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Estimating the Spillover Benefits of Industrial Extension Programs

John Nelson and Irwin Feller

Irwin Feller and John Nelson are professors in the Department of Economics, Pennsylvania State University, University Park, Pennsylvania.

Introduction

In this paper we present the analytical framework being developed for the NIST-funded project, "Feasibility Study of Estimating the Social Savings from MTC Projects," as well as exegesis on the theoretical, empirical, and policy implications of social benefits in conducting evaluations of manufacturing modernization programs. The framework underlies the construction of a survey instrument that we plan to use in interviews with firms purchasing products and services from clients of manufacturing modernization centers. What began as (and remains) a pilot empirical effort to estimate the social returns to manufacturing modernization programs—using a standard formulation of the social returns to R&D investment—has led to a more formal, if still simple, model of the economics of such programs; in turn, this model leads to an emphasis on two aspects of these programs' economic impacts that have received limited attention in recent evaluations: (1) the potential importance of spillover benefits from these programs, and (2) the need for greater analytical clarity (and empirical tests) in gauging the allocative/technical efficiency and (re)distributive impacts of modernization programs.

Section II contains a discussion of why incorporating social benefit impacts is likely to be important in conducting large-scale evaluations of the long-term effects of manufacturing modernization programs; it also places estimation of social benefits alongside other ongoing lines of evaluation research. In section III, we present a brief summary of the standard social benefits approach to R&D investment, describe the basic model used to estimate social benefits and costs, and summarize evidence from several prior studies of social returns to innovation. In section IV, we extend the basic model to include MEP-type programs and discuss their possible social benefits from the customers' viewpoint.

The Dynamics of Manufacturing Modernization Program Evaluation

The perennial plague of intervention programs is their propensity to claim credit for all or most improvements in the condition of clients without considering alternative explanations. Any review of recent reports of or by federal and state technology development and modernization programs would reveal numerous cases of these symptoms. (Feller 1992; U.S. General Accounting Office 1995; Shapira, Youtie, and Roessner 1996). Evaluation research, with its standards of internal validity, essentially constitutes safeguards against the malady of false attribution.

In the case of manufacturing modernization programs, both theoretical and empirical reasons suggest a different potential bias—the understatement of (gross) social benefits. This understatement occurs, in our view, because evaluations of these programs for the most part are directed either at the operations of the centers themselves or the behavior or performance of the firms that are their "customers" or clients. Many legitimate reasons for this emphasis exist, including accessibility of data, accountability, and attention to process as well as to outcome variables. We do not suggest that efforts to improve center- and firm-based evaluations be slowed or halted. However, we note that the implicit market model underlying this orientation assumes that the benefits generated by manufacturing modernization programs are captured by and reflected in economic variables associated with the behavior or performance of the client firm. This static perspective holds even for "best-practice" evaluations that construct control or comparison groups, account for industry effects, or employ large-scale, market-based economic databases (Jarmin 1995; Luria and Wiarda 1996; Oldsman 1996). To the extent that the economic benefits of center activities extend to firms that purchase products from center clients or to imitators in the client's industry, spillover benefits are an addition to and indeed may exceed the benefits that accrue to clients—hence, the focus of this paper on the evaluation of social benefits from manufacturing modernization programs.

We suggest that the structure of manufacturing modernization programs contains implicit dynamic market relationships that would tend to frequently create divergences between private and social returns. These divergences arise out of the (conventional) characterization of the industry structure of the intended audience for manufacturing modernization centers—that is, small- and medium-sized enterprises (SMEs) operating with some form of technological lags in highly competitive market environments (U.S. Office of Technology Assessment 1990; National Research Council 1993). Although centers were initially charged with disseminating new (advanced) technologies to client firms, in practice, most of the modernization effort is directed at moving client firms up to (industry) best- practice techniques using off-the-shelf technology or other information in the public domain (Shapira 1990; National Institute of Standards and Technology 1992).

Assume an initial Salter-type distribution of cost schedules of firms within an industry, ranging from pro-typical best-practice equalization of factor prices and marginal rates of substitution within the existing set of available technologies, to those whose variable costs are equalled by product price. Under these conditions, the extent to which client firms of manufacturing modernization programs benefit from these engagements is, in part, a function of their distance from best-practice. Even for firms near or at some industry production frontier, the services provided by the manufacturing modernization center are likely to be readily accessible to other nonclient firms.

To the extent that the benefits provided by manufacturing centers are readily accessible to other firms or these firms employ other competitive means to match the price/quality bundle offered by clients of the modernization program, it is possible that the added profits received by any single firm because of improvements associated with modernization program services will be bid away relatively quickly by imitative or other offsetting competitive actions by other firms in the industry. In this framework, Manufacturing Technology Center (MTC) clients may gain short-term advantages over rival firms (e.g., achieve increases in sales), but find these advantages are soon dissipated as other firms respond. Over time, the result of this dynamic process of improvement and imitation is to put more firms on lower unit cost curves, but for no firm to realize a sustained long-term gain in profits, market share, etc. Further, given changes in costs, it is not certain whether the number of firms that survive will increase or decrease.

These dynamics, in effect, repeat for SMEs the technological treadmill noted by Cochrane for U.S. agriculture: a steady stream of (exogenously supplied, cost-reducing) technological improvements that must be adopted by firms in order to survive but which over time yield relatively little in the way of increased rates of return to suppliers, and instead show up mainly as decreases in prices to firms that buy from the adopting firms.[1]

A number of modifications to this scenario would permit firms to achieve sustainable longer-term gains. These would include the relative mix of product and process improvements across firms or industries, the appropriability regime relevant to a particular technology or industry, supply and demand elasticities of MTC firms and their customers that induce relatively greater changes to quantities demanded than prices, and Matthew-like interrelationships between initial distributions of relative efficiencies and propensities to seek and implement services provided by MTCs, so that initial technological leaders or clients of modernization programs extend their lead over average and worst-practice firms. Which, if any, of these scenarios holds is an empirical question, although the triage language surrounding manufacturing modernization programs would seem to suggest an emphasis on the improvements of client relative to nonclient firms.[2] Our objective here is mainly to note that more attention must be paid to assessing the loci (client firm, nonclient rivals, upstream supplier, or downstream customer) of potential benefits from manufacturing modernization programs.

With this background on the dynamics of modernization, we now turn to the main task of the paper. In the next

[1] To quote Cochrane, " . . . why do farmers generally adopt new methods? It is easy to see why the first farmers undertake a new method or practice. They benefit directly. And we can understand why neighbors of the enterprising first farmers adopt the technology: they see the income advantage and make up their minds to give it a try. But, as more and more farmers adopt the new technology, output is affected and the price of the commodity declines. This price decline acts as a burr under the saddle of the followers, the average farmers; the price of their product is declining, but their unit costs of production are unchanged. *To stay even with the world these average farmers are forced to adopt the new technology*. The average farmer is on a treadmill with respect to technological advance" (Cochrane, 1958, p. 96).

