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The Prospects for Modernizing Soviet Industry

Steven W. Popper

January 1990

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This report assesses the Soviet effort to improve economic performance by improving the quality of machine-building products. The author contends that the modernization program addresses only the symptoms of economic inefficiency, not the root cause. The senior Soviet leadership does not yet have an understanding that the goals set for the modernization program depend on fundamental reform of Soviet economic institutions. The Soviet enterprise is not the equivalent of the Western firm--the Soviet enterprise manager is subject to more uncertainty, retains less control, and faces less well specified performance criteria. Emphasis on the adoption of new machinery may impose a net cost on the economy rather than a benefit--and with disappointing results. The success of an effort to modernize Soviet industry depends upon efficient use of information, requiring more substantial reform of the economic system. True modernization is possible only with an adequate system for setting prices, sufficient competition, removal of ministerial authority, and reform of the way the average Soviet enterprise is organized.

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The Prospects for Modernizing Soviet Industry

Steven W. Popper

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A Project AIR FORCE report
prepared for the
United States Air Force

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PREFACE

This report assesses the Soviet effort to improve economic performance by improving the quality of machine-building products. It considers the effect adoption of the most advanced types of manufacturing equipment will have on the ability of Soviet industry to support the needs of the economy. The findings will be of interest to those concerned with current Soviet reform efforts, the role of the machine-building sector, civil-military tradeoffs, and the Soviet experience with high technology.

Although this report stands alone, it is best understood as a continuation of earlier research,¹ which used an inductive methodology to examine the phenomenon of modernization in one sector of the Soviet economy and to draw conclusions about the effects of the program at the level of the enterprise. The present study builds upon those findings, elaborating them to generalize the discussion. The report may therefore be viewed as a critique of Gorbachev's modernization program as a reflection of Soviet technology policy. It develops a structure to assess the prospects for modernization in an era of *perestroika*, especially as applied to the more advanced, leading-edge technologies that are intended to claim an increasing share of Soviet capital investment resources.

The study is based upon material available through the first quarter of 1989. Since then, the priority of the modernization program has clearly been displaced by the need to increase production of consumer goods. This policy choice was forced by several factors. One of these was the failure of the modernizing design originally envisioned by the Soviet leadership. In the time allotted it was not possible for modernization to increase the capacity of Soviet industry to satisfy all demands placed upon it. This study may be read as an examination of the causes of that failure. However, it is more than a postmortem. The basic approach to general economic planning and technology policy under *perestroika* appears to remain unchanged. This certainly applies to the current campaign for "conversion" of defense industry capacity. Therefore, this study will be valid for analyzing future Soviet programs for industrial modernization and technological development as long as there is no more profound change in the Soviet economic system than appears likely at this time.

¹Steven W. Popper, *Modernizing the Soviet Textile Industry: Implications for Perestroika*, R-3779, October 1989.

This study is an integral part of the Soviet Economic Reform and Modernization Project conducted under the auspices of the National Security Strategies Program of Project AIR FORCE, RAND's Air Force sponsored federally funded research and development center.

SUMMARY

An essential component of Gorbachev's *perestroika* campaign is the modernization of Soviet industry. The machine-building sector is held to be the key: If the machine builders produce high-quality equipment for other sectors, the performance characteristics of industry as a whole will be increased. In line with this concept, the machine tool industry receives special attention, since it will produce the machines the machine builders will use to build all other machines.

The present leadership believed haste was required to countervail the trends of recent years, caused, in their view, by an overly repaired capital stock at a technological level that is slipping in relation to other industrialized nations. The program is designed to be an antidote to ills manifested as a badly adapted pool of manufacturing equipment. This study contends that **the modernization program addresses only the symptoms of economic inefficiency, not the root cause.**

There has been a practical separation of *perestroika* into two uncoordinated tracks of modernization and economic reform. **The senior Soviet leadership does not yet have a general understanding that the goals set for the modernization program depend crucially upon fundamental reform of Soviet economic institutions.**

The modernization program emphasizes the production of radically higher-quality equipment in sufficient quantity to affect Soviet industrial productivity. The emphasis on hardware misses the point. It is difficult to set quality standards from above in the absence of knowledgeable, motivated, and sovereign consumers. The term *quality* has many dimensions. Relying on a system of state-enforced quality standards will probably not equate with economic utility since the measured characteristics will only be a subset of those most important to machine uses.

Soviet institutions and the campaign elements of the modernization drive have led authorities to set quality standards by supposedly matching the leading edge of world technology. This technology frontier approach makes less costly solutions less attractive, resulting in inappropriate technology choice and, ultimately, misallocation of resources. The technology to increase output efficiency need not always be that of the leading edge. **Although a doctrine of technological "reasonable sufficiency" seems a practical course for a modernization drive to follow, the Soviet Union is ill-poised to identify and follow this path.** Machine users lack influence over design decisions, producers are monopolists, prices are not based on

real resource costs, and information flows poorly. As a result, less advanced designs that have never been produced in sufficient numbers are discontinued in favor of higher-technology equipment not well suited to users' needs. **The current emphasis on achieving a specified world technological frontier is a symptom of the inability to determine the true needs of industrial enterprises.**

Although the Soviet Union does possess an aging capital stock of a low technological level, a more serious problem is that capital equipment of all vintages is inefficiently utilized. There is no sufficiently strong incentive for the using firm to adapt to the requirements of new machinery. Further, the enterprise lacks full control over many factors required to achieve more efficient utilization. One reason is intrusion by higher administrative authority. Another is that reform has left enterprise organization unchanged; it is not conducive to generating and accurately assessing information on the manufacturing process and implementing decisions based upon that information. It is little changed from the structure created specifically to respond to the commands from higher authority based upon information forwarded by the enterprise.

This leads to a simple conclusion not given sufficient consideration: **The Soviet enterprise is not the equivalent of the Western firm. The Soviet enterprise manager is subject to more uncertainty, retains less control, and faces performance criteria that are less well specified.** A *perestroika* predicated on the enterprise's coming to behave more like its Western counterpart will lead to frustration.

The adoption of new machinery may impose a net cost on the economy rather than a benefit. In this sense, modernization may appear to succeed when measured by the qualitative level of machine-building output, but it may fail in making industry as a whole more productive.

An insidious aspect of this problem is that there are insufficient means for judging how far practice departs from the optimum. The signs of inefficient utilization come later to a Soviet enterprise than they would to a competitive Western firm. Accounting practices do not provide enterprise managers with the information required to track efficiency of utilization, and the lack of competition will prevent early warning from outside. **Identical machinery will most likely be operated with lower productivity in a Soviet plant than in a Western one.** Even if the Soviets succeed in meeting the modernization program targets, the current economic system will dissipate the effects.

These two problems, inappropriate technology choice and inefficient utilization, become more apparent the higher the technological level of

the equipment. They apply to the advanced manufacturing technologies that are the heart of the modernization effort. Western experience suggests that the most important change in manufacturing technology has not been in the equipment itself, but in the different approach to management that accompanies it. The more successful the use of this type of capital, the more preparation, planning, and reorganization of management that preceded it. Further, the experience of the West argues for incrementalism, not revolution.

The spirit of the modernization drive violates these principles. Wide diffusion of advanced manufacturing technology continues to be the emphasis, with disappointing results. There are serious deficiencies of managerial resources, incentives, independence, flexibility, and information required to apply this expensive equipment correctly.

Compounding the problem, the difficulty in generating adequate information prevents early detection of inefficient use. Indeed, the pressure for more investment in these areas increases, which may lead to a considerable waste of national resources and distract attention from guaranteeing the efficient use of all capital types. Ultimately, this haste will lead to much time being lost in furthering the development of Soviet industry. Some Soviet commentators are aware of these pitfalls, but whether the leadership will pay attention to them will depend on whether they can be weaned away from setting priorities in the simple terms that lend themselves best to quantification.

A modernization drive exploiting advanced technologies to produce a more effective industry will not prove of lasting benefit if development follows an inefficient path. To ignore the need for reform will cause the Soviet economy even greater costs in increasing its technological level, while receiving less benefit from the investment. Past policies have caused the economy to be too profligate. Exploring new, advanced means for being inefficient will not prove to the nation's benefit over the long run.

The success of an effort to modernize Soviet industry depends upon efficient use of information, in turn requiring more substantial reform of the economic system. Reform was not the primary intention of *perestroika*'s drafters. Rather, elements of reform have been applied to deal with the central issue of making the economy more efficient, more productive, and less embarrassing compared with the developed West. But true modernization is possible only with an adequate system for setting prices, sufficient competition, removal of ministerial authority, and reform of the organization of the average Soviet enterprise.

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I. INTRODUCTION

RESTRUCTURING AND THE MODERNIZATION OF INDUSTRY

General Secretary Gorbachev came into office in 1985 determined to redress the economic stagnation that had become apparent during the late Brezhnev period. The codeword for this effort is the now familiar all-encompassing term *perestroika*, or restructuring. The Gorbachevian analysis of Soviet economic decline has called attention to the obsolescent nature of much of the Soviet capital base. One of the indicators of a pre-crisis condition is the increasing technological gap between Soviet and Western industrial practice. As one Soviet commentator has stated, "The fact that we are lagging behind the major capitalist countries [in many areas of scientific and technical progress] is becoming not only clear but also strategically threatening" (Zaichenko, 1988). According to this view, the technological lag of the Soviet Union is both symptom and cause of a failure to provide the economy's production facilities with modern means for achieving the goals set for them by the leadership. Emphasis on the technology gap has affected the approach to industrial restructuring.

