of firms. Firms take the market price of output as given. The market price depends on demand, which is a random variable.

b) the identical firms have a production function of the form $Q_t = F(K_t, L_t)$, where Q_t represents output, K_t is capital, and L_t is labor at time t. For simplicity, we will assume a one-period model, so that all production and consumption occurs at t = 1. Firms rent labor at t = 1 at an exogenous wage, w. However, firms must decide on a capital stock at t = 0 before demand at t = 1 is known (capital takes one period to set in place). Firms purchase capital at t = 0 for an exogenous price p_K per unit. We note that our assumption that capital must be purchased before demand is observed is analogous to assuming that capital is a durable asset without a rental market in a multi-period model.

c) aggregate demand and, hence, market price depends on the 'state of nature.' The state of nature can be regarded as a description of underlying economic variables that determine a consumer's demand, i.e., business conditions. For simplicity, we assume only two states, so that $s = s_H$ (high state = boom) or $s = s_L$ (low state = recession). The probabilities of the high and low state at t = 1 are given by Pr(H) and Pr(L) = [1 - Pr(H)], respectively.

We note that the part of b) that requires firms to choose capital (at t = 0) before they observe realizations of demand drives our demonstration that the capital choice is a risky decision. Modeling the capital outlay as risky in the above sense is clearly appropriate in the case of the steel industry. For example, rolling mills can require an up-front capital outlay of over six hundred million dollars and typically operate for fifteen or more years.

If firms could purchase capital at t = 1 after observing demand, firms would merely observe demand at t = 1 and then choose K and L so as to minimize the cost of producing the optimal level of output q^*. The cost function appropriate for determining the optimal level of output, q^*, is an unrestricted cost function, which determines the cost of producing any output (given that K and L are chosen optimally to produce that output).

The unrestricted cost function is the outer envelope of a set of restricted cost functions. The restricted cost function is the minimum cost of producing any output, given that capital is fixed at a certain level, K^*. The unrestricted cost function is the envelope of the restricted cost functions, because employing the fixed level of capital K^* (along with the appropriate labor input) is the optimal way of producing at least some level of output. However, employing this fixed level of K^* (plus labor) is not in general the cost-minimizing method of producing all levels of output. The relationship between the unrestricted and restricted cost functions, where the latter are shown for several levels of (fixed) capital, is illustrated in Figure 5. Note that while $K = K'$ is the amount of capital which allows the firm to minimize the total cost of producing q', it does not allow the firm to minimize the cost of producing (i.e., q'').

The restricted cost curves of Figure 5 incorporate expenditures on the fixed stock of capital as a component of total cost. But capital is a sunk cost, and what is relevant for determining the output decision of the firm is its (restricted) variable cost curve. These variable cost curves obviously depend on K. In particular, we assume they are convex in the level of output.

This corresponds to assuming that if an input is fixed (K), the production function displays decreasing returns to scale. We also require that the (restricted) marginal cost curve decreases as K increases for all levels of output.

Producers in our model make output decisions based on the realized market price and on their restricted cost function. Since the distribution of market prices is taken as exogenous (although random), the firm can only affect its profit distribution through changing the location of its variable cost curve. Since the location of the variable cost curve depends on the fixed choice of K at t = 0, the firm's profit distribution depends solely on its choice of K. We are assuming, of course, that the firm will act optimally at t = 1. That is, the firm chooses an output such that p = mc, given that it operates on the particular variable-cost curve implied by its fixed choice of K.

We can analyze how the returns to an investment in capital, K' , depends on the distribution of demand, since demand determines market prices. Suppose that the output price may take one of two values at t = 1: either p_L when demand is d_L (recession), or p_H when demand is d_H (boom). Since K' determines the firm's restricted variable-cost function, the firm merely waits for the realization of the output price, in order to determine how much labor it will rent. It chooses labor to equate the output price with the marginal cost of producing that output; i.e., $p = mc(Q) = w^*dL(Q; K')/dQ$, as pictured in Figure 6. If the price is p_H, the firm makes a profit of A + B (profits are $p_H{}^*q_H$ minus the area under the marginal cost curve up to q_H). If the price is p_L, profits are only area A. The dependence of the profits (from investing in a given capital stock) on the output price, which is a random variable, implies the capital decision is risky.

The existence of profits, such as A or A + B, is not incompatible with competition: after all, firms must finance the capital decision at t = 0. Instead, it is useful to analyze the K decision as a gamble. The marginal cost of the gamble is the cost of an incremental unit of K. The marginal return is the improvement in the return distribution garnered by the additional unit of investment. In Figure 7, the incremental return of increasing capital from K' to K'' is C, if p_L occurs, and C + D, if p_H occurs. The cost is $p_K(K'' - K')$. While the total return to K is obviously higher in the high state than in the low state, we also assume that the marginal return is higher in the former case.

Based on the logic of Figure 7, we can define state-dependent 'return to capital' functions RL(K) and RH(K), that relate profits to the firm's choice of K, if a given state (here price) is realized. In Figure 7, for example, $RL(K') = A$, $RH(K') = A + B$, $RL(K'') = A + C$, etc. The expected return to K is:

$$(8) \qquad E(K) = Pr(h)^{*}RH(K) + [1 - Pr(h)]^{*}RL(K).$$

Furthermore, since capital is a sunk cost, the net expected return to K is:

$$(9) \qquad \mathrm{NE}(K) = E(K) - p_K{}^{*}K = Pr(h)^{*}[RH(K) - p_K{}^{*}K] + [1 - Pr(h)]^{*}[RL(K) - p_K{}^{*}K].$$

We are able to represent the profit distribution solely as a function of the present choice of K (at t = 0), because we assume that (given any choice of K) the producer will choose q optimally next period. Thus, q is a deterministic function of K, given either of the (two) possible realizations of demand.

III.B. Price Smoothing as a Means of Insuring the Capital Gamble of Risk-Averse Producers.

In a perfectly competitive market with a complete set of contingent claims, a firm's shareholders would instruct managers of make those investment/production decisions which maximized shareholder wealth. This is because the welfare of shareholders depends on three factors: the available set of goods (including assets), the prices they face, and their wealth. Given a perfectly competitive contingent claims market, the only aspect of securityholders welfare which firms can affect by their production/investment decision is securityholder wealth. Thus the production/investment goal is clear: maximize securityholder wealth.

Complete contingent claims markets permit an optimal allocation of risk-bearing among agents. Nevertheless, as observed by Fama and others, Arrow-Debreu type securities are rare. Such market failure is costly, and is prima facie evidence of high contract costs. Fama maintains that these costs arise primarily from difficulty in monitoring Arrow-Debreu securities relative to fixed payment debt obligations and undifferentiated (by state of the world) equity claims, and also from the agency problems such contracts may introduce with regard to the firm's investment decision.

Our concern is with the implications of such market failure for the firm's investment decision. In the general case in which the firm produces new economic goods with its investment decision, i.e. spanning does not obtain, the investment decision depends on the risk preferences of shareholders. With complete markets or more generally if spanning holds, all consumers discount random payoffs in exactly the same way. However, in incomplete markets without spanning consumers will discount state contingent payoffs differently, i.e. the subjective price in terms of units of consumption at t=0 a consumer is willing to forego to obtain one unit in state's at $t=1$ will vary across consumers. In the case we will consider (incomplete markets without spanning), a firm's managers must take explicit account of the risk preferences of its securityholders in order to choose an investment/production decision maximizing their welfare. In particular, we show how different degrees of risk aversion affect the investment decision even when firm's face the same distribution of payoffs.