[2] Implicit in statements by modernization center personnel about triage processes at work among those firms that partake of their services, those that are potential customers, and those that are not responsive to offers of assistance is a Darwinian model of industry dynamics: improvements in client firms are highlighted, while the demise (or success) of nonrespondents is muted.

section, we review the basic economic model for estimating private and social net benefits of R&D investment. Several critical comments on the basic model then are offered. Following this discussion, we tailor the model to fit the case of manufacturing modernization and discuss potential benefits to customers of MTC clients. In addition, we point out the potentially important role of counterfactuals in quantitative assessments of modernization programs.

Private and Social Benefits of R&D Investment: Spillover Benefits

From a private perspective, the net benefit generated by a technological advance is the difference between discounted revenues and costs. For a private firm, its incentive to develop and apply a technological advance is based on expectations of appropriable net benefits. Indeed, the firm's incentive is to contain spillovers to the extent that they reduce its revenues or increase its costs.[3] However, spillovers are usually unstoppable due to the non-proprietary nature of information and the market competition the innovator faces from imitators and from existing substitute products or processes. To the extent that the innovator cannot capture all of the economic benefits of its technological advance, spillover benefits accrue to competitors as new knowledge diffuses about improved production processes and products; some benefits also spillover to customers in the form of lower prices and production costs, improved product quality, and reduced risks and increased options. Some benefits (or costs) spillover to society as a result of the innovation's effects on the environment or workplace.

If spillovers are zero, then the private return to R&D investment coincides with the social return. When spillovers are positive, the social return will exceed the private return. This difference is an important basis for the government's role in R&D. Spillovers may be so great relative to the private return that the latter is too low to support private incentives to develop a new product or process. In addition, firms might delay investments in innovative activity in the hope that they can "free ride" on the new knowledge produced by the innovative efforts of others. If many firms engage in a "fast-follower" strategy, then technological change either fails to occur or is retarded. Hence, governments may attempt to increase private returns by changing conditions of appropriability that affect revenues or costs. For example, patent policy operates on the revenue side and tax credits for R&D on the cost side of innovation.[4]

Several notable attempts have been made to measure and compare private and social returns to R&D investments, beginning with the pioneering work of Griliches (1958) and Mansfield et al. (1977a,b).[5] The Griliches-Mansfield (G-M)

[3]Strategies that can be used by an innovating firm to capture more of the benefits include patenting and licensing of the innovation; developing patent portfolios; developing lead time and learning curve advantages based on trade secrets; complementary investments in marketing and customer service; cooperative R&D; and merger and vertical integration. On conditions of appropriability, see, among others, Scherer and Ross (1990), von Hippel (1982, 1988), Mansfield (1985, 1986), Levin et al. (1987), Spence (1984), Griliches (1992), Levin, Cohen, and Mowery (1985), Cohen and Levin (1989), and Cohen (1995).

[4]We are not arguing that appropriability is the only condition that can lead to a low private rate of return. Otherwise desirable innovations may not be adopted due to insufficient market demand, costs of regulatory compliance, or the high risks of innovations; see National Research Council (1993) for a discussion of these and other impediments for smaller manufacturers.

[5]We are concerned with only attempts to measure spillovers in a direct manner. There is a

methodology can be summarized as follows: the private return is measured directly by making adjustments to the innovator's profit (quasi-rents) arising from the new product or process; subtractions are made for profits lost (if any) on the innovator's displaced products and for prorated costs of uncommercialized R&D. All costs and revenues are deflated and a time period is chosen to reflect the actual (or expected) economic life of the innovation. The social return calculation follows similar methods, except that the analysis is expanded to cover the entire industry and market. Thus, profits of imitators (if any) are added to the innovator's profits. Subtractions also are made for profits lost on competitors' displaced products and for uncommercialized R&D expenditures made by parallel innovators. The next adjustment is to aggregate the spillover benefits to customers due to lower resource prices, increased productivity, improved product quality, and the like. These benefits are monetized by estimating the increase in consumers' surplus, including an adjustment for increases in quantity demanded. Last, any other social costs or benefits such as environmental or workplace impacts are accounted for and, wherever possible, measured in monetary terms.

Applying the basic model. The G-M approach to calculating the rate of return to R&D is based on a direct (or bottom-up) calculation of the real cost and benefit flows from a certain R&D project, and the calculation of rates of return from those flows. The innovations are divided into three categories: process innovations; industrial product innovations used by firms; and household product innovations. In order to apply the same basic model to all categories, an innovation is regarded as an input that reduces the costs of carrying out an industrial or household production activity.[6] In the case of industrial products, the model focuses on the user's production costs. In the case of households, innovations reduce the costs (including time and inconvenience) of household production activities such as the cost of preparing a meal or washing clothes. In both of these cases, user production cost savings may be offset, in part or in total, by the pricing policy of the innovator. In the case of process innovations, the cost savings are internalized, but some of these savings may be passed forward to customers and knowledge spillovers may accrue to competitors. Hence, the division of the total benefits between the innovator's profit and spillover benefits depends largely on appropriability conditions for the innovation, the pricing policy of the innovator, and conditions of market structure.

The G-M model is illustrated in Figure 1. The output in question is that of the industry (or household) using the innovation, labeled "final output." The innovation shifts downward the supply curve of the user industry, but how far down depends on the innovator's pricing policy. Assume that the user industry is perfectly competitive and its supply curve is horizontal in the relevant range of final output. Let the price (or cost) prior to the innovation be P_1 and quantity demanded Q_1. Suppose the innovator sets a price that yields a profit equivalent to r dollars per unit of final output, where $P_2 - r =$

substantial economics literature on indirect measurement of domestic and international spillovers using regression analysis; see, among others, Mansfield (1991b), Griliches (1992), Nadiri (1993), and Geroski (1995a,b).

[6]Modification of the G-M method is required for new products that improve quality along some dimension. The basic modification is that the ex post demand function for the product must be measured and evaluated. For various approaches and empirical results, see Bresnahan (1986) on high-speed computers; Vroman and Russell (1987) on freeze dried coffee; Trajtenberg (1989, 1990) on CT scanners; Hyde, Newman, and Seldon (1992) on forest products; and Schwartzman (1976), Wu (1984), and Grabowski and Vernon (1994) on new pharmaceutical drugs.

P_3. The innovation produces a cost saving to the user, which appears as a downward shift of the supply schedule from S_1 to S_2. This shift yields a new price P_2 and quantity demanded Q_2. The net gain to users is measured by the increase in consumers' surplus, or area P_1abP_2. This change occurs because of the fall in the production costs of final output, as measured by the shift from S_1 to S_2, and an increase of quantity demanded from Q_1 to Q_2. In addition, a resource saving is captured by the innovator as a profit, or area P_2bcP_3. The social net benefit of the innovation is the sum of these two areas, spillover benefits to users plus the innovator's profit, and is shown as the shaded area in the diagram. The same model applies in the case of process innovations, except that the user's and the innovator's output coincide.[7]

Counterfactuals and R&D timing differences. The G-M model estimates private and social costs and benefits by positing alternative scenarios based on hypothetical "with-and-without" questions: What would have happened if the innovation had not taken place when it did? In the absence of the actual innovation, would a competitor have developed the product or process? If so, when and at what cost? In other words, the proper comparison is between what would have occurred if the innovator had not carried out the innovation and what in fact occurred (Mansfield et al. 1977a, p. 228). This timing difference is crucial to measuring the increased profits attributable to the innovation and the spillover benefits to customers. The innovator's profit is adjusted to account for profits (if any) that would have been made if the innovation had not occurred and the displaced product or process had been used instead. Similarly, if competitors were working on parallel R&D projects, the innovator's investment may result only in the innovation being available at an earlier point in time. Social benefits are calculated only during the period between the date when the innovation occurred and the date when the innovation would have been commercialized had the innovator done nothing. Hence, the social return attributable to the innovator and the social return to the innovation may differ, although some judgment may be involved in carrying out these counterfactual calculations.

