Transfer Pricing with Technology Choice and Demand Fluctuations in a Simple Manufacturing Model

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This paper shows optimal (marginal-cost) transfer pricing with technology choice (K/L) and demand fluctuations (off-peak/peak) in a simple manufacturing model Technology$_K$ is making major components or use of new or capital-intensive technology Technology$_L$ is buying major components or use of old or labor-intensive technology. We demonstrate graphically, mathematically, and numerically that with technology$_L$ available to the manufacturing division to provide the excess of peak over off-peak demand, then the optimal transfer price in t_2 is far lower than if only technology$_K$ were available. This should make marginal-cost peak-load transfer pricing more tolerable to corporation managers. Further, not only P_2 becomes lower, but Q_2 becomes higher. The firm is producing more than if only technology$_K$ were available (under negatively-sloped-demand schedules facing the firm). This has macroeconomic implications in aiding economic growth and increasing the sustainability of economic upturns

Introduction

This paper shows transfer pricing with technology choice and demand fluctuations in a simple manufacturing model. No one has done this before Our model is that of Hirshleifer as presented by a modern managerial economics text (Salvatore, 1989, p. 525). We incorporate features of our previous work on technology choice in a setting of competitive manufacturing.

Transfer prices are the prices that units of a company charge each other for goods or services. Transfer prices in this analysis have no direct effect on a company's consolidated financial statements because intracompany profits and losses are eliminated in consolidation. Further, we assume no tax considerations and no control frictions. Transfer prices can indirectly affect corporate profits if they affect management's decisions on how and what to manufacture and how to price the final goods. It is this indirect impact this article addresses. This is a theoretical paper that highlights implications for policy and for empirical analysis.

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Consider a firm with two divisions: a manufacturing division, A, that sells an intermediate product to a marketing division, B. Division A has two ways to manufacture the product: using technology$_K$, a capital-intensive method (new machines or making components) or using technology$_L$, a labor-intensive method (old machines or buying components) or a combination Technology$_K$ is output rigid and technology$_L$ is output flexible because technology$_L$ can handle changes in output rates more economically. Each technology is the common cost accounting model of linear total costs and capacity limits. Demand for the final product fluctuates between low demand with w_1 frequency and high demand with w_2 frequency.

We demonstrate graphically, mathematically, and numerically that the optimal transfer pricing is that P_1 must lie between the unit variable costs of the two technologies and P_2 must equal what would occur if A used the old or labor-intensive method exclusively in both periods This argues for flexible transfer pricing: low in low-demand times and high in high-demand times. Our new insight is that where managers can use technology$_L$ to supply the increment of peak over off-peak demand, then P_2 becomes dramatically decreased and the swing off-peak versus peak optimal prices becomes muted, compared with only technology$_K$ available. This should make marginal-cost peak-load pricing more understandable and tolerable to corporation managers.

Not only does P_2 become lower with diverse technology available to division A, but also Q_2 becomes higher The firm is producing more than it would if only technology$_K$ were available (under negatively-sloped demand schedules facing the firm). This suggests a profound advantage to having technology$_L$ available in a manufacturing division to meet peak demands—the firm's output becomes higher in peak demand times. This has macroeconomic implications in aiding economic growth and increasing the sustainability of economic upturns.

Novelty of our Approach

The novelty of our approach is that in our model the transfer pricing problem under demand fluctuations is the peak-load problem in utility economics. Our previous work (1995) establishes the conditions when the transfer price problem becomes the peak-load problem. Under the conditions of our model managers should use a flexible system, charging a high transfer price during periods of full capacity and a low transfer price during periods of idle capacity

We base much of our research on the writings of John M. Clark, who wrote extensively on the economics of fixed costs Werner G Frank shows how prescient Clark was. Clark emphasized the importance of "freedom of exit" of durable and specific assets during economic downturns.

The model here, especially the aspect of investment under demand fluctuations, is similar to Williamson (1966) and Crew and Kleindorfer (1986). Williamson does not consider technology choice, which we do here. We use Williamson's approach in determining industry capacity. Crew and Kleindorfer provide the path-breaking work on conditions for diverse technology to coexist. It is our claim (1989) that the choice of diverse technology for competitive manufacturing is a choice between output-rigid ($technology_K$) and output-flexible ($technology_I$) technologies

Typical transfer pricing problems at the end of chapters on transfer pricing in cost-accounting and managerial economics texts and on the CPA exams involve durable and specific assets, linear total costs, capacity limits, and demand fluctuations These factors cause idle capacity to be a normal situation for the major part of a business cycle. This is a theme of John M. Clark.[1] The focus is determining optimal transfer pricing under these conditions

Our work here is a long-run theoretical equilibrium analysis We use the economic principle that marginal-cost pricing generates Pareto-efficient results under theoretical conditions. Elsewhere we explore the practical question of how managers should make capital-budgeting decisions with technology choice and demand fluctuations in a simple manufacturing model. Our conclusions are (1992, p. 416).