In the context of our two period model in which firms make fixed capital outlays based on the distribution of prices next period, we demonstrate that a 'risk average producer' (by which we mean the shareholders of the firm are risk averse) will make a different capital choice than a risk neutral producer even when they face the same distribution of prices. The capital outlay at $t=0$ determines the location of each producer's supply curve next period. Thus, the market supply curve, and thus market prices, will generally depend on the risk aversion of producers.

Further, the investment decision a producer chooses will be different from the choice he would make if there existed a complete contingent claims market which allowed ex ante transfers of wealth across states. However, in the absence of an economywide market for such claims, producers and consumers may be able to effect such transfers through bilateral contracts among themselves. We argue that long-term relationships between producers and consumers may make such agreements feasible even when they are not viable among individual decision agents. The existence of such arrangements allows consumers and producers to realize additional gains from trade, which may induce producers to choose larger capital outlays, thus reducing prices at $t=1$.

Our two period-two state analysis may seem somewhat artificial. For example, in a two state world where the capital outlay of a single firm is the sole determinant of consumption possibilities in either state next period, risk averse shareholders will always dislike greater 'spread' in the payoff distribution. This is obviously not generally true, for even in incomplete markets without spanning a shareholders's subjective valuation of state *'s'* contingent payoffs will depend on his total consumption in state *'s'* from all assets he holds. Thus, even though a firm may only pay off in state *'s'* so that the spread in its payoff distribution is very large, the consumer will put a high price on such a payoff stream if state *'s'* consumption is dear to him. However, our emphasis is on demonstrating how market incompleteness may affect a firm's investment decision, and how within such a context bilateral risk-sharing agreements between producers and consumers can be mutually beneficial. For this purpose, the two period model seems adequate.

The producer's problem at t = 0 is to choose K to maximize his expected utility of wealth:

$$(10) \qquad \mathrm{Max}EU(Wo + \hat{x}(K)) = Pr(h)^* U[Wo + p_H{}^* q_H(K) - C(q_H(K); K) - p_K{}^* k)] + [1 - Pr(h)]^* U[(Wo + p_L{}^* q_L(K) - C(q_L(K); K) - p_K{}^* K)]$$

Here $\hat{x}(K)$ represents the return distribution from a capital choice of K. The producer does so subject to the constraint that he cannot be made worse off by producing than by not producing. That is, his expected utility at the optimal choice of K is no less than if he sets K = 0:

$$(10a) \qquad EU(Wo + x(K^*)) \geq U(Wo)$$

Our first concern is to show how firms with different degrees of risk aversion make different capital choices, even when they face the same NE(K) function. To insure that all consumers (either risk averse or neutral) choose a finite amount of capital, we stipulate that E(K) is concave in the neighborhood of the optimum (this holds as a direct consequence of diminishing returns in the factor inputs: we give a formal justification for this in Appendix A). This insures NE(K) has a maximum. We know from consumer theory that risk-neutral agents will accept any 'fair' gamble. Therefore, risk-neutral producers will choose the level of K at which NE(K) achieves its maximum (i.e., they choose K to set the marginal expected return, dE(K)/dK, equal to its marginal cost, p_K).

Since the return to capital function and its derivative are uniformly higher in the high state than in the low state, the spread of the return-to-K distribution increases with K. (In Appendix B, we demonstrate that for any given distribution of prices p_H and p_L, a risk-neutral firm will choose a larger K outlay than a risk averse firm.) Instead of choosing K such that $dE(K)/dK = p_K$, the risk-averse firm chooses K such that the marginal return to increasing K exceeds its cost (i.e., $dE(K)/dK > p_K$). Since E(K) is concave, this implies the risk-neutral firm chooses more capital than a risk-averse firm.

Figure 8 illustrates the optimal choice of K for both a risk-neutral and risk-averse producer. Since both producers face the same distribution of prices, they obviously face the same NE(K) function. In Figure 8, the bold line depicts NE(K), which begins at both producers' initial level of wealth on the certainty line. The point Wo corresponds to a choice of K = 0, while larger choices of K move the producer along the NE(K) function in the direction specified by the arrows. The progressive departure of NE(K) from the certainty line reflects how the spread of returns increases with K. The parallel lines in Figure 8 represent level sets of progressively higher expected wealth. The risk-neutral producer chooses the point that maximizes his expected wealth (i.e., point A, which corresponds to the maximum of his NE(K) function). However, a risk-averse producer chooses a smaller level of K and correspondingly obtains a lower level of expected wealth (point B).

Each producer's choice of K determines the location of his supply curve next period. Further, the aggregate supply curve is simply the horizontal sum of the supply curves of the n^* firms who produce in equilibrium. If the fact that risk-averse firms supply less capital individually than risk-neutral firms also implies that they supply less capital in the aggregate, then equilibrium prices in an economy of risk-averse agents will be uniformly higher than in an economy of risk-neutral agents for any realization of demand.

We can demonstrate that this conjecture about the aggregate choice of K in the two economies is correct, assuming we stipulate that market equilibrium satisfies the following conditions:

a) at the aggregate equilibrium supply of capital K^*, the implied distribution of prices is such that each firm will choose K_i such that the sum of K_i over the n^* firms who produce in equilibrium is K^*.

b) at the market prices implied by K^* constraint 10a) from the producer's maximization problem will hold with equality for each of the individual firms in the market. Thus, no firm will have an incentive to change its production decision (including those firms how purchase zero capital, i.e., who will not be producing at t = 1).

Condition b) requires that risk-neutral producers make zero net expected profits. Thus, prices are such that at the equilibrium supply of capital, K^*, each risk-neutral producer's optimal choice of capital K_i^* gives him zero expected profits. Given this same distribution of prices, the risk-averse producer's optimal choice of capital is $K_i^{**} < K_i^*$.

However, such a choice must yield negative net expected profits, since by condition b) K_i^{**} maximizes net expected profits by setting them at zero. By Jensen's inequality we see that 10a) cannot be satisfied by the choice, K_i^{**}, since no risk-averse producer originally at the certainty line is willing to place bets that are actuarially unfair.

Thus, the aggregate capital choice must be lower, and prices correspondingly higher, in an economy of risk-averse producers than in an economy of risk-neutral producers; otherwise, risk-averse producers would not produce even if they would have an incentive to do so at a higher distribution of prices. It is in this sense that risk aversion is costly.

From Figure 8, it is evident that risk-averse consumers choose 'too little' K because they effectively place too high of a discount on the incremental returns to capital in the high state. However, if there was an insurance market that allowed consumers to exchange state H for state L wealth, risk-averse producers could be induced to behave as if they were less risk averse. Such insurance could permit producers to achieve a higher mean return for a given spread, or conversely lower spread for the same mean.

In particular, if insurance was 'fair,' risk-averse producers could fully insure and would behave as if they were risk neutral in selecting their optimal K. In other words, the increased spread in the distribution of returns attendant upon an increase in K would not affect the capital decision of producers, since they would simply maximize expected return (point A on Figure 8) and then travel down the fair insurance line to point A' (which is the same expected wealth as A, but is obtained for sure).

An insurance market is valuable insofar as it encourages producers to undertake larger gambles, which in the aggregate pushes out the market supply curve and reduces prices given any realization of demand. However, because of high contracting costs associated with such continent claims, we assume that such an insurance market does not exist in the economy as a whole. But given the strong motivation to provide such insurance, consumers may provide at least partial insurance through entering certain types of vertical arrangements with producers.

The nature of the insurance scheme is as follows: a producer's wealth distribution is known to both the producer and consumer, given his choice of capital. The insurance arrangement allows the producer to contract with consumers to make state-contingent transfers of wealth. The producer 'sells' part of the wealth he will possess if the high state occurs to a coalition of consumers. In turn, consumers pay for this state-contingent consumption by pledging to transfer to the producer a certain sum if the low state is realized. Thus, these bilateral contracts are similar to those that would exist in a complete market, except that they are not freely alienable but specific arrangements between particular consumers and producers.