Measuring returns. Given this broad framework, the data inputs required for empirical measurement of private and social rates of return to innovation can be summarized as follows:

Private Returns to Innovator:

1. Profits (Quasi-Rents) of the Innovator

a. Total costs of carrying out the innovation—R&D invested, plant and equipment at risk, manufacturing start-up, marketing start-up, and R&D modifications.

b. Prorated share of uncommercialized R&D and R&D overhead.[8]

[7] The gain in consumers' surplus equals $(P_1 - P_2)Q_2(1 - ½Ke)$, where e is the absolute value of the price elasticity of demand and $K = (P_1 - P_2)/P_2$ is the proportional change in the price. Adjustments to this basic formula can be made to reflect positively-sloped supply schedules (Griliches 1958; Hertford and Schmitz 1977; Linder and Jarrett 1978; Norton and Davis 1981) and nonlinear demand schedules (Foster Associates 1978). In addition, the basic G-M model has been expanded to account for learning curve advantages (Gottinger 1990) and the effects of regulatory constraints (Bresnahan 1986).

[8] Foster Associates (1978) argue that it is better to follow the practice of the innovator in allocating R&D overhead.

c. R&D cost savings on innovator's commercially successful parallel projects.

d. Incremental profits lost on innovator's displaced products, adjusted for R&D timing differences.

e. Revenues per unit of final output; cost savings plus royalty income on process innovation sales and licensing.

f. Total variable costs per unit of final output (net of taxes, depreciation, interest, and overhead).

g. Incremental profits on increased sales of complementary products.

2. Other Tangible and Intangible Benefits and Costs

a. Reduced (increased) regulatory compliance costs; improved credit rating.

b. Improved R&D absorptive capacity—increases in the ability to recognize, assimilate, and exploit outside knowledge.

Social Returns to Innovation:

1. Social Benefits and Costs of Competitors

a. Uncommercialized R&D costs on abandoned parallel projects.

b. Incremental profits lost on displaced products, adjusted for R&D timing differences.[9]

c. Cost savings on commercially successful parallel projects.

d. Incremental profits on imitations, adjusted for R&D timing differences.

2. Customer, Distributor, and Vendor Benefits and Costs

a. Consumers' surplus gained, adjusted for R&D timing differences; distributor, vendor, and consultant profits.

b. Improved R&D absorptive capacity—increases in the ability to recognize, assimilate, and exploit outside knowledge.

3. Other Tangible and Intangible Social Benefits and Costs

a. Environmental benefits and costs.

b. Costs of prolonged structural unemployment.

c. Improvement (deterioration) in workplace conditions and morale.

Having measured costs and benefits, the final step is to deflate all nominal money flows and capitalize the real flows. Mansfield et al. (1977a,b) use the Consumer Price Index (CPI) as a deflator and calculate an internal rate of return (IRR) on R&D investment. The IRR is that interest rate at which the present value of the historical or future deflated stream of net benefits will equal zero (i.e., the break-even" rate of return; Zerbe and Dively 1994). This is equivalent to the accounting discounted cash flow (DCF) rate of return, except that income taxes are excluded as a cost. It is a measure of the pre-tax, pre-depreciation, and pre-interest real return on the investment in

[9] Measurement of lost profits by competitors must be handled carefully since some of these losses may be transferred to customers in the form of lower prices. The loss due to the innovation should be measured on only the incremental change in output, holding constant the price of the displaced products.

R&D required to produce a commercially successful innovation. The social IRR is calculated similarly, except that the money flows are the real net social benefits, adjusted for any R&D timing differences.

A summary of eight studies applying the G-M model is presented in Table 1. These studies cover a total of 66 innovations distributed as follows: agriculture and forestry products (7); industrial production processes (17); industrial products, including two agricultural products (28); household products, including two drugs (10); telecommunications processes (2); and pharmaceutical drugs (6). (Some studies report only the social return and are typically interested in evaluating public sector R&D investments.)

Several conclusions are apparent in Table 1. First, the social return frequently is substantially greater than the private return, indicating that spillover benefits from innovation are often substantial. The average social return for industrial and household products is two to four times larger than the private return. Second, substantial variation in both private and social returns serves to emphasize the risks associated with R&D activities. Third, the results for industrial processes support the hypothesis that private appropriability is greater if user-based innovation is possible (von Hippel 1982, 1988). The private return in this category is only 20 percent smaller than the social return. Fourth, the private returns on some innovations are retrospectively too low to support private incentives for R&D investment.[10] Fifth, there is evidence that social returns to industrial innovation, even relatively mundane innovations, substantially exceed the returns to agricultural and forestry R&D investments.

Critical comments on the G-M model. In the next section, we adapt the generic G-M model to the specific context of Manufacturing Extension Partnership (MEP) programs. Before doing this, three critical comments on the basic model are in order. First, empirically, data to determine benefits have been based either on publicly available data (e.g., Griliches' study of social returns to hybrid corn; Weisbrod's study of poliomyelitis research) or on questionnaires administered to the firm producing an innovation (Mansfield et al. 1977a; Foster Associates 1978; Nathan Associates 1978; Link 1992). Relatedly, while the G-M model is comprehensive, applications to industrial innovations have focused largely on the innovating firm. Hence, survey questionnaires are developed with the innovator's viewpoint (and bottom-line) in mind, even though spillovers are located elsewhere, either with rivals or customers. With few exceptions, little direct effort is made to obtain information from third-party buyers or sellers. While the innovator is in a position to have good knowledge of some aspects of these spillovers, it lacks insights that may be obtained by focusing on customers. For example, the user of a new industrial product may have to make incremental expenditures to efficiently utilize the new input in its production process; this expenditure is properly included as a social cost of the innovation, net of any costs avoided by the user. Similarly, a customer may realize benefits in the form of new knowledge or improved flow of operations, or in its ability to utilize later upgrades and improvements. Further, the MEP program operates with an openness that is distinctly different from R&D produced in private

[10]Real private rates of returns that are below 10 percent are reported in 6 of 17 cases by Mansfield et al. (1977a), in 4 of 20 cases by Foster Associates (1978), and in 4 of 18 nonregulated industry cases by Nathan Associates (1978).