Gorbachev's drive for *perestroika* emphasizes industrial modernization, designed to directly address the problem of lag. The central policy of this program is to renovate the capital stock of all branches of Soviet industry. In practice, the focus is the Soviet machine building complex,¹ the ultimate source of domestically produced machinery. This sector, in the view of the present leadership, could increase productivity throughout the economy by supplying more productive capital goods. Tracing the process a further step back, within the machine-building sector enterprises producing machine tools, the machines that make all other machines, have been identified as the ultimate source of modernizing impetus. Therefore, a great deal of effort has been directed to increasing the rates of output from the machine-building complex, especially the machine-tool builders; to improving the quality of the goods produced; and to speeding the removal rate of obsolescent

¹Here taken to mean the seven civilian ministries usually referred to as the machine-building and metal-working sector (MBMW). The balance of this study largely examines the problems of modernizing the civilian economy, but the defense industry is undergoing a similar process and is increasingly being called upon to provide goods and equipment in support of the civilian sector. This policy in itself may be viewed as a modernization effort.

machinery to make room for the new. Imports will play a role, but the goal is to develop domestic sources for providing Soviet industry with high-quality producers' durables.

This report assesses the effect the current program for the modernization of industry is likely to have on the ability of the Soviet economy to increase overall productivity and to meet the increasingly more diverse demands placed upon national income.² How likely is it that the combination of modernized production equipment and modified economic institutions will yield the full productivity gains sought by the leadership?

Beyond this, if the modernization effort falls short of full realization, how will productivity of Soviet industry be affected? Will modernization place Soviet industry in a better position than it is today, yielding productivity gains, but at greater cost than if the process had been more efficient, or could it possibly lead to net losses? The questions are crucial for projecting the capabilities of the Soviet economy over the medium and long runs.

STUDY APPROACH

This report will view modernization as a series of micro-level decisions. Many of the crucial issues that will determine success or failure, as well as many of the benefits that a modernization effort seeks to gain, appear as phenomena on the level of the production plant. Although we are ultimately interested in aggregate performance, such change as occurs will be based upon decisions taken at the lowest strata of the economy. The subtleties of these phenomena are often lost when more aggregate analytical approaches are employed. Therefore, this study will ask how modernization is likely to make a difference in its most crucial arena: the shop floor of the Soviet industrial plant.

Such an approach requires specifying the organizations whose decisions are being observed. The modernization scheme includes three types of industrial enterprise: the machine-tool-building enterprise, the producer of the primarily metalworking machines used to make all other machines; the machine-building enterprise, the user of the

²*Modernization* as it is used in this study is a term of art. It is intended to cover the range of activities, policies, and programs designed to increase the efficiency of performance and the qualitative indicators of output in Soviet industry. The words most often used by the Soviets to convey the sense of what the blanket term *modernization* is intended to mean are *acceleration*, *renovation*, *re-equipping*, *scientific-technological progress*, and, of course, *restructuring*, although this last term also incorporates many elements of fundamental reform as well.

machine tools and producer of the other machine types found in a modern industrial economy; and the manufacturing enterprise, producer of final products and user of the processing machinery made by machine builders. The end product of the manufacturing enterprise may also be machinery, such as consumer electronics or automotive equipment.

This neat system of definition is an idealization often compromised in practice. The machine-tool enterprise, for example, will also utilize its own output as an input along with the output of other machine-tool and machine-building plants. Confusion can be limited by recognizing that only the functional relationship between economic agents matters for the purposes of this study. Therefore, although the discussion will speak of "machine builders" and "machine users," an enterprise may play both roles. It stands as a machine builder in relation to the enterprise using its output and as machine user in regard to the enterprise supplying its working capital. Although many plants could be safely categorized as primarily one or the other, there is a substantial middle ground where the activities of the enterprise shade into both domains. The report will deliberately use the terms *machine builders* and *machine users* in the functional sense to clarify the fundamental relationships whose permutations cover the full range of activity and interactions in the USSR. This emphasizes that the act of generating new capital equipment is not the only activity legitimately falling under the rubric of modernization. The effect upon the recipients of machinery must be considered as well.

OUTLINE

Section II outlines the modernization program and discusses its general strategy and intent qualitative terms. It also considers the formal relationship between the modernization program and the reform efforts being carried on concurrently.

Section III treats the problem of how particular types of machinery output will be chosen under the current Soviet institutions and how well suited this equipment will be to the needs of Soviet industrial enterprises. The origin of the Soviet propensity to think in terms of a "world technology frontier" and to use this as a metric to assess fulfillment of a modernization effort will be considered and its effect on the modernization program weighed.

Section IV introduces the topic of efficient utilization of the ensuing stream of new manufacturing machinery. A major problem confronting the Soviet economy is that capital at all levels of technology is used in

an inefficient manner. These problems are likely to be exacerbated as the more complex technical solutions come on line.

The next two sections apply the theses of Sections III and IV to high technology manufacturing equipment. Section V briefly reviews recent developments in the production of advanced manufacturing technology. It states the apparent lessons of Western experience and discusses the potential relevance to Soviet industry.

Section VI uses these propositions to consider the degree of success the current effort will have in emphasizing the domestic production and subsequent diffusion of modern machinery types in the Soviet Union.

Section VII will draw together the major themes to assess the modernization program's chances for success in the terms in which it has been presented by the Soviet leadership. The theme of this section is the need for the Soviet leaders to recognize in policy terms the interconnection between successful modernization and meaningful economic reform.

II. THE MODERNIZATION PROGRAM FOR SOVIET MACHINE BUILDING

MACHINE BUILDING AS THE LEADING SECTOR

The targets of the current five-year plan imply a strategy to "jump start" the Soviet industrial modernization program by front loading investment in the machine-building sector. To increase the productivity of the entire economy, manufacturing enterprises must be guaranteed the delivery of more productive machinery. Hence, attention must be directed toward the activities of the domestic machine-building industry. Efficiency improvements in all branches of industry are to be achieved through the indirect strategy of investment in machine building first. Academician A. G. Agenbegyan, said to be an architect of the current program of modernization, has emphasized not only the importance of accelerating technical progress and the nature of machine building, but also the need for a revolutionary break with investment priorities of the past:

The most important factor, strategically, is to accelerate scientific and technological progress. Such progress, as is known, involves two major processes. One is evolutionary—when the old technology or techniques are improved and updated, but do not basically change. The other process is one of revolution—when essentially new generations of technological systems are invented to substitute for the old ones. Our country, until recently, has been developing predominantly along the evolutionary path of technological progress; we replaced equipment and goods very slowly, instead of scrapping the old technologies and products to develop new ones. Now we have changed our scientific and technological policy and decided to invoke revolutionary changes to modernize our economy technically. Where is our bottleneck? . . . the implementation of a technology is materialized through new equipment, machines, and instruments. It means that machine building, where equipment and machinery are produced, is the main link in new technologies diffusion. (Agenbegyan, 1987.)

I. S. Silayev, the Chairman of the Machine Building Bureau, a supervisory body set above the seven machine-building ministries, has stated the basic proposition clearly: The rate of national economic growth will depend directly on the effectiveness of the restructuring of the machine-building complex, which in turn determines the scientific and technical progress of other branches (Silayev, 1988). The 27th Party Congress set this branch the main task of restructuring the economy by accelerating the technical reequipment of industry. The

underlying message is that the failures of the past occurred, in large measure, because industry operated with obsolete technical means.¹ The policy prescription is focused directly upon investment to produce new technology.

"Our . . . civil machine building is a very backward industry, in light of modern requirements; it is obsolete; and it does not provide other industries with new equipment. Therefore, we are lagging behind in all areas affected by this backwardness. That is why we have proclaimed, and we are now implementing, a new investment policy. The essence of it is to redistribute resources in favor of machine building. (Agenbegyan, 1987.)

Indeed, the party's Central Committee has referred to the current 12th Five-Year Plan as the "Plan of Machine Building" (Grishchenko, 1987). The plan calls for a 43 percent increase in the output of products of the civilian machine-building complex from 1986 through 1990. In addition, the rate at which product lines are updated is to be quadrupled, and 85 to 90 percent of the output produced by the sector is to attain the world technical level standard of quality by the end of the plan period. The reliability and productivity of the machinery produced is to be "improved by a factor of 1.5-2 times." These changes are to be supported by an 80 percent increase in investment in the machine-building sector during the course of the plan (Silayev, 1988).² "Therefore we have a right to expect a leap forward in renewal in 1987 and the subsequent years. Of course, changes are also needed in investment policy" (Agenbegyan, 1987).