We argue that the actual transfers are carried out by requiring participating consumers to pay higher-than-market prices if the low state occurs, while extending them rebates if the high state occurs. But it is critical to distinguish the insurance arrangement itself from the mechanism by which such insurance is provided. The insurance arrangement itself involves a state-contingent transfer of assets (that the producer knows he will possess if the high state occurs) in exchange for a pledge that the consumer will make a prespecified transfer if the low state occurs. There are alternative mechanisms that could bring about such transfers. We merely maintain that the way in which such insurance is actually provided requires consumers to pay higher-than-market prices during recessions, and lower-than-market prices during booms. Thus, we interpret the 'rigid prices' observed in the previous section as the outcome of the mechanism employed to permit the transfer of wealth across states.

The next important question is to determine the terms under which consumers (or coalitions of consumers) would be willing to trade wealth across (possible) future states. We show that a consumer's terms of trade depend critically on two factors: a) consumer risk aversion, and b) the correlation between the consumer's expenditure on steel and his wealth. We regard a consumer's state-dependent wealth as profits he earns as a producer of final goods, so that his wealth may vary with the high and low state experienced by the steel producer. Assuming that the consumer's state dependent profits are exogenously given is obviously somewhat unpalatable, but it nevertheless enables us to identify the factors responsible for differences in subjective relative state prices (the marginal rates of substitution) among different consumers. Gains from trade (the insurance agreement) are obviously directly related to differences in producers' and consumers' marginal rates of substitution between consumption in each state. Intuitively, insurance arrangements of the type considered above tend to be beneficial to the degree that consumers' wealth covaries less with the high demand state than does that of producers's wealth (so that wealth in the low state is relatively less valuable to producers).

We proceed to derive consumer j's acceptance set for trading wealth in the low in exchange for wealth in the high state. Since the mechanism for effecting such transfers involves smoothing the distribution of prices, the boundary of the acceptance set is generated by asking consumer j what set of prices that would leave him indifferent to facing the present prices (p_H', p_L') , given that he must continue to consume $q_{H'}, q_{L'}$ (so that the transfers are effectively lump sum).

We represent consumer j's utility function as below, where w_L and w_H are wealth in the low and high states, respectively:

$$(11) \qquad EU = Pr(h)^*U(w_H - p_H'^*q_H')$$

$$+ (1 - Pr(h))^*(w_L - p_L'^*q_L')$$

Differentiating totally with respect to p_H and p_L and setting the change in utility equal to zero, we obtain the set of prices that consumer j regards as ex ante indifferent to $p_{H'}, p_{L'}$:

$$(12) \qquad Pr(h)\frac{du(w_H - p_H{}'q_H{}')}{dw_H} \cdot (-q_H)dp_H + (1 - Pr(h))^*$$

$$du\frac{(w_L - p_L{}'q_L{}')}{dw_L} \cdot (-q_L{}')dp_L = 0$$

$$(12a) \qquad \frac{dp_H}{dp_L} = \frac{-(1 - Pr(h))q_L \cdot \dfrac{du(w_L - p_L{}'q_L{}')}{dw_L}}{Pr(h) \cdot q_H \cdot \dfrac{du(w_H - p_H{}'q_H{}')}{dw_H}} < 0$$

It is easy to show that this indifference curve between different price pairs is concave, since:

$$(13) \qquad \frac{d\left(\dfrac{dP_H}{dp_L}\right)}{dp_L} =$$

$$\frac{[Pr(h)] * q_H * \dfrac{du(w_H - p_H{}'q_H{}')}{dw_H}[1 - Pr(h)] * q_L{}' * \left(\dfrac{d^2U(w_L - p_L{}'q_L{}')}{dw_L}\right)(-q_L{}')}{\left[Pr(h)\dfrac{du(w_H - p_H{}'q_H{}')}{dw_H}\right]^2}$$

$$= -\frac{dp_H}{dp_L} q_L \frac{u''(w_L - p_L{}'q_L{}')}{u'(w_L - p_L{}'q_L{}')} < 0$$

Figures 9A and 9B depict consumer j's willingness to trade expenditure in state L for an expenditure in state H by giving the locus of price pairs that leaves him indifferent to the initial prices. Note that the slope of the indifference curves depends on the consumer's wealth in the two states (w_H and w_L), the quantities he is committed to purchasing, and the initial prices. These arguments affect the slope of the indifference curve via their effect on the marginal utility of wealth in each state. Wealth is dear in states where consumers do not have much of it. Thus, if $w_L > w_H$ (*ceteris paribus*), a consumer would be willing to trade state L wealth for state H wealth at a much lower price than another consumer for whom $w_H > w_L$. The latter will demand more compensation to trade away state L wealth in exchange for state H wealth for any given amount of state L wealth that he offers (because for him state L wealth is relatively dear). In Figure 9A we illustrate how the terms of trade vary for the same consumer j as his initial wealth distribution changes (given that he consumes q_L units in the high state and q_H units in the low state irrespective of his wealth distribution).

In the second diagram (9B), we draw on result 3): the concavity of the indifference curve increases proportionately with the consumer's absolute risk aversion. Thus, given two consumers i and j with j more risk averse than i, *ceteris paribus*, j will be less willing to assume extreme positions than i. From point A, j demands more state H wealth than i in return for giving up the same amount of state L wealth.

To recapitulate, consumer j's willingness to trade state L wealth for state H wealth depends on:

a) the covariance of his wealth with the high and low state of the producer. The less correlated are the consumer's wealth and the producer's profits, the greater the potential benefit from insurance.

b) the consumer's degree of risk aversion. The greater his degree of risk aversion, the less willing the consumer to trade toward extreme positions.

In other words, if consumers are very risk averse and their wealth covaries strongly with that of producers, we do not imagine much benefit could be derived from the insurance arrangement (since consumers would only be willing to trade state L for state H wealth at very high relative prices).

Thus, we have derived a frontier relating a consumer's willingness to trade expenditure in the low in exchange for expenditure in the high state. The willingness of coalitions of consumers to offer such trades implies that the producer faces a new and expanded opportunity locus giving his returns to any choice of K.

Figure 10 replicates Figure 8, but with an important addition. In Figure 10, the producer's return locus is extended from the original NE(K) function to include the opportunities consumers present for making *ex ante* exchanges of wealth across states. These insurance possibilities are represented by a series of lines which extend from points along the NE(K) function to the southeast. A different insurance line is associated with each point on the NE(K) function. The shape of the insurance lines depends both on the degree of risk aversion of consumers and the covariance of their wealth with the state of demand in the producer's industry.

In the absence of insurance, the producer chooses $K = K'$. Given the same distribution of prices but allowing for insurance, the producer's new optimum (in the diagram) becomes K''. We have assumed that the producer could trade along the curve that left the consumer at constant expected utility. More generally, producers and consumers would have an acceptance region that lies between the consumer's indifference curve and the producer's original indifference curve. Anywhere within this region, both consumers and producers are better off than initially. Firms and the coalitions of consumers involved will bargain to share the benefits of these 'insurance gains' among themselves.

But the existence of such insurance arrangements in the aggregate precludes firms from making increases in expected utility by employing them. In fact, the new equilibrium requires that aggregate K be greater than or equal to the initial equilibrium K, with prices in each state uniformly lower (exclusive of transfers). This is because if at least some firms benefit from the insurance arrangement, then prices will be strictly lower than in the initial equilibrium. To prove this, it is obvious that prices cannot be higher (and K lower) than initially, since in that case firms could ignore the insurance and make a gain in expected utility even by choosing their former level of capital. This violates equilibrium condition b). Thus, aggregate K must equal at least its initial value before insurance was introduced. Aggregate K could remain unchanged only if no firms employed the insurance. Firms would only utilize the insurance if by doing so they could increase their expected utility over its initial level. This does not imply that firms must choose a larger level of K than initially. However, the existence of possible increases in expected utility at the initial level of prices means that the initial level of prices fails equilibrium condition b). Thus, prices must drop in the new 'insurance' equilibrium (which implies aggregate K must increase).

