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The Economics of Quality Optimization

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Abstract

This article looks to find the balance between quality and the cost of quality by deriving mathematical specifications that determine the optimum level of quality in a variety of situations. The main conclusion is that the commitment to quality improvement is neither open-ended nor costless. Rather, it should follow the rules of economic optimization if it is to be worthwhile.

Keywords: quality management, quality optimization, marginal benefit of quality, marginal cost of quality

I. Introduction

Defective and deficient goods and services increase production costs as they entail a loss of labor time and raw materials. They also delay delivery schedules and force the firm to hold larger inventories or personnel or both. They also reflect negatively on a firm's reputational capital since deficient durability and reliability are associated with bad quality, and a consumer impression of bad quality significantly lowers the demand price that consumers are willing to pay for bad quality products. Thus, investing in improving product quality helps reduce the cost of production and contributes to increasing sales revenue.

Quality is also a form of product differentiation. This makes it a form of non-price competition, just like advertising and delivery and maintenance services. This is especially important in markets characterized by monopolistic or oligopolistic competition. However, improving quality is costly. It requires not only more advanced testing procedures, techniques, and personnel, but also a solid commitment to total quality management, which involves, among other things, allocating valuable resources to training, education, lifting morale, and improving company administration and coordination. However, reaching a goal of zero defective items is neither reasonable nor feasible if the purpose is to maximize the profit function. Thus, using marginal analysis, economic theory helps determine the optimal level of quality in each case and situation that is associated with profit-maximization. This is because quality management, just like any investment, needs to be checked for economic feasibility, i.e., to find its optimum amount where the marginal benefit an additional unit of quality improvement is equal to its marginal cost.

In this light, quality management is viewed from an economic perspective in this paper by deriving mathematical specifications that may help us determine the optimum level of quality in a variety of situations.

II. Literature Review

While quality management and improvement have become a big fad in recent years, and while the literature devoted to different aspects of quality management has grown into an amorphous and expansive body over the years, the articles dedicated to discussing investment in quality from an economic viewpoint remain relatively sparse and few, especially since the 1980's when a handful of such articles appeared. A good summary of articles on the economics of quality management dating to the eighties and early nineties is available in Shughart, Chappell, and Cottle (1994, pp. 372-404). Other textbooks in Managerial Economics might have a few pages on managing product and process innovation (See, for example, Acs and Gerlowski, 1996, pp. 357-362). Otherwise, interest in economic evaluations of quality management seems to have waned.

Generally speaking, quality control has conventionally taken a statistical bent with emphasis on the sample size, and hence the cost, necessary to test for the presence or absence of a given threshold of allowable errors or defects. This concept was gradually replaced by an emphasis on total quality control, which advocated continuous training and quality improvement and ceasing dependence on mass inspections. It is precisely the omnipotence of such a new post-modern cult that should propel us to re-examine the economic tenets of the feasibility of any investment, not just one in quality management. Hence this paper, which seeks to delineate a compact, set of general rules for sound investments in quality improvements.

One early, and still pertinent, treatment of the economic aspects of managing quality is that of Montgomery and Storer (1986). Although its main focus is the economic design of statistical process controls, it pioneered in laying out the elements of the cost of quality, namely, the costs of prevention, appraisal, internal failure, and external failure. The first is the cost of adopting measures to minimize substandard and faulty production, so it is pre-emptive in nature. Appraisal costs are those associated with inspection and identifying defective items coming out of the product line. Internal failure costs pertain to breakdowns and the waste of resources associated with faulty product units. External failure costs result from defective and substandard items reaching the customer base, resulting in warranty costs, loss of reputational capital, etc…

Furthermore, Montgomery and Storer identified, in the same article, two types of quality management which statistical process controls can help improve: 1) quality of design, and 2) quality of conformance. Design is about product characteristics, that is, choosing the "right" ones. Conformance, on the other hand, is about constructing a manufacturing process that succeeds in making the intended design. For example, if the product were intended to be a disposable item, it would not pay to manufacture it in a way that requires too many premium materials, which would cost too much in terms of the purpose intended for the product.

Another interesting paper discusses quality control in economic research, namely in leading journals in the field such as the American Economic Review (AER), the Journal of Political Economy (JPE), and the Quarterly Journal of Economics (QJE) between 1963 and 2000 (Laband, Tollison, and Karahan, 2002). This is actually an empirical study of the process of screening articles by editors in the aforementioned top journals. Quality control in economic research is tantamount to editorial prevention and appraisal to minimize the incidence of publication of defective (non-recited and/ or substandard) articles. The authors studied the drastic decrease of critical commentary (a sign of external failure according to Montgomery and Storer?!) in economics journals over the decades under study, and found it to be the result of higher preventive and appraisal costs expended by authors and editors, although the authors of the article did not use the terminology of Montgomery and Storer specifically.

A rather mathematically challenging paper relating environmental quality control to economic development through a non-linear Cobb-Douglass production function, with a special application to the Russian economy, is discussed in Rovenskaya (2012). The model developed therein is essentially a sophisticated attempt to integrate environmental considerations into the goal of achieving economic development. Since it is concerned with macro-level, and GDP as a whole, it remains outside the strict focus of the micro-level in this paper, although the two approaches are complementary, and not mutually exclusive.

