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A Numerical Example Illustrating Cost of Idle Capacity in Manufacturing

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Abstract

We present an elaborate numerical example of a competitive manufacturing industry in the United States facing demand fluctuations to illustrate cost of idle capacity in manufacturing. We show that given demand fluctuations, such as the business cycle, significant cost of idle capacity is not only ordinary and necessary but desirable! We recommend manufacturing firms in the United States increase outsourcing major parts and components to increase output-rates flexibility. Outsourcing is rising in recent years with advances in internet, computers, and telephone. Manufacturers today can depend on getting needed parts "just-in-time" from outside suppliers without maintaining inventories of parts or capacity to produce parts.

1. John M. Clark: The Economics of Overhead Costs

John M. Clark (1884-1963) wrote of the desirability of manufacturing plants to operate at their normal capacity with production costs per-unit output the lowest. John M. Clark attributed the main problems of the business cycle to the dominant role of fixed costs that are incurred irrespective of output rates:

   "It is needless to point out that overhead costs play a fundamental part in the behavior of business at every stage of that many-sided phenomenon, the business cycle. The part they play is most paradoxical. For they make regular operation peculiarly desirable and peculiarly profitable, so that business feels a definite loss whenever output falls below normal capacity, yet it is largely due to this very fact of large fixed capital that business breads these calamities for itself, out of the laws of its own being. And the largest businesses, which have the highest percent of constant costs due to invested capital, are, as we have seen, precisely the ones which fluctuate the most, so far as employment is an index. There is something about the commercial-industrial system which

bewitches business so that it does just the thing it is trying to avoid, and is held back from doing just the thing it yearns to do—maintain steady operation and avoid idle overhead. And while the contributing causes of this strange auto-hypnosis are many and of varied character, technical, financial, commercial, and psychological; the underlying fact of large capital plays a central part, and the inelasticity of costs, sunk costs, and the shifting and conversion of overhead costs are all facts of major importance" [1][1].

2. Recent Articles on Manufacturing Idle-Capacity Costs

In our *Cost Management* March/April 2011 article [2] we argued, referring to Baxendale-Foster *Cost Management* September/October 2010 article [3]:

"John M. Clark taught us to expect productive capacity to exceed average demand as a normal and desirable situation, due to irregularity of demand and inelasticity of supply. This produces idle capacity as a normal and desirable situation for much of the time. John M. Clark advocated cost accountants to isolate cost of idle capacity from cost of producing goods. Sopariwala and Baxendale-Foster do this in their illustrated example. Baxendale-Foster showing cost of idle capacity by activity is an important refinement over Sopariwala, who shows just the total idle capacity to the firm. Baxendale-Foster has a good discussion, showing the importance of isolating cost of idle capacity. We can hope cost-accountants will do as Baxendale-Foster illustrates: use ABC costing and isolate cost of idle capacity by activity. Idle-Capacity Costs in ABC Absorption and Direct-Costing Income Statements we praised the Baxendale-Foster proposal to show idle-capacity cost in manufacturing by activity".

In our *Cost Management* May/June 2011 article [4] we stated:

"I made the percent calculations using Clark's probable total economic cost of the car as the base. Cost of idle capacity at 12.8 percent is clearly a significant cost factor and must be carefully planned and controlled. Clark, in 1923, gave us a detailed illustration that today we can learn much from on the proper way to make its calculation. A firm needs both an economist and an accountant to provide the necessary information to calculate this cost element. An economist would make the discrete estimates of output rates and their likelihoods. An accountant would prepare flexible-budget amounts on an annual basis for each of the output rates projected. The accountant and the economist would then examine alternative scenarios using spread-sheet analysis. The fundamental calculation of the cost of idle capacity should be as Clark did it in 1923".