The Instruments and Institutions of Modernization

The machinery designed to transform Soviet industry is to be provided by a domestic machine-building sector that is not only the beneficiary of a great infusion of investment resources, but is also intended to be operating with different rules than have obtained during previous investment drives. The hallmark of the Gorbachev modernization program is the quest for economic efficiency. To be sure, other campaigns have emphasized increased production in one or several sectors, or even, at least formally, a greater degree of attention to the indicators of quality (e.g., the 10th Five-Year Plan). Indeed, an emphasis on shifting from an "extensive" to an "intensive" strategy of economic

¹Problems with the manner in which these means were allocated and operated are not completely ignored, but receive less emphasis in antistagnation polemics.

²In spite of an intention to restrict new investments in 1989, Prime Minister Ryzhkov has reiterated that machine building will continue to receive high priority. See *Prauda*, October 28, 1988.

development and growth has been a feature of Soviet rhetoric since the early 1970s. But the current drive raises above all other desiderata a goal of using the resources of the Soviet Union more efficiently. Efficiency is the goal not only in the narrow sense of cost minimization but also in the broader allocative sense as well: ensuring that the nation's resources, placed in the hands of enterprises, will be used to produce goods of greatest value in fulfilling demand and stimulating economic growth.

The mechanisms being used are a mixture of shifting administrative priorities, a measure of reform of the existing system, and the familiar trappings of a campaign. The campaign elements, which may be reduced to a series of slogans ("*perestroika*," "acceleration," "metal saving," "achieving the world technical standard"), are of interest because they give insight into the aspects of enterprise operation most likely to draw the attention and interference of local party elements. In the instance of this modernization program, the campaign elements provide a specific frame of reference for enterprise and branch managers seeking solutions to the problems that beset industrial production. The campaign approach forcefully conveys the central authorities basic message. However, there is a distinct risk of having the campaign mentality too narrowly circumscribe the range of solutions that lower-level managers will feel free to explore when confronting specific problems. Such campaigns achieve their effect only through the crudest means and often lead to perverse compliance with indicators and campaign slogans. The dual emphasis on quality indicators and greater output levels increases the potential for conflicting goals to undercut the modernization program.

The central leadership uses administrative procedures to direct the activities of lower-level personnel through priority setting, target setting, and compliance monitoring, long the instruments of the command economy. The principal measure is the dramatic increase in new fixed investment, with investment priority directed toward the machine-building sector. This investment is targeted toward the production of higher quality, more productive machinery, enforcing a preference for the renovation and modernization of existing plant rather than the construction of new facilities.

Three further administrative measures have accompanied the priority allocation of investment. The first is to mandate accelerated rates for retirement of older vintage capital. An abiding problem in Soviet industry has been the tendency to retain equipment beyond its economically useful life. Expenses for capital repair mount, and new installations are denied an adequate labor force to operate the

machinery properly; but where the enterprise budget constraint is soft³ and a reserve for meeting plan targets is vital to an enterprise's success, the incentives to resist scrapping obsolescent machinery are great. Even if costly to maintain and inefficient to operate, they form a reserve for "storming" a formally or informally stated output plan. From 1978 to 1988, expenses for repair to capital located in the machine-building sector doubled. One-fourth of the nation's machine tool stock, six million workers, and 20 percent of ferrous metal production are devoted to capital repair. Yet one quarter of the equipment in the sector is estimated to require immediate replacement because of wear and tear, and one-half needs "radical modernization" (Karpunin, 1988).⁴ Targets have been set for increasing the rate of capital retirement, and enterprises report this as one of their basic indicators.

Another administrative step is the introduction of the system of *gospriemka*, State Acceptance, to provide an external guarantor of output quality at the level of the enterprise. The intent is to guarantee a greater supply of producers' goods of markedly superior quality that will in turn raise levels of productivity in the recipient industries. The end-users of machinery produced by the machine-building sector cannot control the quality of the equipment they accept because even with adoption of the new Law on the State Enterprise (Association), the persistence of effective monopolies means they will not have *de facto* customer sovereignty in the wholesale sector for quite some time. The state must play the authoritative role left vacant by lack of true customer sovereignty in the form of *gospriemka*.

Finally, creation of supraministerial (the Agro-industrial Committee,⁵ the Bureau of Machine Building) and cross- or infraministerial organizations (intersectoral science and technology complexes; all-union scientific-production associations complete the classic picture of reform through redrafting the hierarchy of economic administration.

The modernization program as developed by Gorbachev is distinctive because reform elements have been presented as concomitants to the

³That is, financial losses may be subsidized from sources outside the enterprise without undue stigma attaching to its management.

⁴In figures from the Armenian SSR where the machine tool industry was established in the decades of the 1960s and 1970s, equipment more than ten years old accounts for between 23.1 percent and 51.8 percent of the capital stock at the republic's three machine-tool production associations; and in the case of one association, metal-cutting machinery that is more than 20 years old accounts for 15.3 percent of the total (Gevorkyan, 1985). These enterprises may be fortunate in the state of their machine stock. In the course of transferring civilian light industrial enterprises to defense ministries in line with recent policy shifts, it was found that as much as 60 percent of the transferred equipment was completely worn out. (Prime Minister Ryzhkov's statements at October 19, 1988, Council of Ministers Meeting as reported by Moscow Television; FBIS-SOV-88-206, October 25, 1988, p. 54.)

⁵Formed in 1985 but dissolved in 1989.

campaign. Mechanisms are being discussed, and to a certain degree introduced, to increase the volume and importance of direct, horizontal contracts between enterprises in directing the economic activities of individual producers. If fully implemented, these would decentralize the system of material supply to some extent. In addition, individual enterprise responsibility (but not necessarily true authority) is to be enlarged through the expanded system of self-financing intended to tie the development possibilities of the enterprise in part to its successful performance as a producer and marketer of its output. There have also been discussions about the fundamental wage regime within the enterprise and the nature of employment relations. The extent to which any of these measures is fully implemented remains an open question.

Gorbachev is an apt student of recent Soviet economic history. He knew (or quickly learned) that the Soviet system is geared to increasing the volume of output without satisfactorily guaranteeing a commensurate increase in its quality. This presents a conundrum: How can a national leader use the system to command that priority must be given to the production of newer, higher-technology machines without recapitulating the mistakes of late Brezhnevism, producing machines for which there is no demand—"bad" new machines?⁶ Clearly, the utility of output can best be judged by the customers, if possessed of sufficient information, opportunity, and incentives. Therefore, there is a need to increase the horizontal links between producers and customers (a favorite Gorbachevian theme) through contracting and wholesale trade. The shift to full economic accounting for enterprises, *polnyi khozraschet*, is an integral part of this design.

Although the modernization program appears to emphasize the command/administrative aspects of the design, certain reform elements carry modernizers' hopes that this campaign may meet with more success than have several of its predecessors. In particular, the reforms designed to increase lateral communication between production enterprises and the drive to increase enterprise financial responsibility are the tools that Gorbachev trusts will force machine builders to produce the equipment types most needed by the economy.

In practice, modernization and economic reform have proceeded along two uncoordinated tracks. The reform elements have come in an episodic fashion because reform as such was never the primary intention. Rather, elements of reform have been applied to make industry more efficient, more productive, and less embarrassing in comparison with the industry of the developed West. (This last, not a very good reason by the lights of economic analysis, may be among the most

⁶The problem of commanding quality is the subject of Sec. III.

important to the leadership and may be skewing the activities falling under the rubric of the modernization effort.) This is why reform did not begin in sectors more amenable to change such as agriculture, the service sector, or housing. Modernizers of the Gorbachevian stamp feared a declining industrial base. There may have been a more efficient, more considered means of preparing for an orderly transition, but by that time it would have been too late. Soviet industry would be hopelessly behind in the race for the technological frontier. In the words of Alexander Gerschenkron, their race is not so much against the clock as against someone (Gerschenkron, 1962). In this respect, they recapitulate a long-standing tradition in Soviet economic development, what Grossman (1983) has called the "economics of virtuous haste." The approach is not as monomaniacal as in the past, but it still indicates certain indifference to cost that undercuts the philosophical message of the reform measures. In this sense, it sets modernization in opposition to reform, inadvertently undercutting any advantage large-scale modernization might confer. The Soviet leadership appears to underestimate the direct connection between economic reform and the efficient utilization of the equipment to be produced under the modernization program. This need to "show results" may prolong the time required for such learning about the reform process to occur.

The Role of Advanced Manufacturing Technologies

Taking its cue from the April 1985 Plenum of the Party Central Committee, the Ministry of the Machine Tool and Tool Building Industry, in a sense the core of the civilian machine-building sector, set the main lines for modernization. On the leading edge of the ministry there is to be a "several fold increase" in progressive and advanced types of metal-working equipment: specialized machine tools, numerically controlled machine tools "including general-purpose ones," flexible manufacturing modules, flexible manufacturing systems, industrial robots, and automatic and semiautomatic lines (*Stanki i Instrument*, 1985).