The last article to be cited in this review was written by a law professor in the Boston College Law Review (Buck, 2017). However, it tackles a quite relevant concept, albeit in a descriptive style: the impact of the high cost of health care and pharmaceuticals on the quality of health care, and life and death decisions patients and health care professionals have to make as they are forced to take the forbidding cost of health care into consideration. This, in fact, illustrates the whole point of our paper, in a drastic manner, of how improving quality is not a free good, especially given the abundant waste of resources and monopolistic pricing in the health care industry.

All of the above, however, do not lay out specifically the optimal conditions for adopting quality improvement measure, which is the task we turn to next.

III. Quality

Quality is defined as activities designed to improve the organization and its services and also is known as achieving a pre-defined standard. It is also believed that quality is the set of characteristics of a service or product that bear on its ability to affect customers' buying decisions and satisfaction which is a determining factor influencing activities of entities (Rahnamayroodposhti, 2008). If a product fulfills the expectations of customers, the customer will be pleased and will consider that the services and products are of an acceptable or even high quality. If his or her expectations are not fulfilled, the customer will consider that the services and products are of low quality. This means that the quality of a product or service may be defined as its ability to fulfill the customer's needs and expectations. Quality needs to be defined first in terms of characteristics or parameters, which vary from product to product. For example, for an electronic or mechanical product these are performance, reliability, safety and appearance. For pharmaceutical products, parameters such as chemical and physical characteristics, toxicity, medicinal effect, taste and shelf life may be important. For a food product they will include nutritional properties, taste, texture, and shelf life and so on (UNIDO, 2006). Customers seek maximum quality, and if they are able to get it at the going market price, say in the case of non-price competition amongst firms attempting to cater to different tastes, then that is tantamount to the consumer getting that extra unit of quality for free. As far as firms are concerned, if improving the quality of production techniques leads to an equivalent reduction in production costs in the long-run, the improvement in product quality need not put a strain on their profit margin, under that strict condition. However, because of the trade-off between cost and quality, to maximize profit this theory is not always true (Hilton et al., 2008).

IV. Costs Of Quality

Cost is known as price of making goods or doing the services. There is a direct relationship between cost and organizational efficiency. From this perspective, efficiency means the ability to convert inputs to output at the lowest possible cost (Hilton et al, 2008). Cost management is an approach used to realize decisions made for planning, controlling and developing competitive strategies and it is noteworthy to say that striking a balance between this factor and other dimensions of competition such as quality and time is necessary to apply managerial principles aiming to maximize the profits and value creation of the organization in current and future activities (Rahnamayroodposhti, 2008).

V. Model Specifications:

Assuming a profit function $\pi = TR - TC$, where $TR = P.\, Q(A, K, L, M,\ldots)$, and $TC = rK + wL + mM + \ldots$, where TR is total revenue, TC is total cost, P is the price of the product x, K is capital, L is labor, M is raw materials, r is the cost of capital, w is the cost of labor, m is the cost of raw materials, and A is a catchall expression denoting the level of technology, management, and other institutional factors pertinent to the quality of production, such as the qualities of design and conformance of the product x, then π can be written as:

(1) $\Pi = P. Q (A, K, L, M,) – (rK + wL + mM +\ldots)$.

Thus, if $d\Pi/dK$ and $d\Pi/dL$ are the marginal contributions of an additional unit of capital and labor, respectively, to profit, it follows that $d\Pi/dA$ is the marginal contribution of an additional unit of quality improvement to profit, be it an improvement in the quality of the production process or the product x per se, that is, be it an improvement on the production or consumption end of the market.

Starting with an assumption of constant prices, it follows that:

(2) $d\Pi/dA = P. dQ/dA$.

Since A is assumed to be a constant term in standard textbook production functions, it paradoxically follows by definition that A is not a differentiable variable. In such a case, improvements in the quality of the production process or of the product would have no derivable impact on the profit function, ceteris paribus, and would only play a role as an exogenous shifter to be handled from the point of view of comparative statics. Otherwise, an improvement in the production process A would exogenously increase profit by an increase in output resulting from the exogenous shift in A multiplied by the constant price P (under the strict assumption that the increase in A was costless, which is a realistic assumption if we maintain the assumption of exogeneity).

If the assumption of a constant P, in this case, is relaxed, then the impact of quality improvement on profit could be positive or negative, especially if demand is inelastic, and price decreases resulting from a larger quantity produced are not offset by increased consumer demand. This would cause total revenue to decrease, assuming all else constant, and incentives for improving the production process specifically would be diminished. Stagnation in production techniques and management would likely follow. The same does not necessarily apply for incentives to improve the quality of the product itself, since that would set the firm apart in terms of product differentiation endowing it with the ability to increase prices for its product. In such a case,

(3) $d\Pi/dA = P. dQ/dA + Q. dP/dA$, where $dP/dA>0$.