> Managers should draw (by using their computer and spreadsheet program) a SRAC curve for each investment possibility This paper focuses on the shape of the SRAC and the importance of knowing its shape in capital-budgeting decisions

Output Flexibility

Different technologies have varying degrees of output flexibility in the sense of ease of handling changes in the rate of output. This is a non-standard definition. Economists define output flexibility as the relative flatness of the short-run average cost (SAC) and short-run marginal (SMC) curves. An output-flexible technology has flat-bottomed SAC and SMC curves, while an output-rigid technology has steeply U-shaped curves. Furnovsky (1973) uses the term *production flexibility* while Hiebert (1989) uses the term *cost flexibility*

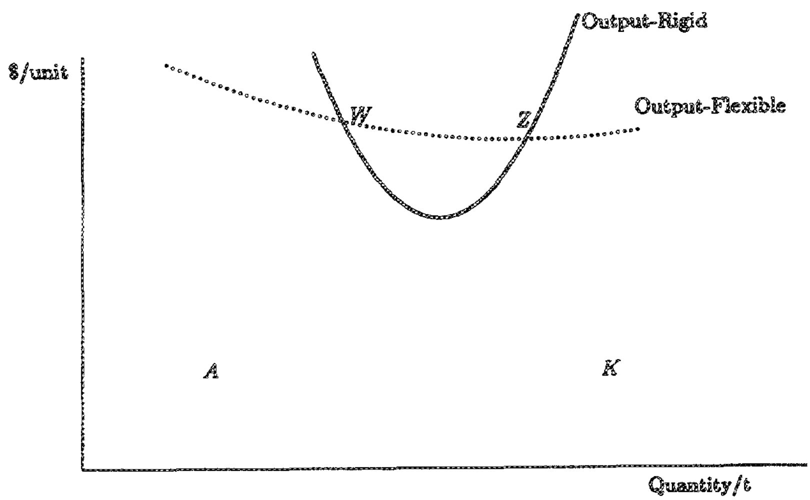
Figure 1 is from a classic article by George J. Stigler (1939)[2] showing SAC curves of two types of plants producing the same product One curve represents the output-flexible technology, and the other shows output-rigid technology (Stigler, 1939, p 317). In Stigler's illustration, if output rates were to fluctuate between points W and Z, then the output-rigid technology would produce at lower costs. If they were to fluctuate

[1] Clark (1923, p iv) states " indeed the whole subject of the book might be defined as a study of discrepancies between an ever fluctuating demand and a relatively inelastic fund of productive capacity, resulting in wastes of partial idleness, and many other economic disturbances Unused capacity is its central theme"

[2] Friedman (1962, p 138) suggests that Stigler may have been the first to write on the economics of output flexibility Stigler, however, traces the foundations of the subject to J.M Clark's (1923) earlier work, noting (Stigler, 1939, p 312n) "Most of the phenomena under consideration have been discussed, although not with reference to formal cost theory, by J M Clark in *The Economics of Overhead Costs* (1923), especially chapters v and vi"

between points A and K, then the output-flexible technology would produce at lower costs

Figure 1—Short-Run Average Cost Curves of Two Technologies



Output flexibility used here is strictly *production volume* flexibility (Chang, 1993, p. 77; Roller, 1990, p. 418) and not product-design flexibility (also called *economies of scope*).[3] Output flexibility is useful under fluctuations in demand for the same product. Product-design flexibility is useful when which products demanded fluctuates, such as when consumers at certain times demand product A more than product B for a given price while at other times they demand product B more than product A at the same price (Chang).

Optimal Transfer Pricing under Demand Fluctuations with Linear Total Costs and Diverse Technology

Definition of the Model and its Terms and Assumptions

In this study we have a manufacturing or production division, A, transferring an intermediate good to a distribution or marketing division, B There is no external market

[3] Kaplan (1989, p 217) states "Computer technology also permits much greater manufacturing flexibility Increasingly, firms will compete based on economies of scope—the ability to produce a wide variety of products on the same manufacturing equipment- -as opposed to economies of scale- spreading fixed factory and divisional costs over a large volume of products. the traditional source of competitive advantage for large U.S manufacturers " Milgrom and Roberts, for example, when they talk of flexible equipment refer to ease of switching to a different product The model in this paper assumes single-purpose equipment.

for the intermediate good. One unit of the intermediate good is used to produce each unit of the final good. The final good is a single homogeneous product and is perishable or semiperishable such as cement. We use Q to indicate an output rate for either the intermediate or the final good. The firm is formed of only divisions A and B and it manufactures and sells only product Q. We assume no tax considerations and no control frictions.