Spillover and Appropriated Benefits of Innovation: The G-M Model

Figure 1

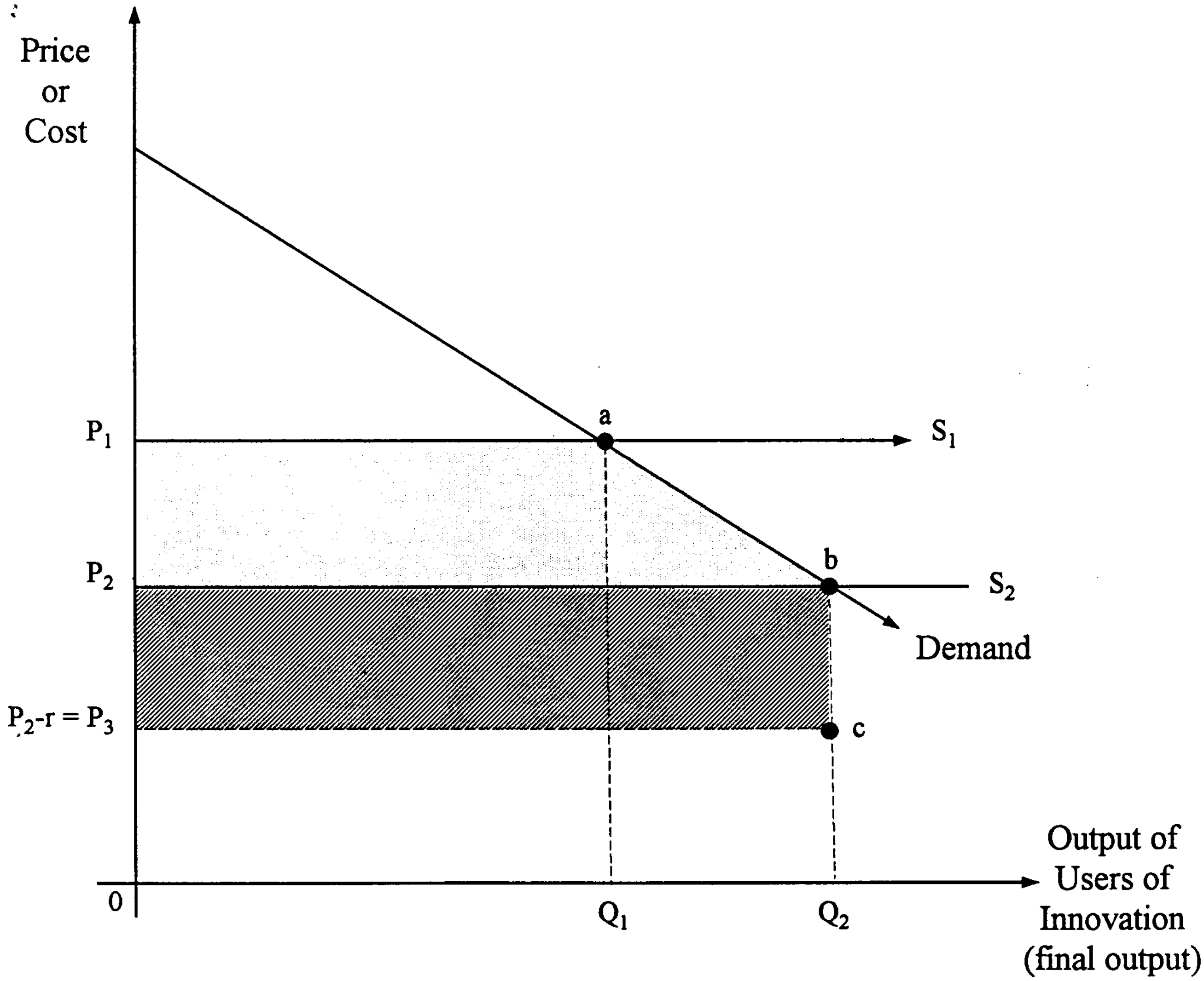


Table 1: Summary of Eight Studies that Apply the G-M Model toInnovations

Study[a]	Product or Process	Range of Annual Returns (%): Private	Range of Annual Returns (%): Social
Agricultural and Forestry Products			
Griliches (1958)	Hybrid corn		35–40
Griliches (1958)	Hybrid sorghum		20
Peterson (1967)	Poultry		21–25
Schmitz and Seckler (1970)	Tomato harvester		16–46
Bengston (1984)	Particle board		18–22
Haygreen et al. (1986)	Timber utilization		18–36
Westgage (1986)	Containerized seedlings		37–111
MEDIAN RETURN			27
Industrial Processes			
Mansfield et al. (1977)	4 processes	4–47	13–92
Foster Assoc. (1978)	4 processes	20–69	20–198
Nathan Assoc. (1978)	9 processes	38–157	20–157
MEDIAN RETURN		50	60
Industrial Products			
Mansfield et al. (1977)	10 products	0–42	0–307
Foster Assoc. (1978)	12 products	0–127	0–472
Nathan Assoc. (1978)	6 products	0–70	0–173
MEDIAN RETURN		17	77
Household Products			
Mansfield et al. (1977)	3 products	4–214	45–209
Foster Assoc. (1978)	4 products	23–148	28–178
Nathan Assoc. (1978)[b]	3 products	3–28	0–150
MEDIAN RETURN		28	62
Regulated Industry Processes			
Nathan Assoc. (1978)	LD telephone	7	26
Nathan Assoc. (1978)	Oceanic cable	0	371
Pharmaceutical Drug Products			
Weisbrod (1971)	Polio vaccine	---	12–21
Nathan Assoc. (1978)[b]	Glaucoma drug	28	0
Nathan Assoc. (1978)[b]	Rubella vaccine	3	150
Wu (1984)	Three drugs	19–74	65–160
MEDIAN RETURN		28	67

[a]Medians are calculated using the data for each individual innovation.

[b]Two drug products are reported in both the household products and pharmaceutical drug categories.

research laboratories. The openness of the information environment means that spillover benefits to customers and rivals may be large relative to private benefits, and, as noted earlier, would be missed in evaluations that focus on centers or their clients.

Second, while our empirical focus will be on the customers of modernization center client firms, it is important to identify the market conditions under which this focus will be appropriate. In order to do this, Figure 2 depicts the G-M model at the level of the innovator's output and the industry supply function, where the demand function is that of the customers. Let S_1 represent the industry supply function prior to the innovation, with a market price of P_1 and industry output Q_1. An innovation by Firm L shifts its marginal cost curve to MC_L, but some of the new knowledge spills over to other firms in the industry as a public good. Assume that costs of imitation and learning curve advantages yield a net cost advantage to the innovator, so that in Figure 2a the new industry supply schedule is given by S_2. The new market price is P_2 and the new industry output is Q_2. Under these conditions of market supply, customers realize a gain given by area P_1abP_2, reflecting the fall in the market price and the increase in quantity demanded. In addition, Firm L appropriates a profit (quasi-rent) equal to area P_2efg. The total social gain is given by the shaded area in thediagram. Note that the private gain to the imitators is zero, and any horizontal cost-savings that accrue to these firms are passed forward in their entirety to customers in the form of lower price/quality bundles. An evaluation of this market situation should focus on the cost-savings to the innovator and the lower price in the market (or the cost savings to imitators, but not their profits).