In Herath H. B. and Kusy, M. I. *Cost Management* September/October 2014 [5] they note with approval:

"Aranoff proposes a further refinement to consider activity capacity constraints to separate the cost of idle capacity in Baxendale and Foster and Sopariwala into excess capacity cost and idle-capacity cost. Excess capacity of an activity is the limit placed on the usage of available capacity due to the constraint imposed by another activity in a production process. Idle capacity, then, is the under-utilization of each activity's capacity compared to the constraining activity. The caveat in the above articles is the importance of considering the cost of idle capacity in determining the economic cost for pricing and efficient management of operations".

3. The US Cement Industry: A Competitive Manufacturing Industry

This paper is an outgrowth of my study on the US cement industry [6]. The US cement industry has, approximately, the restrictive assumptions of the theoretical model of this paper: single-homogeneous product that is costly to store over the business cycle, competitive manufacturing, linear-total-costs with capacity limits, alternative technologies available, durable and specific assets, and reactivation of semi-obsolete plants during economic peaks.

4. Manufacturing Cement over a Business Cycle: The Supply Side

We assume a single-homogeneous product, Q, cement. We assume ease of entry of new cement manufacturers. We assume a business cycle of two states of demand, $D_1 w_1$ and $D_2 w_2$, off-peak and peak, each with a likelihood, where the likelihoods add to one. Cement-manufacturing plants require durable and specific assets, and have linear short-run total-cost curves with absolute capacity limits. There are two types of cement-manufacturing plants, plant$_K$ and plant$_L$, each having linear total costs with absolute capacity limits. Cement-manufacturing plants have a per-ton cement variable cost VC made up of direct materials, direct labor, and variable factory

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[1]John M. Clark, 1923, page 386.

overhead; per-ton cement fixed-factory-overhead costs *FFOH* (fixed factory overhead per-year per-plant divided by maximum cement production rate per-year per-plant) and per-plant capacity q (maximum cement production per-year per-plant).

We envision investors and managers walking into a cement manufacturing plant store that has two shelves: each with a model plant that costs, say, $1,000,000 to build. On one shelf is a model of plant$_K$ and on the other shelf is a model plant$_L$ (see **Figure 1**).

Investors or entrepreneurs can order any multiple or fraction of the model plants. No economies of scale exist for plants. Thus the long-run marginal cost (LRMC) and long-run average cost (LRAC) for plants in the cement-manufacturing plant store are horizontal. These customers of the cement-manufacturing plant store have to decide technology$_K$ or technology$_L$ and then choose the plant size (or the number of plants). The assets are durable and specific meaning that the plants will last a long time, say 50 years, and are useful only for making cement.

5. Cement over the Business Cycle: The Demand Side

There are two groups in our hypothetical society: Producers (manufacturers of cement) and consumers (households who buy cement). Consumers buy cement in a free market on a daily basis from various manufacturers where each manufacturer posts its prices. Consumers pay the lowest price per-ton cement in the local market. The intersection of this price with the consumer demand schedules (off-peak and peak) determine the quantity of cement the consumers order. Consumers pay market price times quantities purchased, $TR = P \times Q$ (total revenue to suppliers equals market price times quantities).

6. The Numerical Example

Investors that go the cement manufacturing store decide on technology$_K$ or technology$_L$ and then on the plant size which is given by n the number of plants. Fractional size plants are permitted. $n_K = 1$ means that capacity is 0.72 tons per cycle and $n_L = 1$ means that capacity is 0.90 tons per cycle. This follows **Figure 1**. $VC_K = \$24$ per ton while $VC_L = \$31.20$ per ton as in **Figure 1**. $FFOH_K = \$12.00$ per ton while $FFOH_L = \$4.80$ per ton as in **Figure 1**. The short-run average (SAC) curve falls as output increases and reaches a minimum at $VC + FFOH$.