Nothing less is to be tolerated than output equal to the best world level. The Soviet economy needs to make up for the lapses of the past, and the machinery produced today will form the bulk of the nation's stock of productive capital in the next century. During the peroration of his address at the 1987 Party Central Committee conference on the fulfillment of the modernization program, Gorbachev reiterated this theme clearly:

I would like to emphasize again and again that the goal of reaching the highest world level of machinery, equipment, and instruments that are being manufactured is the primary task of machine building. . . . Machine builders will receive any kind of help they need from the state. But their answerability for the fulfillment of all the decisions adopted will also be increased.⁷

This represents the greatest statement of priority support the party leader could give, and it puts machine builders on notice. It circumscribes the routes along which their major activities may proceed and emphasizes that higher, central authority will be the final arbiter of their success. The emphasis on the "hardware" aspect of modernization is clear.

This orientation toward the technological aspect of modernization is not only a prime feature of the program in machine building, but provides an important avenue for speculation over the outcome of the program. A serious question remains whether a search for high-technology machinery *per se* is a correct solution to the Soviet Union's problems with declining total factor productivity. The answer is neither simple nor obvious. In focusing on the need to develop high-technology, leading-edge capital types, Gorbachev may be overemphasizing one aspect of modernization to the detriment of the overall program.

The goal of the modernization program ought not be to increase the technological level of the Soviet capital base. This must be viewed merely as a means for transforming Soviet patterns of economic productivity. Clearly an aging and increasingly obsolescent stock of productive capital is detrimental to reaching this goal. But emphasizing the material aspect will obscure inadequacies that could well negate the sacrifices made during the modernization drive.

ASPECTS OF MODERNIZATION POLICY

The analytical framework of this study builds upon four questions of policy. These are the criteria the modernization program must satisfy to revitalize the economy; the success of the program must be judged in accord with them.

Two of these are familiar to planners inside the Soviet Union and to outside analysts.⁸ First, will the quantity of output be sufficient to meet the plan targets? This question is suggested by the frame of reference for past Soviet policy decisions. Western analysts have

⁷*Pravda*, July 26, 1987, p. 2.

⁸See, for example, the able study by Matosich and Matosich (1988).

provided independent assessments of plan feasibility in quantity terms and have gone beyond to ask about the appropriateness of the targets.

Recently, a second question has received more prominence. Will the quality of the ensuing output be adequate to support the intentions of the planners? There have usually been quality indicators of some form or another in Soviet plans, but these have most often taken second place to the goal of fulfilling the plan for quantity. More recently, the prime movers of *perestroika* have emphasized the quality dimension. The notion that quality and quantity may be antithetical has received new attention; the current leadership is predisposed to reject the comfortable compromises of the "period of stagnation." Indeed, by March 1987, while the Soviet press was extolling the tough stance on quality taken by the *gospriemka* inspectors, exhortations were being published to make up the indebtedness of the quantity shortfall.⁹

Several factors distinguish the present modernization effort and the environment in which it is being enacted from what has gone before. There is a marked qualitative difference between traditional Soviet machinery stock and equipment of the sort targeted by the modernization strategy. Further, the nature of the competition between East and West has been changing and taking new forms. This requires a redefinition of Soviet goals in the external environment and further suggests the allocation of national income among alternative uses should also be reassessed. Political changes, particularly the greater emphasis on providing for civilian needs, have changed the priorities for resolving competing Soviet domestic resource claims. These shifts indicate the need to address two further policy issues for modernization. They may in fact be as important as the first two, or even dominate them.

The third question asks how the current system will select the types of capital equipment most suited to the needs of Soviet industry. Even if the Soviets could hypothetically be guaranteed the capability of producing machinery of any sort at any desired technological level, a serious problem remains of deciding what machine types are appropriate to produce. Using the world technological frontier to guide the modernization of Soviet industry along a broad front may be a poor, even counterproductive, strategy for achieving the goals desired by the Soviet leadership. Too many resources may be expended to produce equipment that may be unsuited for the actual tasks facing the industrial enterprises using it.

The fourth question shifts the focus from the producer to the user of the newly produced equipment. Modernization must ultimately depend

⁹"Industry: February's Results," editorial in *Sovetskaya Estoniya*, March 18, 1987, p. 1, in JPRS, *Soviet Union Economic Affairs*, June 13, 1987, pp. 32-34.

upon effective use of the capital placed at the disposal of industrial enterprises. Will recipients be effective users of the machinery that results from modernizing the output of machine-building enterprises?

There is surely a relation between the themes of appropriate choice and effective or efficient operation.¹⁰ However, the question of efficient utilization suggests that even if the Soviet modernization strategy is pursued more effectively than there is any reason to expect *a priori* it will be, the technologically advanced capital produced may not be used in a way to fully justify its tremendous cost to the economy. A discussion of modernization should include consideration of the ultimate effect of the process, not merely its implementation.

A corollary to both themes is that there are potential efficiency gains available to the economy if it uses the existing capital stock more rationally. But this is unlikely, given the current status of the reform measures accompanying the modernization drive. A more fundamental reform of the economic apparatus will be needed to make modernization an efficient process.

¹⁰Complete efficiency, maximization of benefit while minimizing cost, is seldom seen in practice. Effective use lies within the region where the net benefit is positive. A question for this study is how effective Soviet utilization of modern manufacturing technology is likely to be, or whether such equipment might possibly prove to be ineffective in application.

III. THE QUANDARY OF APPROPRIATE TECHNOLOGY CHOICE

SETTING AND MEETING STANDARDS

The difficulty in choosing the precise output of the machine-building sector during the modernization drive stems from the problem of defining quality. Added to the task of assuring that qualitative standards are adhered to once set, there is a prior need to establish which qualities are to be measured. In setting standards, choices are made about the criteria to be used in judging output. Therefore, choices are indirectly made about the nature of the equipment machine builders will choose to build.

The concept of quality has several dimensions. In one sense, a machine with more capabilities or adhering to a higher technological standard may be viewed as being of a higher quality than a machine not possessing these features. Another sense asks how reliable a machine is in use. A machine that is easily serviceable during the infrequent intervals when it needs service, or that enjoys a long service life, may be said to be of higher quality than one that breaks down frequently or is not amenable to rapid repair. Machine quality could also be defined in terms of the machine's suitability to its intended purpose and the type of output it is capable of producing. A machine may be of a high technical standard and reliable, conforming to the first two meanings, but it might be ill suited to the task the user would like it to perform or to the conditions under which it will be used. If standards of quality are to be adhered to, this would certainly appear to be an important determinant of how those standards should be set. Further, each of these three broad headings subsumes myriad discrete machine characteristics, factors that determine what the overall quality of a machine might be.

Given the magnitude of the information problem inherent in quality assessment, the actual end-user of the machine is best suited to determine when specific features are useful for the intended purpose. That is where the greatest store of information resides about what a piece of equipment is intended to do, what it actually does, and how well it fits into the prevailing production process. The user's information should be decisive for influencing decisions over the types of machines to be manufactured. Indeed, recent research suggests this store of local information is so preponderant that in many instances users may play

a much larger role in actual machinery design and innovation than was previously thought (von Hippel, 1988). In this new view it is the user, rather than the manufacturer, who identifies needs and initiates steps to meet them. However, this can be the case only in the absence of institutional constraints on the user's ability and willingness to render effective judgments.

The buyer of the machinery must have an incentive to be discriminating. To the extent that the purchaser's budget for capital investment faces a hard, binding constraint, there will be more probing scrutiny of the equipment to be acquired. The less the end-user is made financially responsible for the purchase of poor quality equipment, the less judgment need be exercised so long as the purchasing enterprise's ability to meet its own goals is not compromised. This has traditionally been the case in the Soviet Union where central authorities possessed sole control over flows of investment resources. These were provided effectively without cost to the enterprises. Past attempts to make enterprises more accountable for the results of investment choices have been compromised by the possibility of *post facto* negotiation, blurred lines of accountability, and soft budget constraints.

The Law on the State Enterprise was enacted partly to address this problem. The ideal is now for enterprises to become self-financing and assume full economic accountability. Investment resources are to come from internal funds and repayable bank credits.

Only during the transitional period . . . will it be necessary for enterprises to be compensated from centralized funds. . . . Obviously, the norm [for profit retention] should be differentiated taking into account the degree of wear and tear on enterprise equipment and also the rates of growth and updating of its products that ensue from state orders and contracts. (Grishchenko, 1987.)

It is one thing to state such an intent and another to achieve it. "Transitional" periods have shown a disquieting tendency to be of extended duration in the Soviet Union and in other centrally planned economies engaged in economic reform. An important role remains for the central authorities in setting the norms governing investment fund formation. The draft version of the Law on the State Enterprise (Association) provided for all depreciation funds for renewal and retooling to remain at the disposal of the enterprise, in accordance with the principle of self-financing. However, the final version allows ministries to set "prescribed normatives" for the share of depreciation funds retained by the enterprise. The reform economist L. I. Abalkin has stated that central policies of redistribution lead to a shortage of funds for capital renewal. The language in the decrees on state orders

makes it perfectly legal for a ministry to turn this theoretically economic lever into a "traditional edict method" of administration (Rytov, 1988a).¹

This leveling continues to apply to the revenues of enterprises within a branch, bolstering weak or unproductive collectives. "The brakes have been applied" to the implementation of economic accountability and self-financing and funds are still confiscated to support faltering enterprises (Cherniak, 1988). "Distribution of income is problem number one." It is not clear that under the conditions currently obtaining in Soviet industry, enterprise management will feel itself more in control over its investment decisions, nor will it necessarily have greater incentive to be discriminating in machinery selection because of greater accountability.