In Figure 2b, we consider an industry composed of three types of firms: (1) the innovator denoted by Firm L; (2) a F-group of firms that imitate the innovation; and (3) technological laggards. Following the innovation, the supply schedule does not shift over its entire range, so that the market price and industry output are unchanged. The innovator's marginal cost schedule falls to MC_L, while the marginal cost schedule of the imitators is given by MC_F. The benefit to Firm L from innovation is represented by area P_1hfg and the spillover benefit to imitators is given by area hkme. The total social benefit is the shaded area in the diagram, but no vertical spillovers accrue to customers. Rather, under these market conditions all benefits of the innovation, private and social, are captured by firms in the industry. An evaluation of this market situation should focus on the cost savings to the innovator and to its imitators.

Third, in recent work, Mansfield (1991a) demonstrates how the G-M model can be used to measure the social returns to academic research of an applied nature (i.e., academic research occurring within fifteen years of the commercialization of an innovation). A key insight is that academic research can speed-up the commercialization of new products and processes. Thus, the relevant research findings could have been obtained by other means (through industrial, government, or foreign research), but commercialization of the innovation would be delayed by some time period without the academic research in question. Note that this speed-up can occur regardless of whether academic and private R&D are substitutes or complements, although the measurement issues and policy implications are somewhat different in the two cases. We argue in the next section that R&D timing differences and the question of substitute/complementary R&D resources are a potentially important part of any attempt to evaluate manufacturing modernization programs.

Extending the G-M Model: Modernization Programs and Customer Benefits

In this section, we extend the G-M model by considering in detail the possible spillovers to customers of MTC client firms. The G-M model measures customer spillover benefits as a cost reduction due to a decrease in an input's price (holding quality constant), but user benefits may include other impacts on the customer's production and marketing of its product. In this context, we also seek to relate our approach to existing evaluation studies. Beginning in 1991, the National Institute of Standards and Technology (NIST) began to develop a common set of measures for gathering and reporting program activities and outcomes (National Institute of Standards and Technology 1993, 1995). Three broad groups of metrics were identified: (1) center performance standards such as number of technical projects initiated; (2) client valuation measures such as impacts on sales, costs, and employment; and (3) client progress measures such as changes in total sales, productivity, and employment income. Our focus will be on the second and third categories.

Several critiques and summaries of evaluation efforts have recently appeared in print (Luria and Wiarda 1996; Oldsman 1996; Shapira et al. 1996). These studies suggest that most current evaluations of technology modernization programs suffer from three major analytical shortcomings. First, the objectives of the MEP program are often defined so broadly—particularly at the state and local levels—that any serious attempt at evaluation is likely to falter for data or methodological reasons. Second, absent a strong analytical framework, some of the data collected in these evaluations are irrelevant to economic outcomes that matter for the MEP program's main objective: namely, small business survival through modernization. Third, as mentioned previously, the measurement of spillover benefits is absent from the current evaluation framework, and no attempt has been made to pose counterfactual questions regarding time paths toward technology modernization and enhancement. We discuss each of these shortcomings in turn and relate them to the G-M model.

Small-business survival. The economic survival of SMEs depends on their bottom-line profitability and cost-competitiveness. Hence, an attempt to evaluate MEP must focus first and foremost on the change in profits and/or costs brought about by the program, including proper accounting of the costs of program services and transfers between economic enterprises. Thus, it is meaningless to say that a client's sales have increased if accounting losses continue to occur on these sales. More broadly, an improvement in the technical efficiency of the client firm is not necessarily synonymous with the nominal objective of small-firm survival if the sales increase for the MTC client is matched by re-distributive sales losses by equally efficient nonclient domestic enterprises. Not all sales gains of client firms can be assumed to be at the expense of foreign firms, leaving unchanged the competitive positions of other domestic firms. Again, the analogy with agriculture is appropriate: improved efficiency, large social benefits, and systematic reduction in the number of firms (Feller 1993). Measuring changes in sales, however, is the hallmark of current MEP evaluations and such data are prominently mentioned in NIST literature on the MEP program.[11]

Measurement metrics. Current evaluation efforts have included a broad array of economic and technical metrics. The difficulties of interpretation and estimation of these metrics stem in part from the lack of a strong analytical framework. Thus, outcomes

[11]We recognize that there can be confusion regarding whether attainment of one objective implies positive steps toward attainment of other objectives.

from program interventions that measure the incremental level of resources used in production (a cost to the client) are mixed with metrics that measure incremental cost savings (a benefit to the client) from these interventions. Firm-level evaluation metrics in current use include cost savings, increased business revenues, added investment in plant and equipment, changes in market share, impacts on profitability, improved access to information, changes in management strategy and organization, employee training and skill development, and changes in technology adoption rates (Shapira et al. 1996, p. 191). Without denying the usefulness of some of these benchmarks, these metrics need to be integrated in an economically meaningful way to shed more light on the main objective of the MEP program.

Our framework to integrate this host of evaluation metrics is illustrated in Figure 3 and Table 2. In Figure 3a, we consider an industry made up of two types of firms: technological leaders with a marginal cost schedule given by MC_L and technological laggards (MTC clients) with a cost schedule given by MC_C. The leaders' output is given by Q_L; these firms are assumed to be producing at full capacity before and after the intervention. The laggards' output is given by $Q_1 - Q_L$; these firms are assumed to be producing with excess capacity. The initial market price is P_1.

Suppose initially that only the client firms benefit from MTC services, and that after an intervention occurs their cost schedule shifts to MC_C*. The direct cost savings associated with the intervention is given by the area abcd. This area represents the real savings of resources associated with technology transfers and related improvements in business practices. In addition, there is an adjustment in the market price from P_1 to P_2. The fall in the price results in an increased output for the client firms given by $Q_2 - Q_1$. This change results in a net social benefit from the increase in consumers' surplus, which is given by area bcea, and the total social benefit is the shaded area in the diagram. It is worth noting that the total change in consumers' surplus is given by area P_1ceP_2, but area P_1baP_2 is a transfer from leaders' profits to customers. Furthermore, depending on the price elasticity of demand, the sales revenue of the MTC clients may go up or down; what happens depends on a comparison of area bcda and area Q_1deQ_2, where the former represents a gross decrease in sales revenue due to the lower price (on the original output) and the latter represents a gross increase in sales revenue due to the increased output (at the new price). Hence, measuring changes in sales revenue is not itself a measure of the net economic impact of the manufacturing modernization intervention. Finally, note that the area bcda can be measured at either the level of the client firm (a technical cost savings effect) or the user/customer (an allocative consumers' surplus increase).