Thus, we have shown how coalitions of consumers and firms can potentially gain by exploiting insurance agreements among themselves. Coalitions of consumers specifically entering into such agreements gain to the extent that they bargain to a favorable point in the acceptance region. Interestingly, there is also a spillover effect even to those consumers who do not enter the arrangement. This is because the very existence of such arrangements—if they are utilized—implies that the distribution of prices must decrease.

III.C. Monitoring the Arrangement

Using price smoothing as the mechanism to provide insurance suffers from the defect that producers have an incentive to change their production decision at $t = 1$ in response to the new, smoothed distribution of observed prices. In fact, it is obvious that using price smoothing as a means of effecting transfers of wealth across states is infeasible in the context of a one-period model. If, for example, demand was high, producers would not sell to consumers at the lower agreed-upon price, nor would consumers pay premiums over prevailing market prices if demand was low. They would renege on the agreement, because there is no punishment for doing so.

Thus, if the insurance agreement is to exist in the context of a one-period model, transferring wealth across states must be accomplished through some a mechanism other than by price smoothing. A possible arrangement would involve the producer and coalition of consumers contracting with a third party. Both producer and consumer could be required to post a bond equal to the transfer they may be called on to make next period. Thus, the third party is responsible for enforcing the agreement by providing the requisite wealth transfer by deducting from the posted bonds as demanded by the *ex ante* agreement.

Steel consumers and producers, however, do not appear to rely on external agencies to secure long-term agreements among themselves. Contracting with a third party is costly. Producers and consumers have an incentive to devise an arrangement that they themselves can monitor without turning to outside sources. The problem that such self-enforcing arrangements face is to devise a mechanism for carrying out an agreement that both believe is in the interest of the other to uphold.

In other words, agents must ask: under what conditions can I expect the person with whom I contract to be reliable? Lester Telser observes that we cannot infer that an agent will continue to perform his end of the bargain simply because he has done so in the past. Rather, it is "information about someone's return from reliability that is pertinent in judging the likelihood of his reliability."

In an intertemporal context, not all consumers would benefit from these insurance arrangements, since the producer could only promise to reduce expected expenditure 'over the long haul.' For example, transient consumers of steel would be remiss to pay premiums in low states for the promise of rebates during boom states, if they did not expect to consume a sufficient supply of steel in the future to justify paying the current premium. However, all consumers would have an incentive to say that they would support the insurance scheme during periods of high demand when they receive the 'coverage' (rebate). How can firms separate those consumers who will reliably pay premiums and thus satisfy their end of the insurance arrangement from those who will not?

We argue that price smoothing does become feasible in an intertemporal context precisely because producers can judge whether an agent's 'return from reliability' (i.e. return from maintaining the insurance agreement) exceeds the cost. Firms do so by basing insurance payouts on a customer's past purchasing history. Consumer's who have a long history of faithfully paying premiums receive more favorable transfers during high-demand states than less stable customers. We call a consumer's history of paying premiums his 'stock of loyalty.' By basing 'rebates' on a consumer's stock of loyalty, producers are able to separate those consumers who can achieve long-term benefits from the arrangement from those who cannot. Thus, firms set up a self-selection mechanism by essentially requiring consumers to pay an entry fee: only those consumers who benefit by reliably maintaining the agreement can be induced to pay the fee. While we have generally treated these transfers as if they were monetary payments (i.e., in goods), such transfers may also assume the form of favorable lead times.

Firms may also cheat by not supplying the requisite transfers during boom states. For example, the firm may fail to meet promised lead times, or may refuse to sell at the agreed on price (the market price minus the appropriate discount). Firms would undertake such actions to increase their expected utility above the 'zero increase in expected utility' required by equilibrium condition b). There is always an incentive to expropriate loyal customers; after they have paid their entry fee, it is costly to change suppliers. However, non-cheating firms could offer better packages to new customers than cheating firms, where we may define a package as the relation between lead time or price a customer receives and his stock of loyalty. Any cheating firm would be limited to the extent that there is a considerable volume of new customers entering the market, and because loyal customers could switch if expropriations were too high. In general, we expect that firms would have little to gain through cheating.

Thus, we have shown how it becomes possible to secure the benefits of the insurance arrangement by using price smoothing as a mechanism to effect transfers of wealth across states. Firms separate those consumers who will adhere to the agreement from those who will not by basing payouts on past premiums paid by the customer. By doing this, consumers tell firms whether they are 'reliable' by the composition of their purchases. This ability to make monitoring less costly is what allows producers and consumers entering into these arrangements to secure benefits of trade not available in the economy as a whole.

V. Conclusion

While we find some support in favor of rigid pricing on the part of domestic producers, we maintain that it is wrong to conclude that such pricing implies anticompetitive practices. If steel were priced so as to afford all customers equal terms of sale each period, no customer would agree to pay prices that exceeded those of another producer.

The observation that some consumers are willing to pay particular suppliers prices that exceed those of other suppliers selling the same material product motivates our investigation into reasons for long-term relationships between buyers and sellers and their implications for prices. We argue that producers and consumers can mutually benefit by entering into arrangements whereby consumers effectively coinsure the risk of a producer's capital outlay. Rigid prices emerge as the vehicle for providing insurance transfers.

Further, our analysis provides a basis for the belief common among steel-purchasing agents that it is better to pay premiums today to avoid suffering large price increases during tomorrow's boom. It is rather difficult to provide an economic justification for why consumers would simply desire smoothed input prices (since the cost function is concave in factor prices, assuming consumers can choose inputs optimally after observing prices). However, we argue that consumers' motivation for purchasing from suppliers with smoothed prices is not because they desire a smoothed distribution of factor prices for its own sake. Rather, these smoothed prices represent the outcome of implicit insurance agreements between producers and consumers which can lower the expected costs of consumers.

Appendix A: How Restrictive is it to Represent E(K) as Concave?

We may represent E(K) as:

$$Pr(h)^*[\max p_H^* F(L;K) - w_L \cdot L] + [1 - Pr(h)]^*[\max p_L^* F(L;K) - w_L \cdot L].$$

The terms in brackets are restricted profit functions for a *fixed* choice of K. The optimal choice of L depends only on the price (p_H or p_L) and the choice of K. Thus, the terms in brackets are functions of K, and are easily recognized to be unrestricted profit functions (a different one corresponds to each price), only gross of the cost of capital.

We know that a necessary condition for these unrestricted profit functions to be bounded is that the production function exhibit diminishing returns after some point (beyond some choice of K,L). If we assume that this is true, then E(K), which is a (convex) sum of functions which are eventually concave, must itself eventually exhibit concavity.

Thus, regarding E(K) to be concave is no more restrictive than assuming the (unrestricted) production function exhibits decreasing returns.

Appendix B: Proof that the Risk Averse Producer Chooses a Smaller Capital Outlay than the Risk Neutral Producer, Given that They Face the Same Distribution of Prices

Repeating (10) and (10a) from the main text, we have:

$$(1) \quad \max EU(Wo + x(K)) = Pr(h)^* U[Wo + p_H{}^* q_H(K)$$
$$- C(q_H(K);K) - p_K{}^* K] + [1 - Pr(h)]^* U$$
$$[Wo + p_L{}^* q_L(K) - C(q_L(K);K) - p_K{}^* K]$$

subject to the constraint that the producer cannot be made worse off by producing than by not producing. That is, his expected utility at the optimal choice of K is no less than if he sets K = 0:

$$(1a) \quad EU(Wo + x(K^*)) \geq U(Wo).$$

Here $x(K^*)$ is the distribution of wealth implied by the optimal choice of capital K*.