To model demand variability, we assume a demand cycle of two periods, t_1 (low demand) and t_2 (high demand), occurring with frequencies or probabilities w_1 and w_2 where $w_1 + w_2 = 1$. The demands are independent in the sense that the price charged in one period has no effect on the quantity demanded in the other. To have periods of high demand and low demand, we assume that the quantity demanded in t_2 is greater than the quantity demanded in t_1 for the same price. To focus on direct output response, we assume that product Q is perishable in the sense that one cannot store it, economically, from period to period. Even if storage is possible, but because it is costly, it does not eliminate the problem of optimal capacity under demand fluctuations.

The capital assets to produce Q are durable but with a limited useful economic life. We assume the capital assets to be highly specific or specialized to the production of only product Q and to have a high cost of transfer or conversion for an alternate use (for example, a cement kiln).

Intuitively, one can think of the two technologies identical except in a decision to make or buy a major component needed for the final product: technology$_K$ opts for making the component, while technology$_L$ opts for buying the component ready made from suppliers.

Technology$_K$ becomes capital intensive (expensive to build and cheap to operate) because of the machinery needed to manufacture the component, while technology$_L$ is labor intensive (cheap to build and expensive to operate) because of the reduced need for this machinery. Technology$_K$ will have lower variable operating cost-per-unit, due to the presumably lower variable manufacturing cost per unit to make the component than the cost to buy the component. This assumes there are no specialist firms that can manufacture the component at a lower cost. Technology$_K$ will have higher cost-per-unit capacity because of the specialized machinery to manufacture the component.

One also could think of an example of old versus new cement kilns where new kilns have lower per-unit operating costs due to technological improvement in cement kilns. The per-unit capacity cost of old kilns would have to fall for old kilns to be competitive with new kilns. This is much like prices on existing long-term bonds falling if yields on new issues rise.

We can envision managers of division A walking into a plant manufacturing store that has two shelves: technology$_K$ (the manufacturing of all components or new technology) and technology$_L$ (the buying of sub-components or old technology). On each shelf is a model plant that costs \$1,000,000 to build Managers of division A can order any multiple or fraction of the model plant of each shelf. We assume no long-run economies of scale for each technology.

A Linear Total Cost Model with Capacity Limits

In this model each technology-plant has:

- Constant per-unit variable operating cost.
- Constant fixed-capacity costs.
- A maximum operating rate.

Let b be constant per-unit variable operating cost. Let β be per-unit fixed-capacity cost where the numerator is the constant fixed-capacity costs over the cycle (or over the period) and the denominator is the maximum that the plant can produce over the cycle (or over the period). Thus, β is an average fixed cost at maximum operating rates.

Let q be maximum operating rate. With linear short-run total cost (STC) curves and capacity limits, short-run average cost (SAC) per unit falls steadily and reaches a minimum when output rates are at maximum. With STC = $bq_t + \beta q$, the minimum SAC = $b + \beta$ when $q_t = q$. In this formulation STC = VC + FC where VC denotes variable costs (VC = bq_t) and FC denotes fixed costs (FC = βq). The use of linear total costs with capacity limits is a common cost-accounting model; see Aranoff (1986, p. 588).[4]

Let n_K be the number of plants with technology_K and n_L be the number of plants with technology_L. Each plant_K has a b_K, β_K, and q_K (capacity rate), and each plant_L has a b_L, β_L, and q_L. A necessary condition for there not to be a dominant technology is that the short-run marginal cost curves of the plants of each technologies must cross; otherwise, whichever short-run marginal cost curve lies everywhere below the other would always be the more economical technology. For example, no technology can have both a higher b and a lower q Let technology_L have the higher b and the higher q.[5]

Behavioral Model

The behavioral model is short-run marginal-cost pricing. Managers of division A are pure price takers with output rates determined by price-marginal-cost equality. The requirement that managers be pure price takers with linear total cost curves and absolute capacity limits assumes that managers will produce at their capacity q when the market

[4] We refer the reader to Johnston's (1960) excellent and probably still valid chapter 6, "A Critique of the Critics," where he justifies linear short-run cost functions, p. 170 "Three important points to note . (a) that in the majority of cases where statistical tests have been applied, the hypothesis of a linear total cost function has not been rejected, (b) that most often no statistically significant improvement on the linear hypothesis is achieved by the inclusions of second- or higher-degree terms in output, and (c) that supplementary tests, such as the examination of incremental cost ratios, usually confirm the linear hypothesis."