Another prerequisite for the end-user to be an authoritative judge of machine quality and a wielder of influence over machinery manufacturing decisions is the possession of adequate information. There must be both sufficient information available to assess quality and channels for communicating this assessment. Soviet enterprise managers have not been blessed with many opportunities to gather information, either from the outside world or from within the Soviet Union itself, upon which to base assessments of quality. In many branches there is little awareness of foreign production practices or equipment. Often there is little enough contact with the experts on, and designers of, Soviet machinery. The enterprises are left to figure out as best they can the optimal operation procedures for the machinery they are given. What information they do have is based upon observation within their own plant. Even this may be severely limited in usefulness by inefficient means of communication within the enterprise or may be subject to skewed assessment because of interests that coincide with only a subset of the performance indicators. Section IV will deal more fully with the problem of information within the enterprise.

Even if enterprises have an incentive to make accurate quality assessments of their equipment and have sufficient data for an informed judgment as to what characteristics they feel worthy of emphasis, there must be a channel for communicating these evaluations authoritatively to the machinery producer. The simple exchange of data and experience has been frustrated by traditional Soviet

¹"In the past, before the switch to self-financing, an enterprise could keep 70 percent of its above-plan profit. Now, when working for oneself should be encouraged even more, a plant has the right to keep only 30 percent." The author, an enterprise manager, cites another factory in his city of Sverdlovsk making a similar product. There the norm for wage fund formation is 0.7 percent for every 1 percent increase of net output versus 0.3 percent for his plant. The only reason for the difference is non-economic: access to the minister's ear (Yefimenkov, 1987).

economic organization. Information flows have been largely constructed to move vertically; plans and indicators are received from above while information on performance is forwarded from below. Horizontal information flows between enterprises have been attenuated. This situation is exacerbated when the producers and the users of machinery are in two separate ministries—that is, in two different, largely self-contained, hierarchies of information flow. Cross-ministerial communication has been notoriously difficult throughout the period of command planning and has affected Soviet ability to innovate quickly and tailor output to requirements.

Implicit in the logic of the Soviet economic system as it existed in the past was the need for an over-arching intelligence guaranteeing that the various agents, operating within the existing system of incentives, would be working together. Incomplete information and inadequate means for processing it meant that intelligence could not gain the omniscience necessary to play its intended role.

Recently, aspects of reform have been introduced to redress these problems, but the results have been meager. Incentives are simply lacking. A discussion in the Council of Ministers “proved that many vertical ties have *already* been broken during the process of the pyramid’s ‘shake-up,’ while horizontal ties have *not yet* been established” (Valavoy, 1988; the emphasis appears in the original). Little has been done to change the asymmetry of power between quasi-monopolistic producers and input-starved end-users.

There is a more active aspect to horizontal communication of information. This entails end-users of capital equipment informing machine builders of their specific machinery needs in an authoritative manner. But problems of monopoly and local market power remain; producers are unwilling to produce and consumers are unwilling to accept orders. The customers of the machine builders are not in a position to exert authority and to communicate their information actively. There is still pressure to strengthen these linkages in typical Soviet fashion through bureaucratic means and formal vertical integrations. Such organizational complexing comes at the expense of enterprise autonomy. The Chairman of the Machine Building Bureau has stated that “life² insistently calls for production to be organized in large units that handle everything from R&D to final delivery and servicing of a working system.” He has called for yet another new organizational form, the State Production Association (GPO), to provide authoritative communications between machine builders and machine users. “There is a danger that State Production Associations will

²For which we might read “Soviet experience.”

become monopoly producers, thus increasing *diktat* over consumers. But this will be mitigated by the system of competitive state orders, and by the new management mechanism and Law on State Enterprises" (Silayev, 1987).

This is an admission from the highest authority that under present conditions producers cannot be held accountable by their customers. If there was no other intervening authority the modernization effort would follow the same worn patterns of the past. Whether the reform policies already instituted, along with those currently in prospect, will eventually alter this asymmetry of authority is a question beyond the scope of this study. However, the creation of *gospriemka*, and the great emphasis laid upon it, is tacit admission that at least under present circumstances the end-user is not in a position to set and enforce standards of quality.³ The state will be the arbiter.

A system of state-enforced standards for judging the quality of output will most likely not equate to economic utility. In its simplest form, this might be understood as a problem of information. As has been suggested, "quality" stems from many characteristics ranged along several dimensions. To be aware of all these factors, to assess them properly and in a timely fashion, and to remain current as they are modified is a greater task than Soviet (and other) bureaucracies have shown themselves capable of in the past.

The difficulty goes beyond one of gathering, processing, and analyzing information. There are also conflicting local interests, differences in interpretations of the campaign aspects of the modernization program, and asymmetries in understanding the proliferation of machine varieties and characteristics.

The setting of state-imposed quality standards, coupled with the restrictions on practical enterprise authority that Soviet institutions impose, means that during the modernization drive technology choice will be the decision of ministries and other state organs. Indeed, this is given the imprimatur of *perestroika* because one of the roles left to the ministry by the formal documents of reform is to act as the planning staff for technological development of the branch. The results will not be the ones the drafters of reform intended.

THE DRIVE TOWARD THE TECHNOLOGICAL FRONTIER

Central administrative control over quality assessment is most problematic for the assessment of the appropriateness of a given machine

³For support, see also A. Petrov in an untitled article in *Argumenty i Fakty*, No. 18, 1988, p. 8.

for its intended purpose. The system does not use the full range of information available in the economy, particularly the great repository developed in the daily experience of production managers. This is perhaps the most important information source in any economy, but certainly one of the least utilized in the Soviet system. No matter how sophisticated the algorithms used to calculate the quality of a machine, the set standards will depend on rules of thumb based upon easily quantifiable aspects of quality. These are not necessarily equivalent to the choices that end-users possessing customer sovereignty would make.⁴

The rule of thumb for determining output quality given most prominence in the campaign accompanying the current modernization program is to assess the technological level, measured against an inferred world standard. This appears, on the face of it, to make practical sense. Given the shortage of meaningful information in the Soviet system, the Soviets identify world best practice to divine the direction for developing their output profile.⁵

Such a system seems to conform to the abiding interests of the Soviet leadership if, indeed, one of the prime motivations of the drive to modernize is a perception of increasing technology lag. Therefore, the Soviet leadership say in their messages to all levels of the machine building sector's hierarchy: The greater the fraction of the nation's output that may be classified as equivalent to leading technologies found elsewhere, the more it may be presumed that the technological gap has been closed and the efficiency and modernity of production found abroad successfully emulated at home.

There are several problems with this approach, both in theory and in practice. The campaign rhetoric suggests that the Soviets envision a well-defined technological "frontier" clearly indicating the route to be followed in machinery design and production. The reality is not nearly so clear. In any sector of production, best practice consists of a continuum of technologies selected according to the circumstances attending their use. Many may be found operating, to one degree or another, at the same time in different production locales. In addition, even if a technological "frontier" can be identified through objective means, the question of the dynamic path one takes to achieve this level is not easy to resolve and will surely depend upon local circumstances.

⁴A price system not based on real resource costs makes it difficult to calculate the balance between the marginal cost of a design feature and its contribution to marginal revenue product in the Soviet setting.

⁵This is roughly analogous to the scheme used to generate efficiency prices for hard goods traded within the Eastern bloc (CMEA) market. The CMEA price is based upon a five-year moving average of the hard currency market price. The necessity for such a scheme stems from a similar inability to generate meaningful information within the system.

Sophisticated Soviet observers are aware of this. But a large-scale state program of administrative control over quality standards, hence output choice, cannot operationalize these subtleties. Someone must choose the standards to be enforced. So why not let increasing technological sophistication be the prime criterion? After all (we might hear the Soviets say), high technology is what seems to determine industrial power today, and high technology is what the Soviet economy needs.⁶

This view illustrates the drawback of substituting a set of administrative standards for absent customer sovereignty. To put it quite simply: The Soviet Union does not need high technology. Nor, for that matter, does any other economy. What it needs instead are those technologies that will render the industrial capital stock highly productive and efficient. High technology is important, but not necessarily *all* important in achieving this goal. Yet, the code word has become the standard for determining success in machine building.

Maximum emphasis is being placed upon achieving or surpassing the international level for equipment. Great importance is being attached to determining this level and to guaranteeing that designers not only stay on top of world developments but anticipate future development trends and incorporate them in current designs.⁷ The head of the Machine Building Bureau, I. S. Silayev, has stressed that designers must not wait for orders to come in for new technological forms.

Today's most important task is to create high level technology. Such is born not in production, not in the workplace, but rather in the scientific-research institute and design bureau. If the designer waits for someone to suggest the form of a new technology, then he has simply not earned his title. (Peshlakov, 1987.)