We begin by temporarily assuming that (1a) is satisfied and proceed to derive the producer's first order conditions (FOC) for choosing K. The FOCs are:

$$(2) \quad Pr(h)^*[dU(RH)/dRH]^*[(dRH/dK) - p_K] +$$
$$[1 - Pr(h)]^*[dU(RL)/dK]^*[(dRL/dK) - p_K] = 0;$$

where:

RH = profits in high state = $Wo + p_H{}^* q_H(K) - C(q_H(K);K)$

RL = profits in low state = $Wo + p_L{}^* q_L(K) - C(q_L(K);K)$

Equivalently to 2), we have:

$$(3) \quad dEU/dK = Pr(h)^*[dU(RH)/dRH]^*$$
$$[p_H{}^*(dq_H(K)/dK) - (dC/dq_H)^*(dq_H/dK)$$
$$- dC/dK - p_K] + [1 - Pr(h)]^*[dU(RL)/dRL]^*$$
$$[p_L{}^*(dq_L(K)/dK) - (dC/dq_L)^*(dq_L/dK)$$

$- dC/dK - p_K]$

By the envelope theorem,

$[p_H{}^*(dq_H/dK) - (dC/dq_H)^*(dq_H/dK)] = [p_H - (dC/dq_H)]^*(dq_H/dK) = 0;$

similarly:

$[p_L - (dC/dq_L)]^*(dq_L/dK) = 0.$

Thus, 3) simplifies to:

$$(4) \quad dEU/dK = Pr(h)^*(dU/dRH)^* \\ [\ -dC(q_H(K);K)/dK - pK] + \\ [1 - Pr(h)]^*(dU/dRL)^* \\ [\ -dC(q_L(K);K)/dK - p_K] = 0$$

$$(4a) \quad Pr(h)^*(dU/dRH)^*[\ -dC(q_H(K);K)/dK] + \\ [1 - Pr(h)]^*(dU/dRL)^* \\ [\ -dC(q_L(K);K)/dK] = \\ p_K{}^*[Pr(h)^*(dU/dRH) + (1 - Pr(h)^*(dU/dRH))]$$

Equivalently, we have:

$$(5) \quad \frac{Pr(h)^*\dfrac{du(RH)}{dRH}^*\left[\dfrac{-dC(q^H(K);K)}{dK}\right] + [1 - Pr(h)]^*\dfrac{du(RL)}{d(RL)}\left[\dfrac{-dC(q^L(K);K)}{dK}\right]}{Pr(h)\dfrac{du(RH)}{dRH} + [1 - Pr(h)]\dfrac{du(RL)}{dRL}} = p_K$$

We observe that the change in expected profits consequent on an increase in K, gross of the cost of capital, is:

$$(6) \quad dE(K)/dK = Pr(h)^*[\ -dC(q_H(K);K)/dK] + \\ [1 - Pr(h)]^*[\ -dC(q_L(K)/dK]$$

The risk-neutral producer chooses K, such that $dE(K)/dK = p_K$ (this is evident from equation (5)). E(K) is concave in the neighborhood of the optimum. If we can show that risk averse producers choose K such that $dE(K)/dK > p_K$ (so that the expected marginal revenue from increasing K exceeds its marginal cost at the optimal K), we will have proven that risk-averse producers choose a smaller level of K than risk-neutral producers.

Equation (5) tells us that showing $dE(K)/dK > p_K$ is equivalent to showing that $dE(K)/dK$ exceeds the left hand side (lhs) of (5) when evaluated at the optimal choice of K. Therefore, we must simply show that:

$$(7) \qquad \frac{dE(K)}{dK} > \frac{Pr(h)*\frac{du(RH)}{dRH}*\left[\frac{-dC(q^H(K);K)}{dK}\right] + [1 - Pr(h)]*\frac{du(RL)}{dRL}*\left[\frac{-dC(q^L(K);K)}{dK}\right]}{Pr(h)\frac{du(RH)}{dRH} + [1 - Pr(h)]\frac{du(RL)}{dRL}}$$

Note that at the optimal K, (du(RH)/dRH) = a and (du(RL)/dRL) = a', where a and a' are constants. Further, since U is concave, and profits in the high state exceed those in the low state, a' a. Thus, after dividing through by a, the rhs of (7) is:

$$(8) \qquad rhs \text{ of } 7) = \frac{Pr(h)*\left[\frac{dL(q_H(K);K)}{dK}\right] + [1 - Pr(h)]*\frac{\alpha'}{\alpha}\left[\frac{-dC(q^L(K);K)}{dK}\right]}{Pr(h) + [1 - Pr(h)]*\frac{\alpha'}{\alpha}}$$

When $\alpha'/\alpha = 1$, which corresponds to the case of the risk neutral producer whose utility is linear in profits, $dE(K)/dK$ = rhs of 7). However, when $\alpha'/\alpha > 1$, which corresponds to the case of the risk averse producer, the rhs of 7) is less than $dE(K)/dK$. This is because the derivative of the rhs of 7) with respect to a'/a is uniformly negative, so that when $a'/a > 1$, the rhs of 7) is less than dE(K)/dK:

$$(9) \qquad \frac{d(rhs \text{ of } 7)}{d\frac{\alpha'}{\alpha}} = \frac{\left[Pr(h) + (1 - Pr(h))(*)\frac{\alpha'}{\alpha}\right](1 - Pr(h))\left[\frac{-dC(q_L(K);K)}{dk}\right]}{[Pr(h) + (1 - Pr(h))\frac{\alpha'}{\alpha}]^2}$$

$$\frac{-\left[Pr(h)*\left(\frac{-dC(q^H(k);k)}{dk}\right) + [1 - Pr(h)]*\frac{\alpha'}{\alpha}\left(\frac{-dC(q^L(k);k)}{dk}\right)\right][1 - Pr(h)]}{\left[[Pr(h) + (1 - Pr(h))]\frac{\alpha'}{\alpha}\right]^2}$$

The denominator is obviously positive, so the sign depends on the numerator, which equals:

$$(10) \qquad [1 - Pr(h)]*[(Pr(h) + (1 - Pr(h))(\frac{\alpha'}{\alpha})\left(\frac{-dC(q^L(k);k)}{dk}\right)] -$$

$$[1 - Pr(h)]*\left[Pr(h)\left(\frac{-dC(q^H;k)}{dk}\right) + (1 - Pr(h))\frac{\alpha'}{\alpha}\left(\frac{dC(q^L(K),K)}{dk}\right)\right]$$

$$= [1 - Pr(h)]\left[Pr(h)^*\left(\frac{-dC(q^L(k);k)}{dk} + \frac{dC(q^H(k);k)}{dk}\right)\right]$$

Since $dC(q_H(K);K)/dK < dC(q_L(K);K)/dK$, this numerator is negative. Thus, $d(rhs)/d(a'/a) < 0$. When the rhs is evaluated at $a'/a > 1$, $dE(K)/dK > pK$ at the optimal choice of K. Since by assumption both risk-averse and risk-neutral producers face the same NE(K) function, this condition implies that risk-averse producers choose less capital.