In the numerical example, shown in **Table 1**, $SAC(\min)_K = SAC(\min)_L = \$36$ per ton for simplification. This makes technology$_L$ dominate since if investors only seek profits they would choose only technology$_L$. Technology$_L$ relies on outsourcing which may a be drawback to some investors as outsourcing gives less direct control to managers. I argue elsewhere on conditions for indifference between technology choice [7][2].
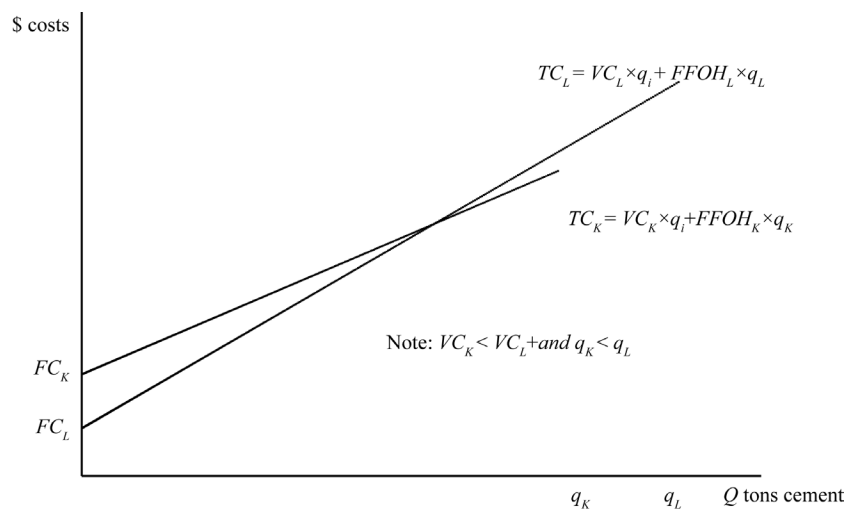

Figure 1. SR total-cost curves of Plant$_K$ and Plant$_L$.

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[2]Aranoff, G., "Competitive Manufacturing with Fluctuating Demand and Diverse Technology: Mathematical Proofs and Illuminations on Industry Output-Flexibility," *Economic Modelling* 28 (2011) 1441-1450.

Table 1. Numerical example.

$TC_K = 24q_i + 12q_K$	see **Figure 1**	$TC_L = 31.2q_i + 4.8q_L$	see **Figure 1**
$VC_K =$	$24.00 per ton	$VC_L =$	$ 31.20 per ton
$FFOH_K =$	$12.00 per ton	$FFOH_L =$	$ 4.80 per ton
$q_K =$	0.72 tons per cycle	$q_L =$	0.90 tons per cycle
$FC_K = FFOH_K \times q_K =$	$8.64 per cycle	$FC_L = FFOH_L \times q_L =$	$ 4.32 per cycle
$SAC(min)_K = 24 + 12 =$	$36 per ton	$SAC(min)_L = 31.2 + 1.8 =$	$ 36 per ton
Let $w_1 =$	0.5	Let $w_2 =$	0.5
Let $P_1 =$		Let $P_2 =$	
$VC_L =$	$31.20 per ton	$VC_L + FFOH_L / w_2 =$	$ 40.80 per ton
Let $Q_1 = 1152 / P_1 =$	36.92 tons per period	Let $Q_2 = 3456 / P_2 =$	84.71 tons per period
$n_K = Q_1 / q_K =$	51.28 plants	$n_L = (Q_2 - Q_1) / q_L$	53.09 plants
$TR_1 = P_1 Q_1 =$	$1152	$TR_2 = P_2 Q_2 =$	$ 3456
$E(Q) = w_1 Q_1 + w_2 Q_2$	60.81	tons	
$E(TR) = w_1 Q_1 P_1 + w_2 Q_2 P_2 =$	$2304		
$E(VC) = VC_K Q_1 + VC_L (Q_2 - Q_1) w_2 =$	$1632		
$E(FC) = FFOH_K Q_1 + FFOH_L (Q_2 - Q_1) =$	$672		
$E(\pi) = E(TR) - E(VC) - E(FC) =$	$0	LR equilibrium	
$E(AC) = E(TC)/E(Q) =$	$37.89	per ton	
Cost of idle capacity =			
$E(AC) - SAC(min) =$	$1.89	per ton	
Proof of cost of idle capacity			
$E(TC)$ of production = E(TR) =	$2304		
$E(TC)$ of production if always at SAC(min) =	$2189		
Excess production costs over SAC(min) =	$115		
Excess production costs/$E(Q)$ =	$1.89	per ton	