It is the nature of a campaign that the message becomes simplified. This means that the axis along which products are being judged in the Soviet Union has often become unidimensional in practice. Machine-building enterprises are rewarded for producing goods incorporating technologies viewed as "advanced" and penalized for producing goods employing older technologies. To the extent that a second axis of quality assessment is used, it looks to the reliability of the machinery. Because of the effective disenfranchisement of the purchaser of

⁶Note the deliberate ambiguity in the term *high technology*. It could refer either to a higher standard of machinery output in general, or to a specific class of goods employing microelectronic, cybernetic and other advanced technologies. The ambiguity reflects the actual muddle that has appeared in the definition and execution of modernization and will be discussed below.

⁷See, for example, the remarks of the Minister for General Machine Building, O. D. Baklanov in the TASS report, "Novie rubezhi pererabatyvayushchei promyshlennosti," *Sotsialisticheskaya Industriya*, October 20, 1987, pp. 1-3.

machinery from the process of qualitative evaluation, the third axis, suitability to the intended purpose, itself multidimensional and subject to change, is difficult to incorporate.⁸

A deputy director of a machinery research institute explains what this means in practice:

The branch research institutes of light industry send out to the machine builders demands for new equipment with an overriding concern [*ozabocheny v pervuyu ochered'*] for the technical level of the forthcoming machine. [The technological level] is determined by a concatenation of numerical indicators (productivity, weight, power consumption, etc.). The price of the item is not included in the number of indicators, that is, today the technological level appears as a non-economic category. (Khavkin, 1987.)

He then provides insight into the technique employed to reconcile the various indicators of technological level. The indicators are set equal to those characteristics applying to the best foreign analogues (the best are chosen among those having the highest indicators), and if the machine does not lag in any parameter it is considered to correspond to the "world level." If, however, it lags in any single indicator, it is considered not to correspond to the world technological level. "It is forbidden to produce such an item" (Khavkin, 1987).⁹

This principle pervades all aspects of Soviet thinking about technology acquisition. Recently, an American eager to establish a joint venture to distribute personal computers in the Soviet Union spoke about his frustrations with the effort.

That was terribly, terribly frustrating, because every time there was an advance in technology, that is what they wanted at the Academy of Sciences and the State Committee on Science and Technology—and that is precisely what they could not have because of the restrictions on technology transfer. . . . In fact, what they should have been buying was what was widely available and what was well within the restrictions. They would have modernized at a much, much faster

⁸This also suggests that an important element validating the quality assessments that are made along the second axis may often be absent as well.

⁹That this is literally the system used, not a reification for didactic purposes, may be inferred from a recent article suggesting a new approach intended to replace the standard practice by increasing the number of axes for quality assessment (Bogomolov and Tsaregradskii, 1988). This new model, however, seems only to amplify current predispositions because the major new axis for assessment is the scientific-technical progressiveness of the good. An earlier RAND study also has found that equipment is not adequately described by a handful of parameters but probably depends on scores of descriptors; each user has to evaluate these in the context of its own situation. "The use of [a smaller subset of] product characteristics as a shortcut to measures of value and performance is an uncertain undertaking and cannot be counted on to produce adequate measures of technological change" (Alexander and Mitchell, 1984, p. 52).

rate if they had done so, and the only thing stopping them was their own attempt to get the maximum.¹⁰

A DOCTRINE OF "REASONABLE SUFFICIENCY" IN TECHNOLOGY

The emergence of a new technology by no means suggests that the economically useful applications of previous technological approaches are exhausted.¹¹ The selection of the appropriate technology to be employed should be based on criteria other than mere technological feasibility. Failure to exercise selectivity would lead to efficiency losses in the economy for three reasons. To produce machinery incorporating technology too elaborate for the intended task is to impose unnecessary costs upon the economy as a whole. The costs are compounded if the new equipment does not perform the intended task as well as the equipment it replaces. Finally, if the equipment is so sophisticated that it is beyond the means of the recipient to utilize the new equipment in an appropriate manner, the loss to the economy may be total.

A doctrine of "reasonable sufficiency" for assessing the capital equipment requirements of a manufacturing sector is required. The problem of choosing the output to result from investment for the purpose of materially affecting the efficiency and productivity of other branches of industry is not a trivial one. As one Soviet analyst has pointed out, the movement from scientific idea to finished technical solution must also take into account existing production apparatus, technologies, and equipment.

Under these conditions, in announcing a particular work and calling for its introduction, scientists and planners can involve the economy in rather risky measures and bring about the expenditure of production savings for extremely doubtful purposes. . . . The danger arising from an incorrect determination of the "international level" turns out to be even more considerable when, not having stated 'A', one hurries to pronounce 'B'—the production of certain technical units is undertaken in the absence of the required preparation for such work. . . . This lamentable example [of production and introduction of robots] proves once again that reliance should not be placed only upon the

¹⁰Michael Parks, "Moscow Print Shop Is Latest Beneficiary of Soviet Glasnost," *Los Angeles Times*, March 12, 1989.

¹¹For example, the coal-powered steamship was clearly a more advanced technology than the wind-powered sailing ship. Yet it was only in the last quarter of the 19th century, 50 to 75 years after the invention of the steamship, that the technology of sailing achieved its acme of perfection in the form of the iron-hulled windjammer. In fact, the economically useful life of sailing vessels would have probably been even longer had it not been for such exogenous factors as the Civil War's depredations upon the U.S. merchant marine.

increasing potential of the scientific-technological revolution during the planning and production of new equipment. (Kheynman, 1988.)

The Soviet economy needs to be made more efficient in the use of its material, labor, and intellectual resources. But that does not mean the technology to achieve these ends needs to be leading edge technology in each instance. And although it is true that Soviet machine building needs to produce more output of world-class quality and to master emerging technologies, in a certain sense Soviet industry must learn to walk before it can run lest it stumble badly (and expensively) in its attempt to contend in the race. Or to extend the metaphor, there should be some means for deciding when it is appropriate to walk and when to run.

SHUTTLELESS LOOMS IN TEXTILES

The case study of the shuttleless looms illustrates how state-imposed standards may lead to inappropriate choices in machine building and efficiency losses to the economy.¹² The example deals with a traditional rather than a higher-technology manufacturing process, in a branch with a fairly uncomplicated production process. The problems are magnified as the complexity of the task and sophistication of the equipment increase.

Soviet textile enterprises have long complained that only one machine-building plant, the *Tekmash* production association in Klimov, produces the ATPR, a rapier-system shuttleless loom. The output from this single plant has been insufficient to satisfy the demand of textile producers (Khavkin, 1987). Instead, the textile machine-building plants, soon to be joined by the Klimov enterprise, produce a type of shuttleless loom that uses a more recently developed (hence presumably superior) technology. There is reward in this for the machine builders: The machine has been certified as "world class," so it can be sold at a bonus. The old type is less technologically advanced and carries a low-level certificate of quality, imposing a penalty on the manufacturer.

The textile enterprises cannot use the new loom as successfully as they could the old. It is less reliable and more difficult to repair, it takes up more room (a consideration, since access to construction resources is a bottleneck), and, paradoxically, because of the low quality of raw material inputs to textile manufacture, the rate of yarn

¹²This example, as well as others to follow below, draws upon work discussed in greater detail in a recent study of modernization in the Soviet textile sector (Popper, 1989).

breakage is higher on the more sensitive new machines so production is slower and more labor intensive. In this case the search for the leading edge appears to have imposed a tangible cost on the economy to little purpose.

It is important not to overstate the case for restraint in operating a modernization effort under a narrowly defined technological imperative. Yet this example has a bearing on the extent the program of modernization in machine building will fulfill the expectations of the Soviet leadership.

THE LOSSES FROM INAPPROPRIATE TECHNOLOGY CHOICE

The intent of the modernization program is to provide the means for the Soviet economy to use resources more efficiently, but the institutions for choosing these tools lead to efficiency losses because of inappropriate choices. "An automatic cannon equipped with microprocessor is not needed for firing at sparrows and a simple, cheap cutting machine is fully adequate for obtaining billets from steel rod. Instead of this, in actual practice, and also during the threading of nuts and screws, for some reason they are attempting to employ ultra-modern equipment" (Kheynman, 1988). These losses take several forms.

The Misallocation of Means to Ends

The administrative approach currently in force uses standards that must be viewed as arbitrary. Indications about what equipment to produce may come from outside the system, the "technology frontier" or "international level" approach, or else may be generated by decision-making calculations internal to the system. The former method can be successful only if the observations are validated by the results stemming from the second. Under the current conditions in Soviet industry, the internal means are inadequate to the task, so increased emphasis is placed on external observation.

That decisions have been made based upon observation of the technological "frontier" with insufficient thought for the utility of the resulting output is clear from the example of the shuttleless looms. The costs mount as more advanced and expensive manufacturing equipment becomes the object of this calculus. Soviet commentators have stated that decisions over the production of numerical control equipment, robotic devices, and even entire flexible manufacturing systems have been made for reasons of prestige rather than as the result

of economic calculation. As an example, some 294 flexible manufacturing systems (FMS) are supposed to be in operation in the United States by 1990, but the number called for in the Soviet Union is to be over 2,000 by that date even though those installed up to now have been termed a "total loss" (Vasilyeva, 1988). In 1986, the Experimental Science Research Institute for Metal Cutting Machine Tools reviewed over 300 ministry requests for FMS installations and found only 35 were "sensible and well-founded." Nevertheless, all were included in the Gosplan nominal list—"for the sake of a satisfactory report" (Volchkevich, 1988b).