Finally, if the distribution over states was given by a continuous density function, our two-state proof is easily modified. First, (7) requires us to show:

$$E\left(\frac{-dE}{dK}\right) > \frac{E\left[\left(\frac{du(R)}{dR}\right)\left(\frac{-dC(R)}{dk}\right)\right]}{E\left(\frac{du}{dR}\right)} = P_k$$

Rewriting the rhs, we have:

$$\frac{E\left(\frac{du}{dR}\right)E\left(\frac{-dC}{dk}\right) + cov\left(\frac{du(R)}{dR}, \frac{-dC}{dK}\right)}{E\left(\frac{du}{dR}\right)}$$

$$= E\left(\frac{-dC}{dk}\right) + \frac{cov\left(\frac{du(R)}{dR}, \frac{-dC}{dK}\right)}{E\left(\frac{du}{dR}\right)}$$

Since the covariance is negative except in the case of linear utility, the lhs exceeds the rhs, which proves the result.

References

Acs, Zoltan J., 1984, *The Changing Structure of the U.S. Economy: Lessons from the Steel Industry*, New York, NY: Praeger.

Department of Commerce, *Survey of Current Business*, various issues.

De Vany, Arthur, and Gail Frey, 1982, "Backlogs and the Value of Excess Capacity in the Steel Industry," *American Economic Review*, Vol. 72, no. 3., pp. 441-451.

Erceg, Christopher, Philip R. Israilevich, and Robert H. Schnorbus, 1989, "Theory and Evidence of Two Competitive Price Mechanisms for Steel," *Working Paper Series on Regional Economic Issues*, Federal Reserve Bank of Chicago.

Fama, Eugene F, "The Effects of a Firm's Investment and Financing Decisions," *American Economic Review*, June, 1978, 68, pp. 272-284.

Fama, Eugene F. "Contract Costs and Financing Decisions," unpublished working paper, Graduate School of Business, the University of Chicago, 1985.

Gregory, R.G., 1971, "United States Imports and Internal Pressure of Demand: 1948-1968," *American Economic Review*, Vol. 6, no. 2 (March), pp. 28-47.

Hogan, William T., 1972, *The 1970s: Critical Years for Steel*, Lexington, Mass., Heath and Company.

Jondrow, James M., David E. Chase, and Christopher L. Gamble, 1982, "The Price Differential Between Domestic and Imported Steel," *Journal of Business*, Vol. 55, no. 3, July, pp. 383-399.

Means, Gardner, 1957, Hearings before the Committee on Antitrust and Monopoly of the Committee of the Judiciary, United States Senate, Washington, D.C., Government Printing Office.

Raia, Ernest, 1988, "Developing World-Class Suppliers is Purchasing's Biggest Challenge," *Purchasing Magazine*, January 28, p. 39.

"Smoother Order Flow Can Cut Lead Times," *Purchasing Magazine*, May 7. 1974, p. 26.

Steuer, M.D., R.J. Ball, and J.R. Eaton, 1966, "The Effect of Waiting Times on Foreign Orders of Machine Tools," *Economica* , Vol. 33, no. 132, November, pp. 387-403.

Telser, Lester, 1987, *A Theory of Efficient Cooperation and Competition*, Cambrdige: Cambridge University Press.

Wood, Adrian, 1974, *A Theory of Profit*, Cambridge: Cambridge University Press.

Burnett, Donald F., and Crandall, Robert W., *Up From the Ashes* The Rise of the Minimill in the United States. Washington, D.C.: The Brookings Institute, 1986.

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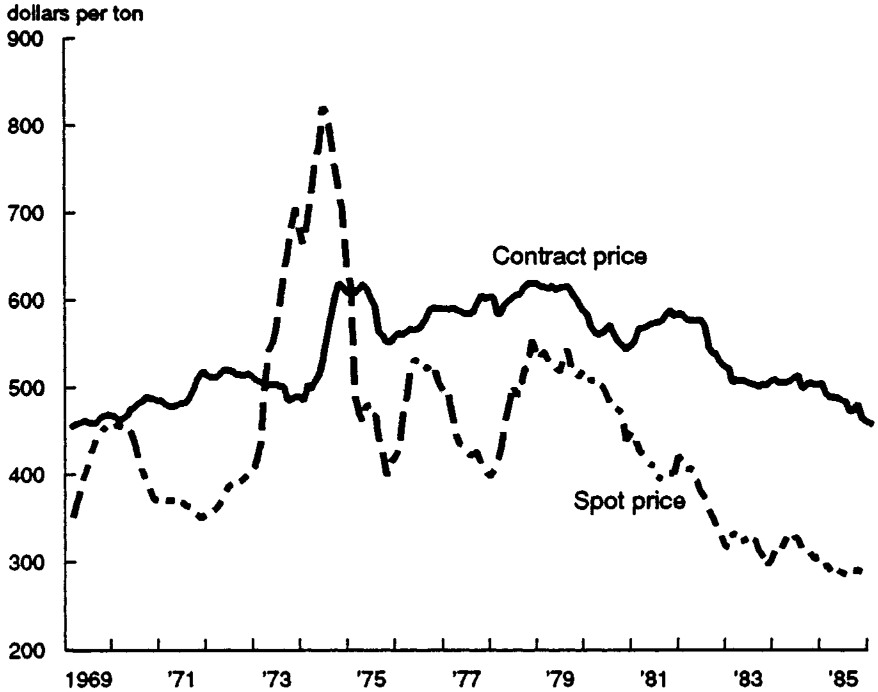
- ERRATA -

Enclosed please find a set of figures that were inadvertently omitted in Working Paper number 1989/9.

Theory and Evidence of Two Competitive Price Mechanisms for Steel, by C. Erceg, P. Israilevich and R. Schnorbus.

Figure 1
Steel price trends: Contract vs. spot markets



NOTE: Both prices are converted to dollar values and appropriately deflated to remove the influence of inflation on steel price trends.
SOURCE: Paine Webber