The G-M Model with Intra-industry Spillovers

Figure 2a

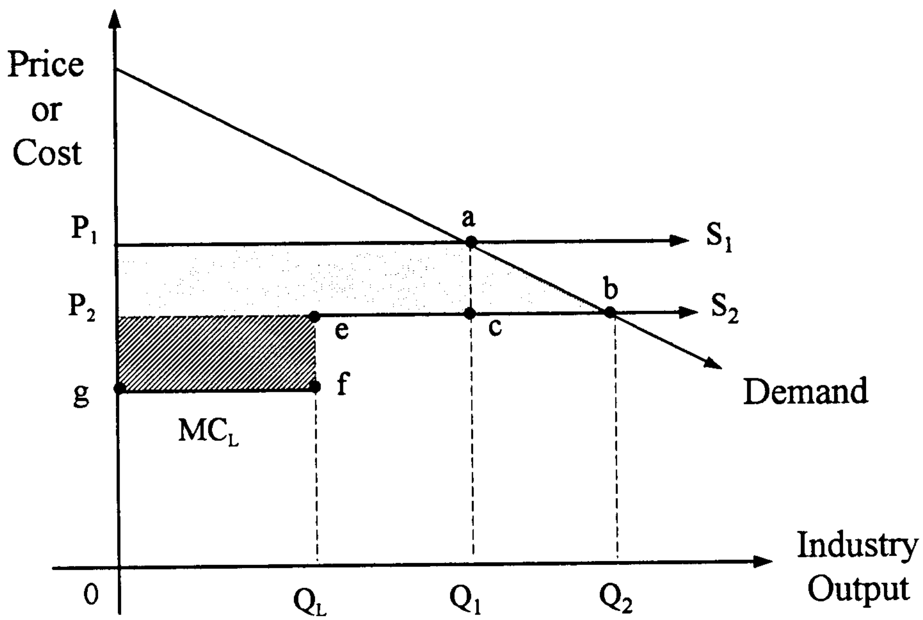
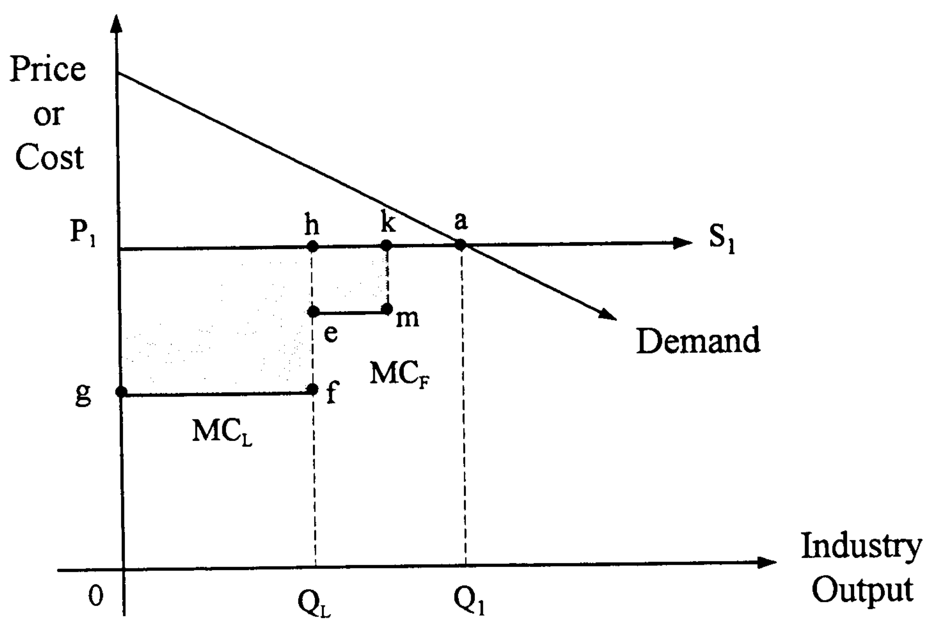