The means for determining the economic utility of pursuing a technological path are inadequate to the task of providing the necessary information. A voluminous Soviet literature provides formulas and rules of thumb for calculating the expected return for a series of alternative investments. These are, almost without exception, useless for the intended purpose (Budnikova, 1986). The data to be fed into such formulas are highly questionable because the price system fails to convey information on true opportunity costs. Soviet critics have called attention to other shortcomings. A survey of 15 machine-building enterprises disclosed that 26.7 percent of metalworking equipment was not used over the course of any given day, double the rate assumed by Central Statistical Administration (Ilyshev and Ilysheva, 1987). There are frequently basic problems in methodology: In some instances wholesale prices are used, and in others, discounted expenditure calculations, yielding contradictory conclusions.

Such formulas are highly susceptible to manipulation and are most often used to justify a position rather than to serve as tools for decisionmaking. A 1986 study showed that economic effects are exaggerated in 80 percent of cases, and by more than 30 percent of the "correct" figure in 30 percent of the cases.¹³ Several important parameters (the standard efficiency coefficient of capital investment is an example) are based upon the subjective calculation of experts. In some cases there is an option of using any of several formulas to calculate economic effect. This permits tailoring the result to suit the desired outcome. Still further, such calculations are employed to obtain solutions to narrowly stated questions. An economic assessment of possible damage to the national economy or to the social fabric from implementing specific scientific and technical measures is not considered.¹⁴

A spot check of economic effect calculations for new technology at enterprises in Minsk revealed that in only a few cases was the

¹³V. I. Shprygin, "Kak sozdat' protivozatratnyi bar'er," *Ekonomicheskaya Gazeta*, No. 32, July 1986, as cited in Bornstein (1987).

¹⁴Of course, neither would a market system consider factors external to specific markets.

methodology applied correctly. The necessary calculations are complicated and require considerable special training to apply. Much has been published on this score. Yet nothing obligates management at the higher levels of planning and decisionmaking to study this literature. Even personnel at the machine-building enterprise itself are sometimes poorly acquainted with them. Given this, "in practice, it is impossible to establish whether the basis for comparison, when the economic effect of new technology is determined, is selected correctly" (Budnikova, 1986).

In spite of the best efforts of Soviet economists to invent sensible calculations for determining the direction of machinery design, they will not be applied if the machine builder has no great incentive to guarantee a satisfactory outcome.

Functional value (*funktsional'nii stoimostnyi*) analysis is still being used on an insignificant scale in the creation of new technical equipment although we have worked out this methodology fairly well. The result of this neglect, on the one hand, is that many kinds of equipment are manufactured at a loss and as a result the resource-intensiveness of the introduction increases and, on the other hand, the consumer qualities are inadequate and this causes an increase in operational expenditures when utilizing this equipment. (Karpunin, 1988.)

And, of course, no matter what course of action the results suggest, these calculations are routinely set aside by higher authorities in making decisions. Neither the end-users of manufacturing equipment nor their algebraic proxies, the results from calculations of economic effect, are the true authorities over what machine types are actually produced.

A potential source for improving economic efficiency by identifying situations where the use of older technologies is satisfactory is lost to the Soviet economy. Where resources are limited and any advances are likely to require a great deal of assigned priority and attention from higher organs of economic supervision as well as cost to the economy, the Soviets cannot be certain where to direct their efforts to best advantage. This will be costly. Given the prominence of the campaign to achieve the world technological frontier, there will be a tendency to use technology overkill in the design and production of manufacturing equipment.

Indeed, the use of the standard calculations even reinforces the view that modernization is following the correct course and that the technology frontier approach best suits Soviet reality. S. Perminov, the Director of the All-Union Scientific Research Institute on Economic Problems in the Development of Science and Technology, offers data on industrial performance according to technological level, defined by the

degree of automation. In the high-technology sector, labor productivity increased by 140.3 percent from 1970 to 1985, and the "return on capital" 19.1 percent. In the middle- and low-technology sectors, however, the labor productivity increase was less pronounced and the measured returns on capital declined by 25.4 and 40.5 percent, respectively. The prognosis for 2000 is for all trends to continue strongly in their current directions. The general conclusion is "in technical re-equipping, reconstruction, and new construction it is necessary to ensure the highest technical-economic level, skipping the middle level" (Perminov, 1988).

The definition of high technology used to generate these data is problematic.¹⁵ Further, return to capital depends crucially upon the value of the resulting output. Indeed, part of the observed effect could be due to the mere presence of these means of production. They might signal that the ensuing output should earn the "N" index, awarded to fundamentally new commodities, and be sold at a premium. This is the means for passing along higher costs and earning larger returns. Higher prices mean higher revenues and a more positive yield on capital investment. The quality of the output could even be inferior to what has been produced on lower-technology capital.¹⁶

This provides a strong argument in favor of price reform and a fundamental break with mark-up pricing policies. It also illustrates that the technology frontier approach to technology choice stems from the well-ingrained predispositions of policymakers and will not be easily modified as long as they can be substantiated through such methodologically ill-defined calculations.

The paradoxes of the present approach are illustrated by several cases. The Nekrasovskii Machine Building collective was forced to discontinue the only product it was successfully exporting for hard currency, a simple seed-hulling machine. It had been in production continuously for four decades and was always in demand. When the criteria of quality assessment were amended, the lucrative seed-hulling machine became one of the collective's loss-makers overnight. The equipment was refused certification because it failed to meet standards. I. Klimenko suggests that this product was a casualty of the system's tendency to carry on "playing at indicators" with respect to quality assessment. He asks, "Is it not time for us to settle the question of our products' compliance with world standards? Is it still possible to put

¹⁵ It is tautological to use labor productivity as a measure of differential performance when distinguishing between technologies by degree of automation.

¹⁶ One could go on. Are the recoupment periods of equal length? Is the older capital being depreciated appropriately? Are the results from an aggregate survey or a sample? If a sector receives priority and therefore is less likely to suffer from bottlenecks, shortage of spares, and other checks to productivity, is it more likely to receive advanced technical means?

these standards in their proper place, turning them from an end into a means? A means for achieving competitiveness for our products in the world market" (Klimenko, 1988).

The Belgorod Production Association "Energomash" produced a new freezer for ice cream production. The freezers cost only 1,900 rubles, worked well, and were profitable. But the freezer was denied certification as not being of world standard quality. It was impossible to place orders for parts and materials; the design never went into production. Now the association is trying to make a more contemporary freezer to meet standards. When the formerly successful association makes the transition to *khozraschet* it will be in trouble because no freezers will appear in 1988 or even 1989. "Thus, it appears it is better to make nothing at all than something useful and very necessary. Isn't correspondence to the world level being upheld too literally if such correspondence isn't dictated by life's necessities?" (Antropov, 1988).

To be sure, there are two sides to these stories. The leadership feels a need to impel machine builders to produce more challenging output and not to complacently turn out the old comfortable assortment. Technology choice is made by compliance with fiat, no longer in the form of direct commands but embodied in the guidelines for the state assessment of quality. But this mechanism is not well suited to distinguish between what is truly obsolescent and what meets the standard of technological reasonable sufficiency.

Specific Problems: General Solutions

A second type of loss comes from new equipment that does not perform its intended task well. Hegel's meditation on the relation of the Universal to the Particular has application here. To paraphrase the philosopher, "No man has ever eaten a piece of fruit." One may eat a cherry, a pear, or a grape; one cannot eat something called "fruit." Similarly, in the Soviet system, state authority utilizes a campaign—given considerable institutional teeth—to implement its vision of what is needed to provide industry with the equipment necessary to be productive. The producers of the equipment concern themselves primarily with pleasing their superiors in the hierarchy of the machine-building sector. As a matter of practice, it will be difficult for specificity to enter into the decision over what equipment the economy actually needs to see produced.

The changing nature of manufacturing technology and the proliferation of new capital types, precisely those the modernization program is intended to provide, might exacerbate the attendant losses to the economy. At one point in Soviet development, setting a priority to

produce more "lathes" versus more "looms" perhaps gave a useful policy direction for machine-building priorities. Current statements such as "We have a need for more modern textile machinery," "We must increase the output of numerical control equipment," or "The current plan period will see the installation of 342 flexible manufacturing systems in machine building alone" may be viewed as stylized abstractions necessary to convey a general sense of what is required. Little has been done to increase the specificity of the decisionmaking mechanism at a time when one can no longer usefully speak of "lathes," or "looms," or even "shuttleless looms," but must specify a large assortment of pneumatic, or rapier-pneumatic, or hydraulic, or micro-shuttle shuttleless looms, weaving two, three, or four yarns with a width of 120, 180, or 240 centimeters, any combination of which will be the best application to one specific output type and production setting but not to others. Only an authoritative final user of machinery will be able to systematically render the distinction between "fruit" and "apples."