Figure 2
Hedonic price schedual

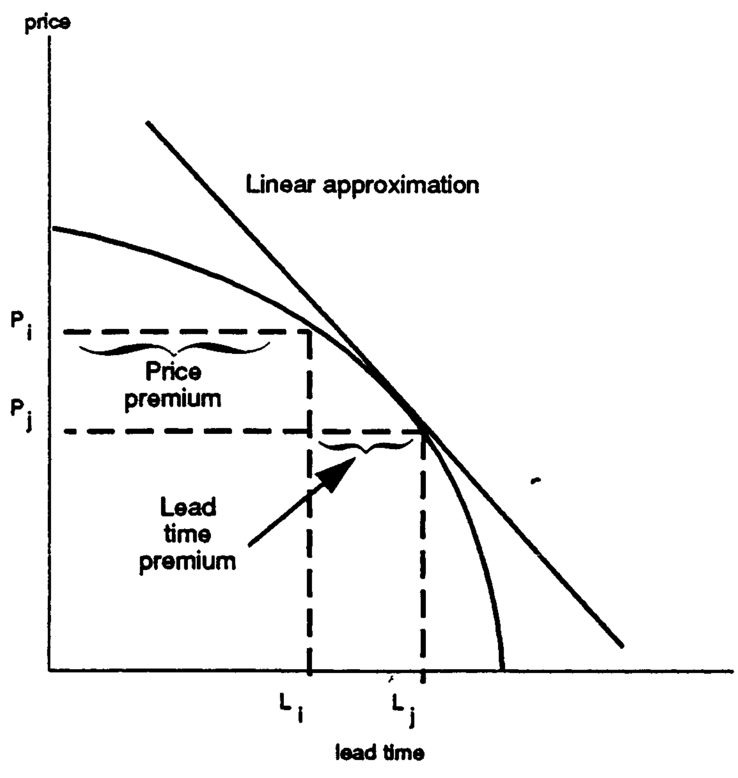
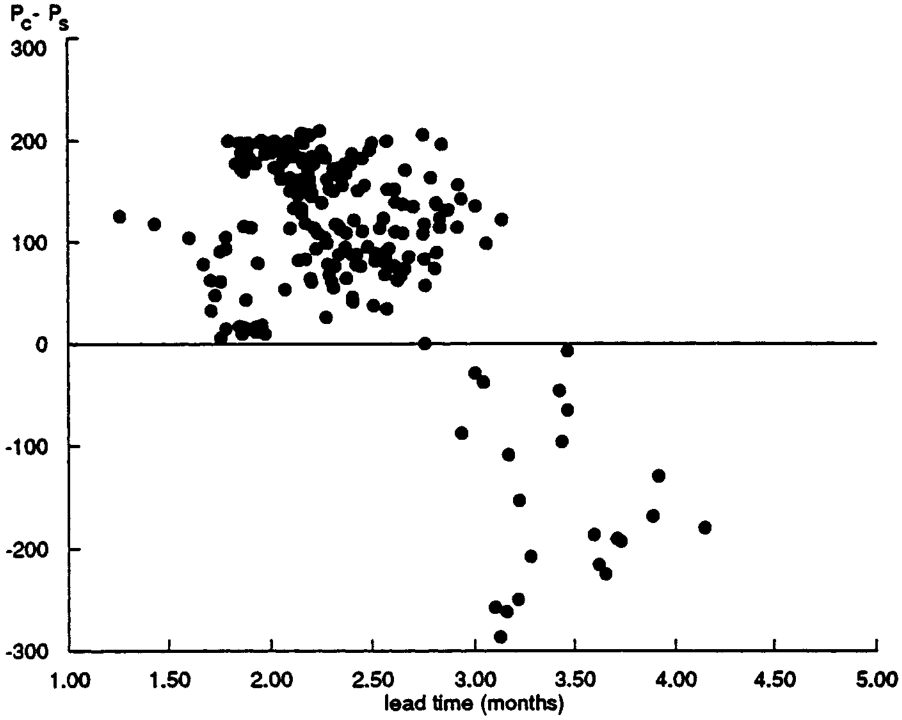
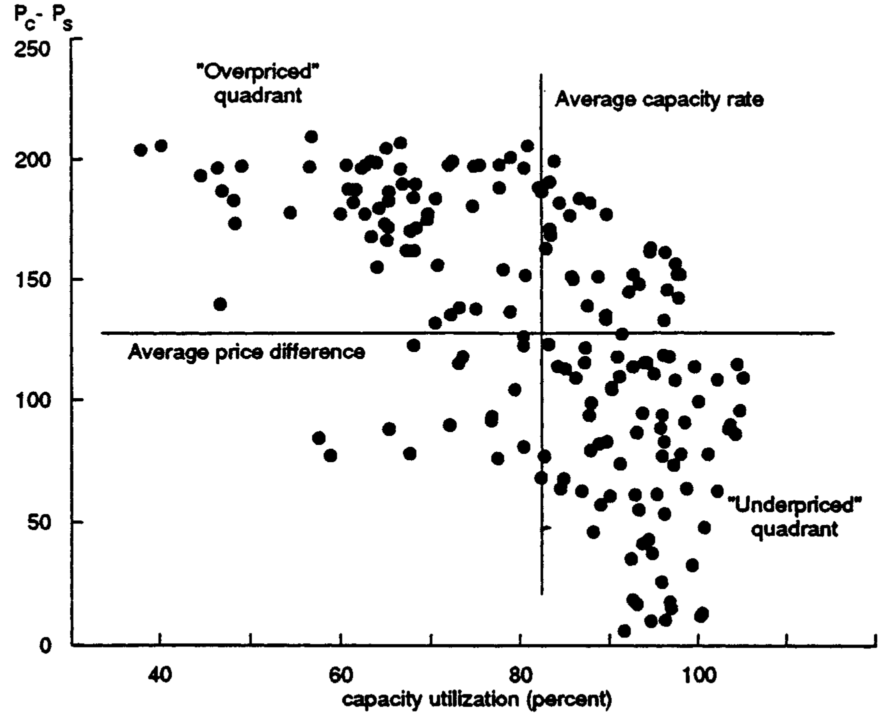


Figure 3
Scatter plot of price premiums vs. lead time: 1969-64



SOURCE: Paine Webber and Department of Commerce.

Figure 4
Scatter plot of premium vs. capacity utilization: 1969-84, excluding 1973-74



SOURCE: Paine Webber and Department of Commerce.