Figure 2b



MTC Intervention Impacts

Figure 3a

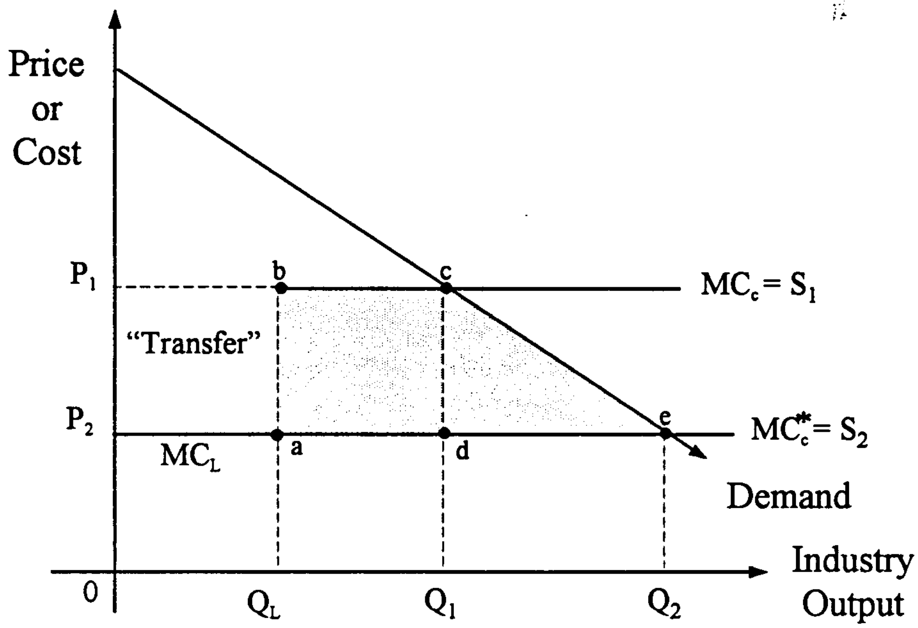


Figure 3b

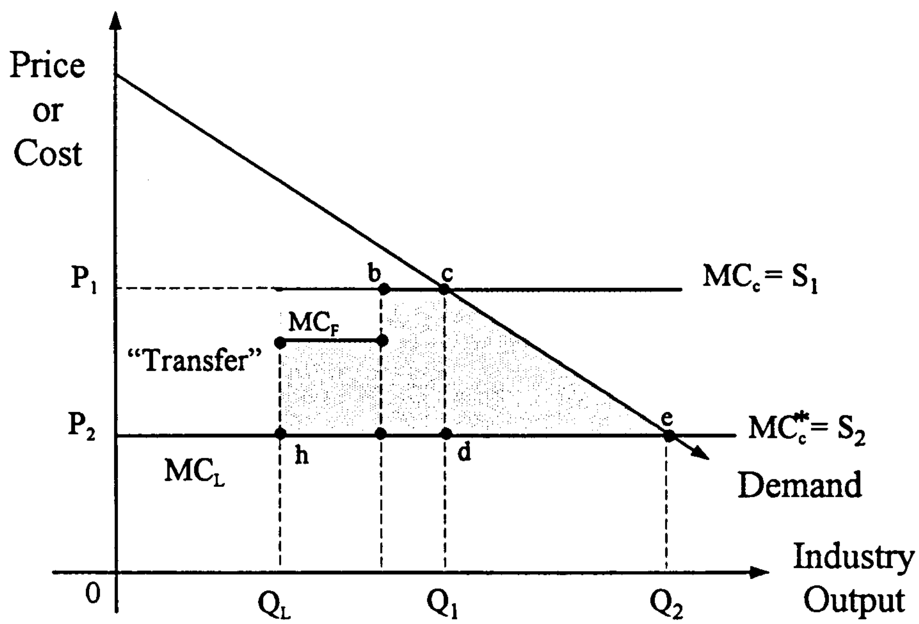


Table 2: Integration of MEP Evaluation Metrics

Evaluation Category	Description of Metrics
COST SAVINGS	Direct and indirect cost savings, especially the aggregate cost savings attributable to MTC interventions, net of any client-provided inputs and fees. Should be adjusted for timing differences. Possible subcategory metrics include labor productivity, value added per employee, reduction in materials costs and scrap/reject rates, investment avoidance, energy savings, improved inventory levels and turnover, reduced machine startup times, etc.
PROFITABILITY BENEFITS	Profitability changes for client firms attributable to MTC interventions, adjusted for timing differences and profits lost (if any) on displaced products and services of clients. Possible subcategory metrics include price–cost margins and new product sales.
SPILLOVER BENEFITS	Cost-reducing spillovers to other MTC clients (scale and scope economies) and to non-MTC firms (nonpecuniary externality). Consumer surplus gains, net of any cost savings measured at the client level. Qualitative gains to customers due to improvements in productivity, product quality and reliability, on-time delivery, service life and reject rate, maintenance costs, etc.
REVENUE IMPACTS	Increased revenues attributable to MTC interventions, adjusted for timing differences and direct revenue losses of other firms. Note that market price changes mean that revenues can increase or decrease. Possible subcategory metrics include changes in market share, business survival probability, export sales growth, hit rates on quotes, etc.
TECHNOLOGICAL AND BUSINESS UPGRADES	Physical indicators such as changes in technology adoption rates, use of computers and programmable controllers, modifications of plant layout, use of statistical quality control, ISO-9000 certification, employee training and skill development, etc. Useful for internal evaluation.
ECONOMIC DEVELOPMENT IMPACTS	Net impacts on regional and state employment, investment, workforce income, taxes, and gross state product. Should be adjusted for timing differences and for multiplier impacts in a general equilibrium framework. Not a valid part of a national benefit–cost analysis.

In addition, there may be cost savings to rivals of the client firm(s) that are reflected in shifts in rivals' cost schedules and the associated adjustment in the market price. This effect is illustrated in Figure 3b, where a spillover to nonclient firms results in cost savings of area fgah. The nature of mainstream modernization programs suggests that beneficial information will diffuse quickly and that the cost of imitation will be low or zero. Hence, the general effect is to move more firms closer to industry best-practice and most of the program benefits are passed forward to customers in the form of lower prices.[12]

In Figure 3, the MTC client firm is a technological laggard prior to the intervention and thus initially produces at a cost disadvantage. This disadvantage is measured by MC_C - MC_L. Figure 2 is based on the premise that the innovating firm is a technological leader. However, the two figures complement each other in several ways. First, it is possible that the MTC intervention pushes the client to the forefront of its industry and some of the cost savings spillover to customers as illustrated by Figures 1 and 2. Second, the industry leaders may realize some spillover benefits from technologies deployed and business practices adopted by the MTC clients, and these cost savings also are passed on to customers. Third, customers may receive other real benefits from association with MTC clients in the form of increased labor productivity, improved product quality, increased R&D absorptive capacity, and similar cost-quality improvements. Further, in a competitive industry, a firm's long-term viability may depend critically on sharing some of these gains with its customers. Fourth, Figure 3 assumes that the industry always operates with a zero economic profit, and a number of conditions may negate this assumption. The main lessons we learn from Figure 3 are that evaluations of the manufacturing modernization programs should look beyond the client firm (to rivals, customers, and vendors) and should focus on bottom-line impacts of interventions.

Using this framework, Table 2 attempts to put the host of current evaluation metrics in a comprehensive benefit-cost accounting framework. Six categories of impacts are examined: (1) cost savings; (2) profitability benefits; (3) spillover benefits; (4) revenue impacts; (5) technological and business upgrades; and (6) economic development impacts. Subcategory metrics also are identified in several cases. The categories of technological upgrading and economic development are intentionally left incomplete: the former is an intermediate impact in the social savings framework, while the latter includes possible second-order effects that extend beyond it.

The Cost Savings category is placed at the center of attention in measuring the impacts of MEP-like programs. As illustrated in Figure 3, this category best reflects the viability of the client firm relative to its competitors in the same industry. Profitability Benefits is the category tied most directly to the G-M model and Figures 1 and 2. In general, we do not expect to see large profitability impacts from industrial modernization programs. Any that do occur are likely to be transitional and difficult to separate from other market developments. However, it is important not to lose sight of the overall viability of the enterprise, and sensitivity analysis of profit impacts should be considered. Spillover Benefits is the category missing from current MEP evaluations. Greater attention should be given to tracing through the impacts of client-firm cost savings and quality enhancements on the operation of the industry and its relationships with customers. The Revenue Impacts category is interesting as an indicator of redistributive impacts on

[12] It is unclear how many and which firms survive, and what size they attain in the long run. We note here a possible tension in the objectives of modernization programs in moving more firms toward industry best-practice and ensuring the survival of smaller enterprise.

the industry. The Technological and Business Upgrades category is a check on internal MTC's performance and intermediate impacts, and is not by itself a measure of the social benefits of interventions. Last, the Economic Development Impacts category is primarily a measure of redistributive gains to particular regions and states. As with revenue changes, many proposed measures of economic development impacts are not measures of net social benefits to the national economy.

Counterfactuals and MTC timing differences. As indicated earlier, the appropriate evaluative approach is a "with-and-without" framework. Absent MTC intervention, some portion of industry laggards may have taken steps themselves to correct technological and business problems. If these corrections would have occurred anyway (without substantial delays or much greater social costs), then the benefits of the MTC program are largely pecuniary or consist of spillover benefits to competitors and customers. In his recent study of returns to academic research, Mansfield (1991a) compares the stream of social benefits from academic research to what it would have been without this investment, holding constant the amount invested in nonacademic research. In other words, the counterfactual question asked is this: "what would happen if the resources devoted to academic research were withdrawn and put to other uses?" In Mansfield's study, the average timing difference is found to be seven years; that is, commercialized innovations that relied on past academic research were available an average of seven years sooner, where this interval is measured from the year when the last research findings were obtained. There is variation across firms and industries in the sample; the lag is longer for large firms and basic industries (e.g., metals) compared to some technologically advanced industries (e.g., instruments, electrical components).

A similar framework applies to the MEP program because the services in question could be obtained from the private sector.[13] The social benefit of government support of modernization is partly a question of R&D timing differences, the resource savings due to scale and scope economies, the public good aspect of the services provided, and the response to institutional failure (Arora and Kelley 1994; Berglund and Coburn 1995). Thus, an additional component of the MEP evaluation is to develop metrics that might pinpoint these timing differences. This information could be obtained from several possible sources, such as client firms and field agents, and by using control group and matched-pair comparisons.

A related issue is the changes that occur by way of resource allocation within the client firm. Having access to MTC services can change the private firm's incentives to carry out its own problem-solving activities. This change can lead to either reductions in resources expended (substitution or "crowding-out" of private R&D) and/or increases in resource productivity (complementary R&D resources). Recent research suggests that R&D grants to small business can crowd out private sector R&D (Wallsten 1995), but to the best of our knowledge this issue has not been investigated in the context of technology extension-deployment programs.[14] Note that

[13] A key premise of MEP programs, supported by a reasonable amount of evidence is that the services could *not* be obtained from the private sector. Oldsman (1996, p. 218) points out that the most common practice is for field agents to refer clients to other organizations for technical services, or as one agent put it, " . . . our basic job is to broker technical services." NIST publications note that the centers are helping to provide upfront sales function for many consultants who previously had ignored this market.