[5] Hiebert (1989, p. 104) makes this same point. "... the marginal cost curves for two plants with different flexibilities will cross at least once."

price is greater than their b, will close when the market price is below their b, and will be indifferent to production if the market price equals their b.

We assume that the demand curves facing the managers of division A are perfectly elastic. To have both technologies viable over the long run, we assume that in low-demand times the market price will exceed b only for plants with technology_K We assume that in high-demand times the market price will exceed b for both technologies.

Thus, in the off-peak period managers produce Q_1 where $Q_1 = n_K q_K$ In the peak period they produce Q_2 where $Q_2 = n_K q_K + n_L q_L$, their maximum rates.

The long-run equilibrium requirement is zero profit. The behavioral assumption is that managers will buy plants from the plant manufacturing store only if they foresee that, after purchase, expected profits over the cycle will be non-negative

The compensation package for divisional managers is based on technology choice and capacity (the decision variables in this problem), with a proviso that profits are not negative. The firm delegates the decision for technology choice and capacity to the managers of the producing divisions only for reasons of managerial development. In this model there is no other reason for the firm to organize into autonomous divisions. We assume no informational or incentive problems. We make the standard economic assumption that managers will behave in a Pareto-optimal way and select technology and capacity to maximize the firm's value.

Graphic Presentation

The long-run decision variables are technology choice and capacity (n_K and n_L). Figures 2 and 3 show STC, SAC, and SMC curves of the model plant on each shelf in the plant manufacturing store mentioned earlier.

Figure 4 shows SMC_A as the sum of the marginal cost curves for all plants_K and plants_L of division A. SMC_A is b_K for amounts up to Q_1, is b_L for amounts between Q_1 and Q_2, and is totally inelastic for amounts over Q_2. Figure 4 shows the marginal revenue curves for the final good, MR_{FG1} and MR_{FG2} The figure does not show the demand curves for the final good: D_{FG1} and D_{FG2} from which the marginal revenue curves were derived. We assume that the D_{FG1} and D_{FG2} curves are negatively sloped. Also not shown are SMC_B, the marginal cost curves of division B, and SMC_{FG}, the marginal cost curves of the firm. We assume that these SMC curves are upward sloping. The SMC_{FG} curve is the vertical summation of the marginal cost curves of divisions A and B.

The firm's best or profit-maximizing level of outputs for the final product is Q_1 and Q_2 is given by points (Q_1,MC_{FG1}) at which $MR_{FG1} = SMC_{FG}$ and (Q_2,SMC_{FG}) at which $MR_{FG2} = SMC_{FG}$. The profit-maximizing prices of the final good will be P_{FG1} and P_{FG2} determined by the intersection of Q_1 with D_{FG1} and Q_2 with D_{FG2}. This analysis follows Salvatore (1989, p. 525), which is based on Hirshleifer but with the author's extensions to demand fluctuations and technology choice.