Thus it follows that the maximization of profit from an additional unit of product quality improvement would require, assuming zero cost for an additional unit of A, that the additional revenue from the adoption of new technology and management techniques, be it from a higher Q or P, continue until $d\Pi/dA= 0$.

However, if the assumption of exogenous shifts in A is relaxed so that A is viewed as a deliberate attempt on the part of the firm to develop its production techniques or product quality or both, it follows that an additional unit of A is necessarily costly to the firm in terms of new equipment, training programs, more skillful personnel, etc… In short, total quality management is NOT a free good. It costs scarce resources. As such, it must be treated like any other investment from the point of view of feasibility and profitability. Therefore, there should exist an optimum quantity of total quality, which is necessarily finite and subject to cost constraints.

Hence, if we assume A to be a function of capital and labor dedicated specifically to improving quality, for example, better machines and more training programs, then we assume A to be function of KA and LA, that is we assume that:

(4) A = f(KA, LA),

where KA and LA are capital and labor devoted specifically to improving quality, and KG and LG are the other general types of capital and labor that are directed towards other aspects of the production process.

Here the cost function can be rewritten as:

(5) TC = TCG + TCA, where:
(6) TCG= rK KG + wG LG + mM + …, and:
(7) TCA= rA KA + wA LA.

Generalizing, equation (7) would become:

(8) TCA= f(rA , KA, wA, LA),

where all resource prices are assumed to be constant

Substituting equation (4) through (8) into equation (1) above we obtain:

(9) Π = P. Q (A(KA, LA), K, L, M, …) – (f(rA , KA, wA, LA) + rG KG + wG LG + mM +…).

Differentiating the profit function Π with respect to A, still maintaining constant product prices for the time being, we obtain:

(10) $d\Pi/dA$ = P. dQ/dA. [dA/dKA+dA/dLA] – dTCA/dA. [dA/dKA+dA/dLA],

The optimization of profit with respect to the quality improvement variable A requires that we set $d\Pi/dA$ = 0. Under first-order conditions then, it follows that:

(11) P. dQ/dA. [dA/dKA+dA/dLA] = dTCA/dA. [dA/dKA+dA/dLA],

Cancelling out [dA/dKA+dA/dLA] from both sides of the equation we obtain the condition for maximizing profit with respect to quality improvement:

(12) P. dQ/dA = dTCA/dA,

since dQ/dA is the marginal product accruing from an additional unit of quality improvement, and since P. dQ/dA is the marginal revenue of an additional unit of quality improvement, it follows that P. dQ/dA = MRA.

In addition, since dTCA/dA is the marginal cost of an additional unit of quality improvement, it follows that dTCA/dA= MCA.

Rewriting equation (12) then we obtain:

(13) MRA=MCA.

Equation (13) simply re-derives the standard economic condition for profit maximization which is that quality improvement in production or product quality should be undertaken until the marginal revenue from an additional unit of quality improvement is equal to the marginal cost of quality improvement, that is, until the revenue from an additional unit of A is equal to the cost of that additional unit.

Variations on equation (13) can be obtained to take different situations into consideration. For example, assume that an improvement in the production process allows a reduction in general cost by cutting down on KG, LG, and M. In such a case, an additional unit of A would increase TC through an increase in TCA and would decrease TCG simultaneously. That is, KG, LG, and M are to be viewed as functions of A, where first partial derivatives are necessarily negative. That is, we assume that KG(A), LG(A), and M(A), where dKG/dA<0, dLG/dA<0, and dM/dA<0. In such a case, equation (13) would be become:

(14) MRA=MCA + dTC/dKG. dKG/dA + dTC/dLG. dLG/dA + dTC/dM. dM/dA.

Since the marginal cost of an additional unit of a resource is its going market price, which is assumed here to be constant, it follows that equation (14) becomes:

(15) MRA=MCA + rG. dKG/dA + wG. dLG/dA + m. dM/dA.

Note that in the case of equations (14) and (15) above where an improvement in the production process induces a reduction in input costs, the incentive to adopt quality improvement would increase to the extent that MCA is reduced by savings in resource costs thereby making another unit of A more enticing. In other words, the cost savings from the reduced employment of general inputs would make a larger expenditure on quality improvement A more worthwhile, given MRA.

Another situation might arise where a quality improvement pertains to product characteristics making it more desirable to consumers thus increasing its equilibrium price. Assuming Q constant for the time being, equation (13) becomes:

(16) Q. dP/dA = MCA,

This means that the improvement in product quality would be worthwhile to the extent an increase in the price of the last unit of Q covers the additional cost from another unit of A. That is, the higher the potential price increase obtaining from better product quality, the more reasonable it is for the firm to invest in expending resources on A.

VI. Conclusion

It should straightforward to generalize the results to the case where an increase in the price of product x is associated with an increase in the quantity sold, or where that is also associated with a reduction in general cost. It would be interesting to see what results would obtain from different types of production, revenue and cost functions in this context. However, the main conclusion here is that the commitment to quality improvement is neither open-ended nor costless. Rather, it should follow the rules of economic optimization if it is to be worth-while.

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