[14] There is a growing empirical literature on potential crowd-outs and the complementary effects of public R&D support. For various contributions, see Levy and Terleckyj (1983); Lichtenberg (1987); Leyden, Link, and Bozeman (1989); Link and Bauer (1989); Link and Rees (1990); and Leyden and Link (1991).

this issue implies a decomposition of the gross effect into two parts—an MTC intervention may lead a client firm to reduce its own expenditures on problem solving, but whatever resources remain may be more (or less) effective than otherwise.

Customer spillover benefits. Current evaluations of the MEP program are focused exclusively on the client firm. To the extent that MTC interventions are cost-reducing and the industry demand for the product is inelastic, this focus is warranted. However, as Griliches has warned:

The more difficult to measure and the possibly more interesting and pervasive aspect of R&D externalities is the impact of the discovered ideas or compounds on the productivity of the research endeavors of others. This is a nonpecuniary externality which is not embodied in a particular service or product . . . it has the classic aspect of a nonrivalrous good and it is usually very hard to appropriate more than a tiny fraction of its social returns (Griliches 1992, p. 30).

In order to complete the evaluation of the MEP program, it is necessary to pose the same question regarding technology extension-deployment services. For example, suppose that an MTC intervention results in a "quality" change for the client's product. Three types of nonpecuniary externalities can arise: (1) other MTC clients may benefit; (2) other non-MTC firms in the same industry may benefit; and (3) customers may benefit. The first two spillovers have been discussed previously. If the spillovers to customers take the form of a price reduction, then the social benefits of the MTC interventions are much easier to identify and quantify. However, spillovers may arise because of improvements in the customer's general operations, including production, transportation, inventory, R&D, and marketing. Identifying these spillovers requires additional detective work. In order to carry out a complete evaluation of MTC social benefits, we suggest the following customer benefits as possible areas for investigation:

Changes in the unit price of an input, holding quality constant.

Changes in the quality of the product that affect costs, productivity, training, reject rates, and maintenance costs.

Changes in the quality of the product that affect delivery time, reliability, service life, and repeat purchase frequency.

Changes in the customer firm's R&D absorptive capacity—its ability to recognize, assimilate, and exploit outside knowledge.

The objective of the empirical portion of our study is not to measure all of the benefits, private or social, that stem from MTC programs. Rather, we directed our attention toward the more modest, but still difficult, task of measuring spillover benefits that accrue to customers of MTC clients.

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Evaluation and Market Failure: Discussion

Sears. One question I had was how the Iowa MTC and the CATD programs are related. For instance, does every Iowa MTC field engineer have a good understanding of CATD, so that appropriate referrals of small manufacturers to CATD can be made?

A second question I had was how assessments fit into the picture. Specifically, I'd like to know if the Iowa MTC conducts a full assessment of the firm's needs and capabilities before referring them to CATD. If not, there's always the danger that CATD will solve a technical problem for the firm, but that more fundamental management or other problems will remain unaddressed.

One final question was raised by the presentation. The paper points out that a substantial portion of the benefits of assisting an individual firm may go to society at large, rather than to the assisted firm. As a system, the manufacturing extension Centers are moving to become less dependent upon public support and more focused on the generation of revenue from fees from the firms served. Depending upon exactly how the numbers work out, we might worry that too heavy a reliance upon revenue generation from firms could eliminate some projects that are beneficial for society, because the Center is asking the assisted firms to pick up too large a portion of the project cost. Don't get me wrong -- the proportion of Center income today that comes from fees paid by assisted firms is quite low, and it seems unlikely that this is currently a problem. But, in the future, as revenue generation from fees picks up, this is a potential problem that we should be on the lookout to catch. An important researchable question is how often do Centers provide assistance in which a substantial proportion of the benefits do not go to the firms assisted.

Regarding spillover effects, one issue in the MEP system is centers have put more emphasis on fee generation. Your paper points out that the benefits may not go to the firm but rather to society at large. So would a rational client be willing to pay for those services? If those cases happen very often, this fee generation approach may not work. So one important question would be how often do we deal with instances in which the benefits do not go to the clients.

Russell. I sense a contradiction between Dan Luria's paper and Irwin Feller's paper. Dan Luria argues for creating more distinctive firms with power at bargaining table rather than firms who must compete on price. In Irwin Feller's universe, the goal is to encourage low prices which will then lead to benefits flowing to the customer.

Feller. This model is not normative. If the MEP client is a distinctive firm, then you have the possibility of fee for service. If you don't and have spillovers, then fee for service is not possible.

The net impacts on regional and state employment, investment, workforce income, taxes, and gross state product should be adjusted for timing differences and for multiplier impacts in a general equilibrium framework. But multiplier impacts are not a valid part of a national benefit–cost analysis.. A distinctive firm might be able to capture more benefits than price sensitive firms, so the spillover benefits would include higher social benefits.

Jarmin. I've estimated spillovers and its the case that not all firms benefit equally from spillovers. Good firms benefit from spillovers. There's a whole host of characteristics of firms that can benefit from spillovers.

Luria. Ron Jarmin's point is that if you are making commodity products for a commodity customer, the client does not get to keep the benefits from program assistance. If you mostly offer services that improve the commodity customer, don't expect to see benefits within the client. It means that maybe you should target companies that are in a better position to resist price pressures.

It might be that MEP commodity centers offering commodity services to commodity customers may look good now, but may not in the future. This also brings up problems with supplier development initiatives. The main services that suppliers seem to want from the MEP are commodity services. We could say we'll work with you on design and engineering but not "price-squeezing" services. Otherwise supplier initiatives will just make things worse.

Roessner. I'd like to address the question posed by Dave Sears about the applicability of the CATD program to the MEP. In our evaluation of CATD, we found that most of the companies were looking for specific cooperative R&D projects, so they probably were not candidates for the MEP center. I think there is almost no overlap between the kinds of problems the companies that go to CATD and the kinds of problems that go to MEP.

Shapira. But under Dan Luria's scenario, which emphasizes product development services, the work of CATD is the kind of thing which MEP should be doing more of.

Gray. There is a move toward more coordination and development of services, so, is it feasible to have a technology development component maybe as a referral process? Another point is that where the MEP is located will either facilitate or limit the ability to deliver technology development services. Are MEP centers housed at universities to make that kind of technology development connections?

Oldsman. This is an issue about what is the nature of the service rendered to the company. Is the service to help them wind their way through the university to help find the one person that can solve the problem?

Ellington. I'd argue that product development opportunities spinoff from the other "commodity" services like ISO 9000; product development itself is not a mainstream MEP service.

Luria. I'm struck that there isn't a well understood bundle of services delivered by the MEP; what you get depends on the field agent's background. In one MEP center, product-development related needs would be referred to a university researcher. But in another center the field engineer may have sufficient knowledge of, for example, the properties of various materials to help the companies directly. So maybe this means that centers need one less person who is an ISO training specialist and one more person who knows about materials.