Figure 2—Short-Run Total Cost Curves of Two Plants

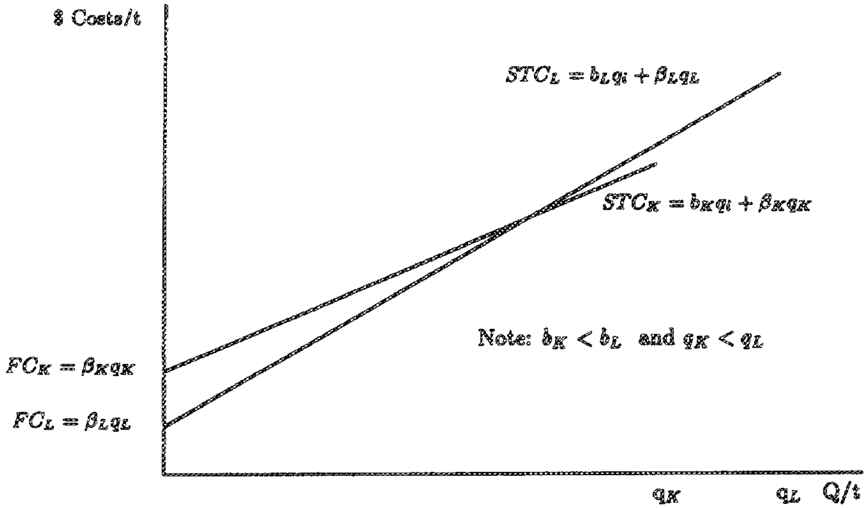


Figure 3—SRAC and SRMC of Two Plants

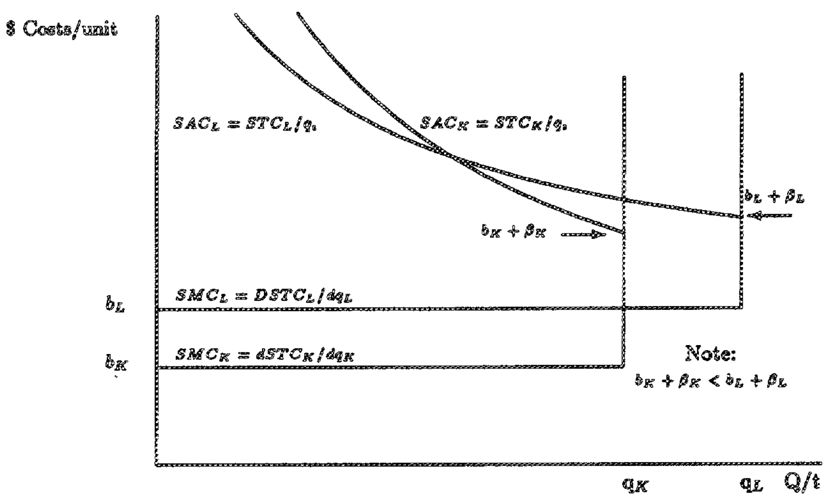
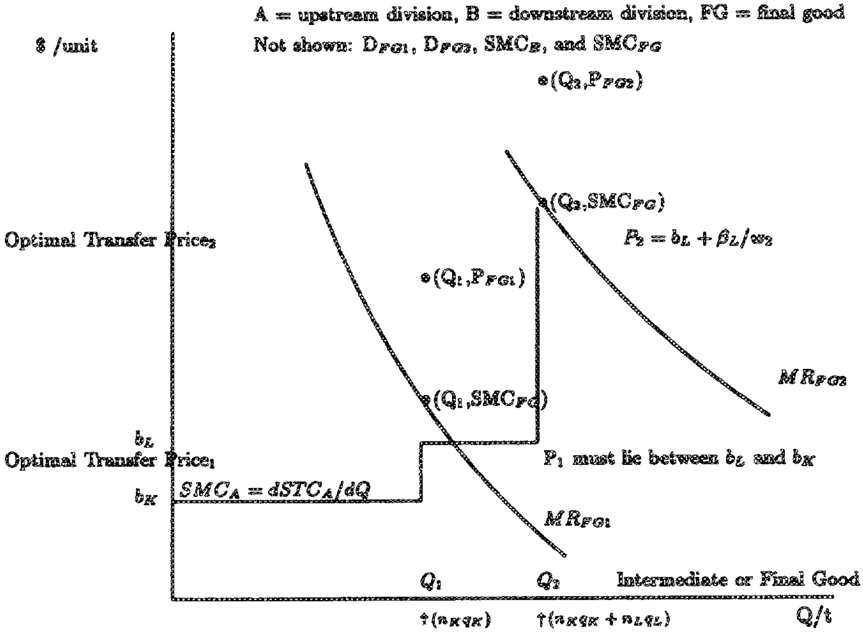


Figure 4—Transfer Pricing with Technology Choice and Demand Fluctuations



The transfer prices of the intermediate product, P_1 and P_2, are set equal to the marginal costs of the intermediate product ($SMC_A = dTC_A/dQ$) at output levels Q_1 and Q_2. The following section shows mathematically the conclusions that P_1 must lie between b_L and b_K and $P_2 = b_L + \beta_L/w_2$.

For division A, P_1 and P_2, the optimal transfer prices, become perfectly elastic demand and marginal revenue curves. These optimal transfer prices intersect the marginal cost of production for division A at output levels Q_1 and Q_2. This assures us that P_1 and P_2 are the correct transfer prices for an intermediate product with no external market facing demand fluctuations and technology choice.

Proposition I

These are the optimal transfer pricing, P_1 and P_2 under welfare maximization and cost-minimizing short-run marginal-cost pricing with two technologies available, K and L. Each technology has linear total costs and capacity limits where $b_K < b_L$ and $\beta_K > \beta_L$ Demand fluctuates such that in t_1, which occurs with frequency w_1, only technology$_K$ is used and in t_2, which occurs with frequency w_2, both technologies are used.