We assume $w_1 = w_2 = 0.5$ and $Q_1 = 1152/P_1$ and $Q_2 = 3456/P_2$ to simplify the numerical example. We assume $P_1 = VC_L$ so that no plant$_L$ would produce in the off-peak. For plants$_L$ to produce in the off-peak would require $P_1 > VC_L$. We assume $P_2 = VC_L + FFOH_L/w_2$ so that plant$_L$ would have $0 LR equilibrium profits.

We can prove $0 LR equilibrium profits to both plants$_K$ and plants$_L$ by imagining each plant has capacity 1 ton per period. Plant$_K$ produces at its SAC(min) $= \$36$ per ton in each period and so needs revenues for 1 ton produced in each period of $P_1 + P_2 = \$31.20 + \$40.80 = \$72$ for the sum of the two periods. Plant$_L$ shuts down temporarily in the off-peak. In the peak $P_2 = VC_L + FFOH_L/w_2 = \$40.80$ per ton which exactly covers the VC_L in the peak time and the $FFOH_L$ in both periods.

The E(AC) of a ton of cement in the industry $= \$37.89$. With the SAC(min) $= \$36$ per ton the cost of idle capacity $= \$37.89 - \$36 = \$1.89$ per ton.

7. Some Insights

In the numerical example, the cost of idle capacity $= \$37.89 - \$36 = \$1.89$. The numerical example uses simple numbers to make the points. The numerical example has rigid assumptions that we feel are fairly realistic and reasonable today in much of manufacturing: no economies of scale, easy entry, demand fluctuations, linear SRTC production functions with capacity limits, and durable and specific assets.

One novelty here is the choice firms have in plants$_K$ or plants$_L$. The assumption is that firms will choose plants$_K$ to produce the minimum needed over the cycle and plants$_L$ to produce excess demand over the minimum.

Table 2. % capacity utilization manufacturing USA.

1972-2013 Avg	1988-1989 High	1990-1991 Low	1994-1995 High	2009 Low	2013 Oct.	2014 Oct.
78.7	85.6	77.3	84.6	63.9	76.3	77.2

Clark wrote of firms keeping old-inefficient plant and equipment for part-time use in high-demand times, to serve only as stand-by units [8][3]. A realistic assumption today is that plants$_L$ rely heavily on outsourcing of major components and parts. Outsourcing is rising in recent years with advances in internet, computers, and telephone. Manufacturers today can depend on getting needed parts "just-in-time" from outside suppliers without maintaining inventories of parts or capacity to produce parts[4].

Plants$_K$ always operate at their SAC (min), thus the cost of idle capacity of \$1.89 per ton is due entirely to plants$_L$ shutting down in the off-peak. Plants$_L$ shutting down in the off peak is good. During a recession, there is little benefit from all plants operating, especially with a semi-perishable and costly to store product such as cement. Investors should choose to invest in plants$_K$ only if they expect to operate at capacity at all times.

United States manufacturing industries are now some 6 or 7 years in a recession, as the statistical releases of the USA Federal Reserve in **Table 2** show[5].

According to the model here, during recessions investors should choose to invest in plants$_L$, with the aim of profiting with the return of peak-demand times. To make policy recommendations, we need research on how realistic and critical are the assumptions of the model.

References

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[8] Clark, J.M. (1961) Competition as a Dynamic Process. The Brookings Institution, Washington DC.

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[3]John M. Clark, 1961, page 137.

[4]An example where firms today are recognizing the advantages of relying heavily on outsourcing in manufacturing is the Reuters November 2014 item "Airbus Emulates Carmakers to Drive Jet Output".

[5]Source: www.federalreserve.gov/releases/.

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