Figure 5
Restricted vs. unrestricted cost functions

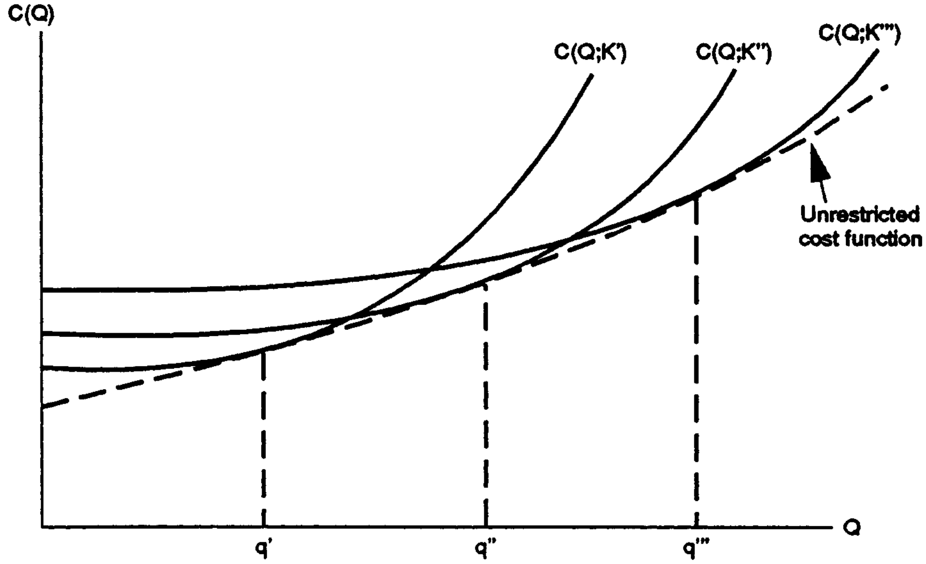


Figure 6
Deriving labor demand from restricted cost functions

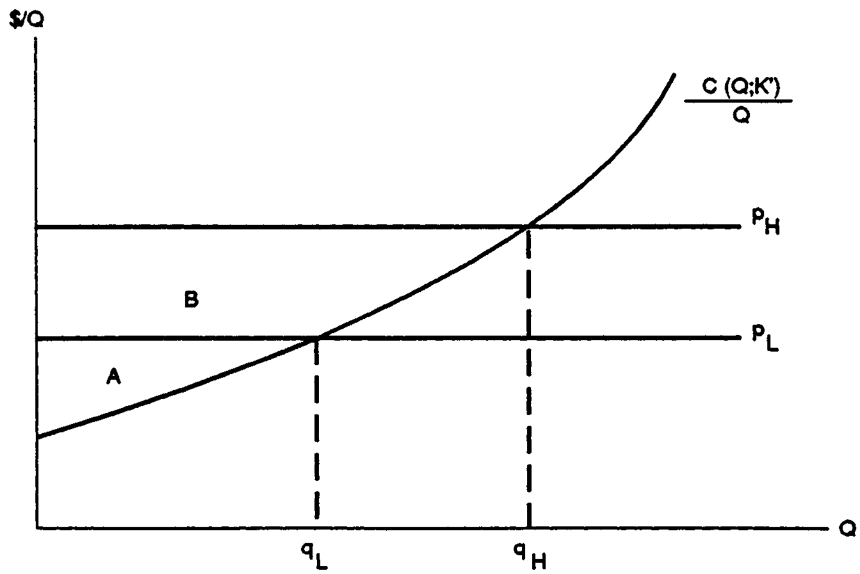


Figure 7
Deriving return on investment from restricted cost functions

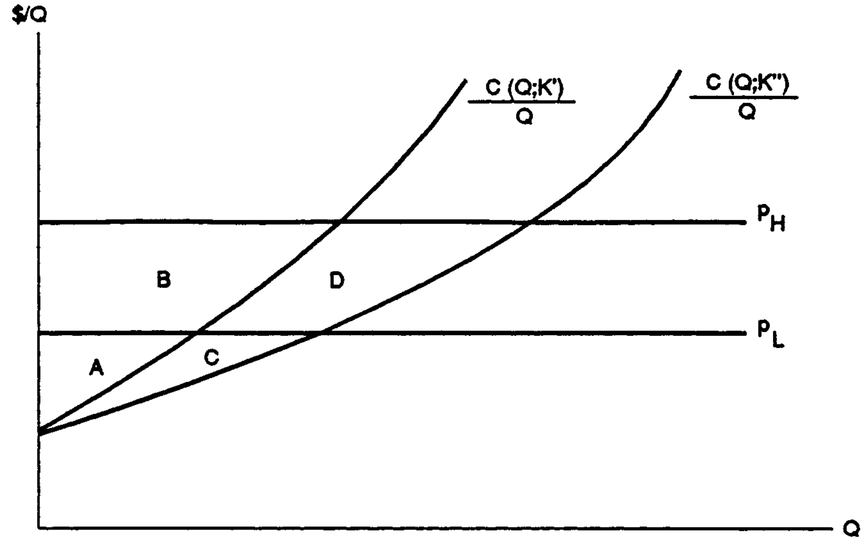


Figure 8
Optimal choice of capital for risk-neutral and risk-averse producers

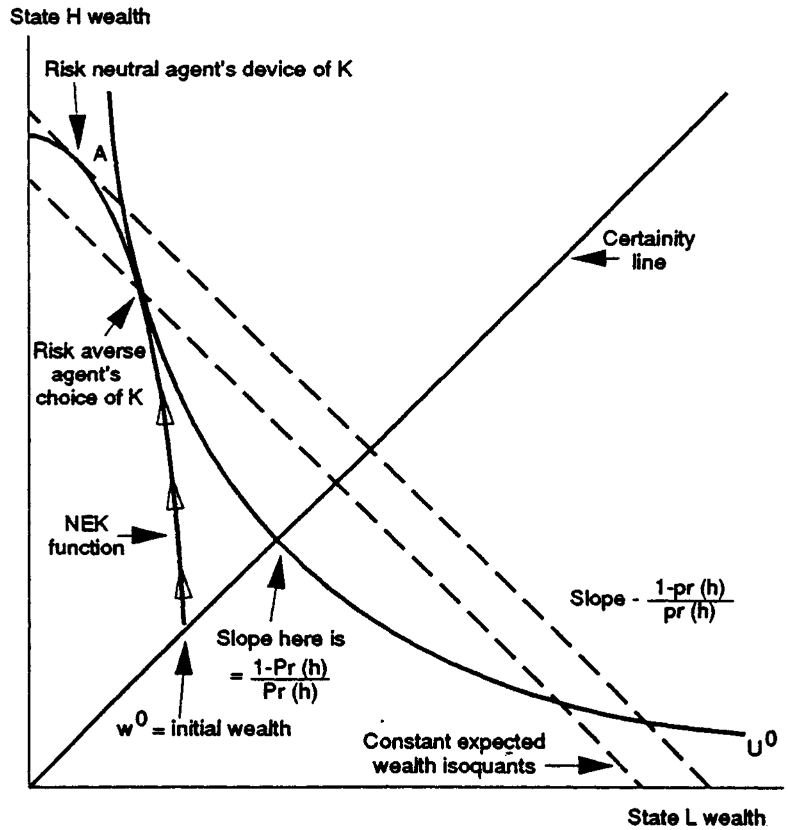


Figure 9a

Consumer willingness to trade states of wealth relative to initial wealth

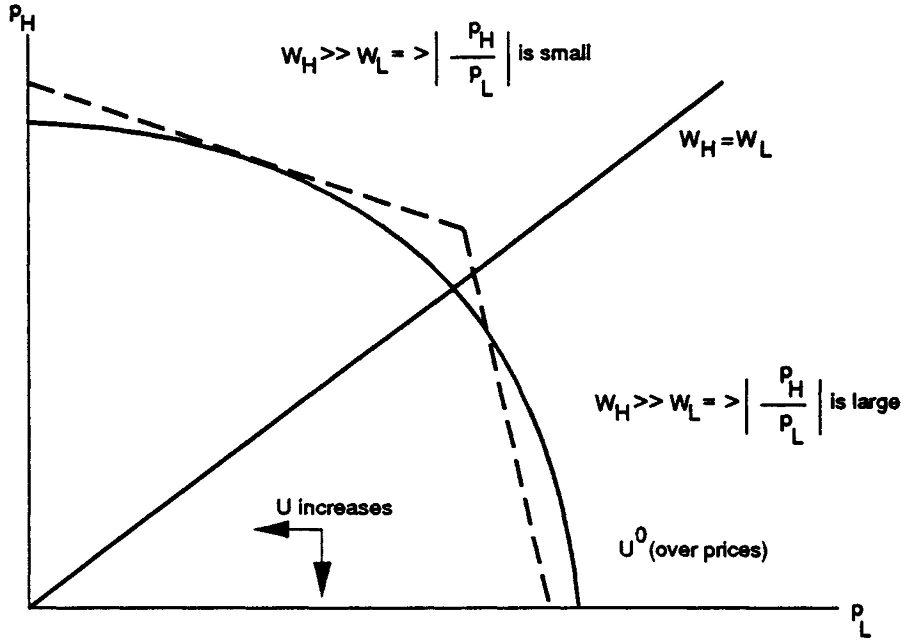


Figure 9b

Consumer willingness to trade states of wealth relative to risk aversion

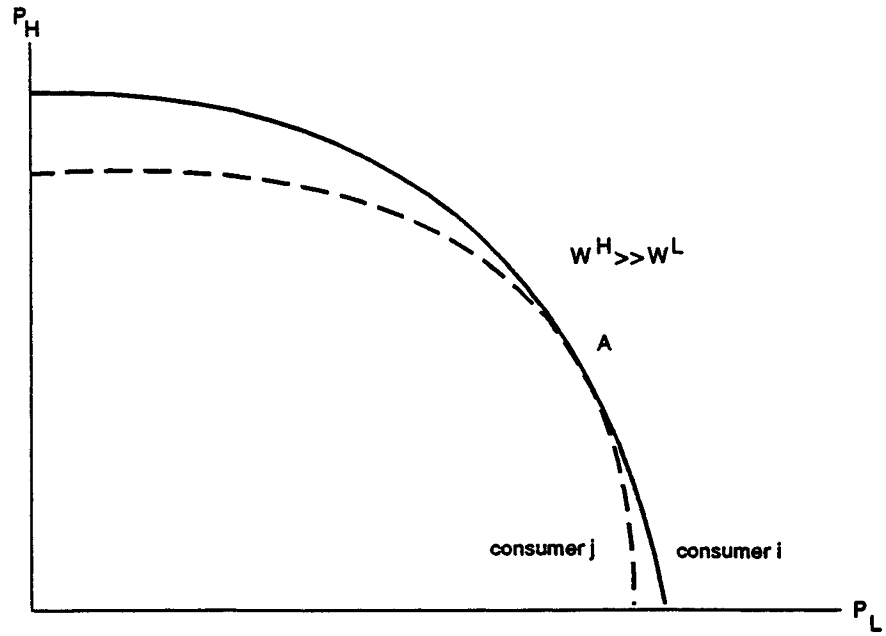


Figure 10

Optimal choices of capital with insurance