(1) $b_K < P_1 < b_L$, and

(2) $P_2 = b_L + \beta_L / w_2$

Proof

We first define some notation and make a few observations. Let n_K be the number of plants with technology$_K$ and n_L be the number of plants with technology$_L$. Each plant$_K$ has a b_K, β_K, and q_K (capacity rate), and each plant$_L$ has a b_L, β_L, and q_L.

With fluctuating demand of known frequencies, w_1 and w_2 where $w_1 + w_2 = 1$, the cost-minimizing and welfare-maximizing outputs are such that technology$_K$ is used at capacity at all times while technology$_L$ is temporarily shut down in off-peak times and is operated at capacity in peak demand times. This means that in the off-peak period t_1, Q_1 is produced where $Q_1 = n_K q_K$ while in the peak period t_2, Q_2 is produced where $Q_2 = n_K q_K + n_L q_L$ because at the peak all plants produce at their maximum rates.

Now to the proof. Applying the zero profit condition to technology$_K$:

(3) $0 = w_1 P_1 Q_1 + w_2 P_2 Q_1 - (b_L + \beta_K) Q_1$

This gives us:

(4) $w_1 P_1 + w_2 P_2 = b_K + \beta_K$.

Applying the zero profit condition to technology$_L$:

(5) $0 = w_2 P_2 (Q_2 - Q_1) - w_2 b_L (Q_2 - Q_1) - \beta_L (Q_2 - Q_1)$.

This gives us:

(6) $P_2 = b_L + \dfrac{\beta_L}{w_2}$.

Equations (4) and (6) can be combined:

(7) $w_1 P_1 = - b_L w_2 - \beta_L + b_K + \beta_K$.

For plants$_L$ to shut down in t_1 requires $P_1 < b_L$. If $P_1 = b_L$, then plants$_L$ are indifferent to producing, and some may be producing. Further, $P_1 > b_K$, or all plants, even plants$_K$, may choose to shut down.

Using Welfare Maximization and Calculus

One can obtain these rules for optimal pricing using welfare maximization (as does Williamson) or by using constraint maximization involving the Kuhn Tucker sufficiency theorem (as do Crew and Kleindorfer). The welfare maximization approach is as follows:

Expected welfare is given by:

(8) $W = w_1 \int^{Q1} P_1(Q)dQ + w_2 \int^{Q2} P_2(Q)dQ - b_K q_K n_K - b_L q_L n_L w_2 - \beta_K q_K n_K - \beta_L q_L n_L$

Technology choice and industry capacity are the variables by entry of n_K plants of technology$_K$ and n_L plants of technology$_l$ where $Q_1 = q_K n_K$ and $Q_2 = q_K n_K + q_l n_l$. The maximization of expected welfare with respect to n_K and n_L gives the pricing rules when capacity is at its long-run welfare-maximizing value and expected profits are zero.

(9) $\partial W / \partial n_K = w_1 P_1 q_K + w_2 P_2 q_K - b_K q_K - \beta_K q_K = 0$

(10) $\partial W / \partial n_L = w_2 P_2 q_L - b_L q_L w_2 - \beta_L q_L = 0$

Equation (9) reduces to:

(11) $w_1 P_1 + w_2 P_2 = b_K + \beta_K$

Equation (10) reduces to:

(12) $P_2 = b_L + \beta_L / w_2$

The satisfaction of the second-order conditions can be shown as follows. The second-order conditions require showing that $W_{xx}, W_{yy} < 0$ and $W_{xx} W_{yy} > W^2{}_{xy}$ where x refers to n_K and y refers to n_L. We have:

$W_x = w_1 P_1 q_K + w_2 P_2 q_K - b_K q_K - \beta_K q_K$ and $W_y = w_2 P_2 q_L - b_L q_L w_2 - \beta_L q_L$

We get:

(13) $W_{xx} = w_1 \dfrac{\partial P_1}{\partial Q_1} q^2{}_K + w_2 \dfrac{\partial P_2}{\partial Q_2} q^2{}_K$

(14) $W_{yy} = w_2 \dfrac{\partial P_2}{\partial Q_2} q^2{}_L$

(15) $W_{xy} = w_2 \dfrac{\partial P_2}{\partial Q_2} q_K q_L$

The second order conditions are satisfied because W_{xx} and W_{yy} are negative due to the assumption of negatively sloped demand curves and the assumption that the other terms are positive. We can show that $W_{xx} W_{yy} > W^2{}_{xy}$ because

(16) $W_{xx} W_{yy} - W^2{}_{xy} = w_1 w_2 (\dfrac{\partial P_1}{\partial Q_1})(\dfrac{\partial P2}{\partial Q2}) q^2{}_K q^2{}_L$,

which must be positive again due to the assumption of negatively sloped demand schedules.

In a similar vein, the constraint maximization involving the Kuhn Tucker sufficiency theorem approach is as follows.

The problem is to maximize welfare subject to a demand constraint that demand be met in each period and to a production constraint that production not exceed capacity. We can set up a Lagrangian, L, similar to Crew and Kleindorfer (p. 41). W is expected welfare given in equation (8), Q_c is capacity, and Q_d is demand.

$$(17)\ L = W + \lambda_1(Q_1 - Q_{d1}) + \lambda_2(Q_2 - Q_{d2}) + \mu_1(Q - Q_1) + \mu_2(Q - Q_2)$$

Crew and Kleindorfer's analysis yields the same optimal pricing rules as does this paper.

Numerical Example

Table 1: Numerical Example for Division A, the Upstream Division

$STC_K = b_K q_i + \beta_K q_K$		$STC_L = b_L q_i + \beta_L q_L$	
$b_K =$	\$24/ton	$b_L =$	\$31 2/ton
$\beta_K =$	\$12/ton	$\beta_L =$	\$4 8/ton
$q_K =$	0 72 tons/cycle	$q_l =$	0 9 tons/cycle
$FC_K = \beta_K \times q_K =$	\$8 64/cycle	$FC_K = \beta_K \times q_K =$	\$4 32/cycle
$SAC(min)_K =$	\$36/ton	$SAC(min)_L =$	\$36/ton
$w_1 =$	0 5	$w_2 =$	0 5
$P_1 = b_L =$	\$31 2/ton	$P_2 = b_L + \beta_L/w_2 =$	\$40 8/ton
$Q_1 =$	36 9 tons/period	$Q_2 =$	84 7 tons/period
$Q_1 = q_K n_K$		$Q_2 = q_K n_K + q_l n_l$	
$n_K =$	51 25 plants	$n_L =$	53 11 plants
$TR_1 = P_1 Q_1 =$	\$1,151 28	$TR_2 = P_2 Q_2 =$	\$3,455 76
$E(TR) = w_1 Q_1 P_1 + w_2 Q_2 P_2 =$	\$2,303 52		
$E(VC) = b_K q_K n_K + b_l q_l w_2 =$	\$1,631 28		
$E(FC) = \beta_K q_K n_K + \beta_L q_L n_L =$	\$ 672 24		
$E(\pi) = E(TR) - E(VC) - E(FC) =$	\$ 0 00		
Aranoff's output-flexibility indicator $E(AC)_K$, expected average costs, with shutdown in t_1 and capacity in t_2		$E(AC)_L$, with shutdown in t_1 and capacity in t_2	
$= E(TC)_K/E(Q)_K =$	\$48/ton	$= E(TC)_L/E(Q)_L =$	\$40 8/ton
$E(AC)_K - SAC(min)_K =$	\$12/ton	$E(AC)_L - SAC(min)_L =$	\$4 8/ton

Table 1 illustrates optimal transfer pricing with technology choice and demand fluctuations in a simple manufacturing model. I purposely set $SAC_{(min)L} = SAC_{(min)K}$ so that readers would not think that the $SAC_{(min)}$ point is of critical importance. Under demand fluctuations with a perishable or semiperishable product (such as cement), often the $SAC_{(min)}$ point is of minor importance. To be true to my model I could have set a lower $SAC_{(min)}$ to technology$_K$; then P_1 would lie between b_L and b_K instead of equaling b_L.

Table 1 illustrates numbers for the cost curves of Figures 2 and 3. Perhaps technology$_L$ is the present method of manufacturing. Division A is considering an investment in newer technology, technology$_K$ that will lower VC and shift FC upward. Technology$_K$ is economically justifiable only if it is expected to be used at 100 percent rated capacity in both periods, t_1 and t_2. The older technology, technology$_L$ would become "stand-by" technology (Clark's phrase) and be used only in t_1, high demand times.[6]

Not shown in the numerical example are the demand and marginal cost curves of the final good sold by the downstream division, division B.

In the plant manufacturing store mentioned earlier there is a model plant_l on one shelf and a model plant_K on another shelf Customers can order any multiple of fraction of the model plants. Thus, n_K, n_l are the long-run decision variables in this problem.

Based on MR_{FG1}, MR_{FG2} (shown in Figure 4), MC_{FG} (not shown in Figure 4), division B determines Q_1 and Q_2 as the Q for the intersections of the MR and MC curves In the numerical example, by assumption, $Q_1 = 36.9$ tons and $Q_1 = 84.7$ tons. Because $Q_1 = q_K n_K$ and $Q_2 = q_K n_K + q_L n_l$, $n_K = 36\ 9/0.72 = 51.25$ plants_K and $n_L = (84.7-36.9)/0\ 9 = 53.11$ plants_l In this way we obtain specific values for the long-run decision variables n_K and n_L.

Using the pricing rules $P_1 = b_l = 31.2$ and $P_2 = b_l + \beta_l / w_1 = 40.8$. $E(\pi) = 0$. This is the expected result under SRMC pricing. We assume that included in the FC is a return on investment at the weighed average cost of capital multiplied by the investment. With $E(\pi) = 0$ we have long-run equilibrium: there will be no tendency for further new investment or disinvestment in the manufacturing of the intermediate product

Using Aranoff's output-flexibility indicator (Aranoff. 1989. pp. 143-144 and 1992, p. 416) one can demonstrate conclusively that technology_l is more output flexible because it has an indicator value of 4.8 versus 12 for technology_K.

Insights and Policy Implications

The main insight of this theoretical study of optimal transfer pricing with technology choice and demand fluctuations in a simple manufacturing model is that with the availability of technology_L, P_2 becomes far lower and Q_2 higher than with only technology_K available. This is an important insight

Technology_l is the buying of components, the use of old or labor-intensive technology It is the more output-flexible technology. This is the appropriate technology for the increment of peak over off-peak capacity. Technology_K is the making of components, the use of new technology or the capital-intensive technology. It's the output-rigid technology. Under long-run equilibrium conditions, technology_K is used at capacity in both off-peak and peak-demand times.

With technology_l available to the manufacturing division to provide the excess of peak over off-peak demand, the optimal transfer price in t_2 is $P_2 = b_l + \beta_l / w_1$. This price is far lower than $P_2 = b_K + \beta_K / w_2$ if only technology_K were available. Normally w_2, the frequency of high demand, is a small fraction of the business cycle and β_K the cost per

[6] Clark (1961, p 137). "Where techniques have not changed radically, occasional peaks may be most economically handled by retaining stand-by units of less than top efficiency, because capital costs of replacing them with up-to-date units would outweigh the operating savings from newer units under part-time operation "

unit capacity of technology$_K$, is a significant number. Thus, $P_2 = b_K + \beta_K/w_2$ becomes an extremely high number

In the numerical example, if only technology$_K$ were available, $P_1 = 24$ and $P_2 = 48$, while the optimal transfer pricing with a mixture of technologies available $P_1 = 31.2$ and $P_2 = 40.8$. Thus, we have a dampening of the price swings under short-run marginal cost peak-load pricing

This should make marginal cost peak-load pricing far more understandable and tolerable to corporation managers. John M. Clark (1961, pp. 121-122) writes with profound insight on the difficulties facing short-run marginal cost pricing in the real world.[7] For further discussion, see Aranoff (1991, pp. 49-51)

With diverse technology available to division A not only P_2 becomes lower but Q_2 becomes higher. The firm is producing more than would be if only technology$_K$ were available (under negatively-sloped demand schedules facing the firm). This suggests a profound advantage having technology$_I$ available in a manufacturing division to meet peak demands—the firm's output becomes higher in peak-demand times This has macroeconomic implications in aiding economic growth and increasing the sustainability of economic upturns

Empirical research is needed to see how common meeting the conditions of the model of this paper are for corporations with multiple divisions that buy and sell products to each other The author is convinced, from experience and intuition, that these conditions do occur with sufficient frequency to be important.

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[7] This solution faces at least two serious difficulties In view of what has been said about the naturalness of excess capacity as generated by competitive conditions in times of normal demand, the conclusion seems warranted that for most producers a majority of the time short-run marginal cost would be less than average cost and would equal or exceed it only in considerably shorter periods of extra-strong demand Only in the latter periods would pure competition permit prices to be raised sufficiently to equal or exceed full economic cost. It is doubtful whether it would be economically feasible to make sufficient profits in such periods to offset the losses incurred in normal and subnormal periods.

This raises the more general question of the usefulness of short-run flexibility of prices in response to changes in demand as distinct from longer-run flexibility in response to changes in costs. The usefulness of the latter is unquestioned; but as to the former, it seems as likely to accentuate general fluctuations in economic activity in order to stabilize them The price fluctuations called for in the case we have been discussing are so extreme as to go far beyond the amount that could render useful service toward stabilizing the economy

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