As a result, Soviet machine builders tend to produce general machine types rather than purpose-built machinery. Machine builders continue to design and build those machines they already know how to build and that emphasize easily quantifiable machine characteristics of interest to external arbiters of quality and plan fulfillment.¹⁷ For every 100 standard turret lathes, there are 46.2 specialized cutting machines in the United States and 8.9 in the Soviet Union; 10.9 bolt- and nut-threading machine tools in the United States and 2.7 in the Soviet Union. The more limited assortment of machine-tool types in the Soviet Union means that metal fabrication is a higher-cost and more metal-intensive, hence energy-intensive, industry than it need be. This applies to the metal to be cut as well. The Soviet Union's domestic ferrous metallurgy industry offers its customers a product line including only some 4000 basic rolled metal shapes, while a single West German firm, Klekner's, "which produces fewer products by far,"¹⁸ is prepared to supply 10,000 shapes (Kheynman, 1988). A Soviet enterprise must spend more time cutting metal than its Western counterpart. The limited number of basic metal shapes must

¹⁷This tendency also stems from the persistence of supply shortage and the underdeveloped nature of the "upstream" relationships with potential suppliers to machine builders. The result is extreme vertical integration within enterprises. Large machine-building plants house a range of auxiliary production facilities. Tens and sometimes even hundreds of thousands of elementary parts and components are manufactured at these enterprises (Karpunin, 1988). This reduces the ability to produce a line with many variations on the basic machine types. Another factor reinforcing a predilection for general machine types is the law allowing a prospective recipient to refuse a contracted equipment delivery up to 45 days before the start of a plan quarter (Yegorshev, 1987). Machine builders are therefore reluctant to build a machine designed to meet the needs of only a specific enterprise.

¹⁸Presumably by volume.

also act as a barrier to the production of specialized machinery, adding yet another hurdle for the potential producer of such equipment.

The problem becomes more serious the more complex the technology. In the Soviet robotics industry, as the logic of the system would suggest, heavily standardized components and subsystems have been used to produce only a narrow range of product types. In the West, a similar modular approach was tried but found to be unsuccessful. Robots need to be custom built or closely adapted to particular applications to achieve their promise (Shaffer, 1987). Similarly, the Soviet approach has been to place a priority on the production of entities called "flexible manufacturing systems." This is a bit like calling for more "assembly lines." The concept is meaningless unless it is specified precisely what types of systems, how they are to be "flexible," and what the systems will manufacture.

Reports on plan fulfillment will note, for example, that whereas during the first four months of 1988 the machine-building sector's contract fulfillment was 99.3 percent for the sector as whole (compared with 98.3 percent during the previous year) with a 6.6 percent growth in production volume, 39 percent of enterprises failed to fulfill their individual contracts (Goskomstat, 1988). In the Ministry for Heavy and Transport Machine Building, 62 percent of enterprises failed to meet contract obligations. Corresponding figures for the Ministry of Construction, Road, and Municipal Machine Building were 56 percent; for the Ministry of the Electrical Equipment Industry, 52 percent; and 42 percent for both the Ministry for Machine Building for the Chemical and Petroleum Industry and the Ministry of the Automobile Industry (Rytov, 1988b). The sector ruble output plan is being met but enterprises are unable or unwilling to comply with the plan on assortment by producing the items called for by individual contracts. Several enterprises are unilaterally refusing to supply planned output or are substantially reducing deliveries (Valavoy, 1988).

A drive to produce equipment specifically designed with a single purpose in mind might be more appropriate than a standard that places a premium (literally) on the use of more advanced technologies. It may be better to have "good old" machines than "bad new" machines. Indeed, there have been repeated calls from within the Soviet Union for machinery production to be given this tenor. This, however, assumes more of a buyer's market than is currently the case. The purchaser needs some way to forcefully draw the attention of the manufacturer to a specific need. In its absence, the tendency will be to conform to the simple message of the campaign to increase the technological level of output and to produce general machinery that demonstrably achieves a set of characteristics by which the assessors of quality have set great store.

According to M. Shkabardnya, Minister of the Instrument Making, Automation Equipment and Control Systems Industry, the machine-building sector will meet 1989's target of having 75 percent of its output classified as meeting "world standards." But he himself expresses a certain disquiet at what such an aggregate figure, expressed in rubles, may actually mean. He suggests that "it is necessary to give some serious thought to the methods for determining compliance with world standards" (Klimenko, 1988).¹⁹

The current emphasis on defining and achieving the world technological frontier is a symptom of a systemic inability to determine the true equipment needs of industrial enterprises. A machine-building enterprise, using its best efforts to produce a machine demonstrably superior to those it has been producing heretofore, nevertheless produces equipment found to have a deleterious effect on its customer's quantity and quality indicators. In the absence of means for generating data upon which rational choice may be based, and an inability to give end-users authority over assessments of the quality of machinery, the Soviets are reduced to casting envious eyes on the capital base of the developed West. The central authorities in the machine-building sector are drawn to what is emerging on the margin, rather than assessing the full capital stock of these economies to gather a clue as to what they should be trying to do. The result is inappropriate choices, squandered national resources, and, as a crowning irony, lost time in furthering the development of Soviet industry.

¹⁹The share of new machinery awarded the highest certification of quality rose from one-quarter in 1980 to one-half in 1985 in response to a premium for quality output (Bornstein, 1987, p. 109). The speeches and antistagnation polemics of the Gorbachev era indicate just how invalid a measure of quality this was.

IV. THE PERSISTENCE OF INEFFICIENT UTILIZATION

The modernization drive addresses negative phenomena stemming from two different problems. The first is the more obvious of the two and receives the most attention. The Soviet Union's machinery stock does, indeed, consist of a large proportion of old machines. This machinery is old both in the average age of the individual pieces of apparatus and the vintage of technology it embodies. In addition, because the research, development, and innovation (RDI) cycle in the Soviet Union takes so long, there is overproduction of machinery young in age but old in nature and performance characteristics.¹ It is to these issues that the modernization program is addressed.

The perception of this first problem of technological inadequacy may mask a second problem as serious as the first. The Soviet industrial machine stock, of whatever vintage, is not used efficiently.² The Soviets are aware of these difficulties. A major source of information on this score is the open Soviet press. The subtlety is in seeing the connection between inefficiency and technological backwardness. The modernization program treats these as separate issues. Modernization will address the hardware problem while the reformist elements to be gradually introduced into Soviet economic life will deal with the problems of efficient utilization. However, large investment in advanced manufacturing technologies could exacerbate existing problems and lead to further efficiency losses. Moreover, to the extent that the problems of efficient utilization are inadequately addressed, the preoccupation with investment could undermine whatever success the modernization program has.

SHUTTLELESS LOOMS REVISITED

The case of shuttleless looms, discussed in Sec. III, will serve for illustration. The weavers' complaint was that the looms embodying the

¹The average duration of the development stage alone is 6 to 8 years for new machine types. As a rule, new equipment is perceived as obsolete before it is introduced into wide use. By contrast, the entire cycle of RDI is 6.4 years on average in the United States, 5.6 years in West Germany, and 3.6 years in Japan (Zaichenko, 1988). The ultimate source of the data is not cited.

²Koppel (1985) states that small-scale numerical control machine tool work stations in Estonia are in production no more than 600 to 900 hours a year; 80 to 95 percent of the time they are waiting for components.

newer technology were not suited to the poor quality of the raw material inputs they received nor were they appropriate to the conditions under which weaving occurred in their plants. However, the manufacture of textiles is, in fact, one instance where it is possible to use technical means to compensate for low material quality and still produce high-quality outputs.³ In this case, the textile manufacturers would need to add several preparatory steps before weaving to strengthen the yarns to be used. Breakage could also be substantially reduced if the weaving machinery were operated a bit more slowly in exchange for increased quality. Were the textile enterprises to readjust their production process, they would be able to benefit from the greater capabilities of the new machines. Why don't Soviet enterprise managers readjust their production systems to make best use of new and more capable capital types?

SYSTEMIC SOURCES OF INEFFICIENT UTILIZATION

The first reason may simply be ignorance. The technical staffs are unaware of the various methods for improving output quality. The predominant orientation of this industry, and of many others in the Soviet Union, has been overwhelmingly toward the domestic market. Wide knowledge of the available range of manufacturing techniques and output choice is not one of the hallmarks of Soviet industry. Generally, Soviet manufacturing enterprises are not well placed to acquire this information except from research institutes within the branch. The quality and quantity of information the institutes give may vary greatly and profoundly affect the success of a technical reequipment program (Lysaya, 1984).

The manufacturers might be affected by a shortage of material resources as well. Given the chronic excess demand characterizing much of the market for producers' inputs in the Soviet Union, it is not an easy matter to acquire the chemicals, instruments, installations, or construction materials required to utilize the possibilities for improving quality.⁴

³Technical insights on textile manufacture were obtained during discussion of this example with staff members of the Institute of Textile Technology, Charlottesville, Virginia.

⁴Construction resources are an especially tight bottleneck, even for a priority sector like machine building. The shortage is exacerbated by long gestation periods. The norms for new project construction compared with the actual average durations of construction projects for several civilian machine-building ministries are 3.5 versus 12.2 years for the Ministry of Transport and Heavy Machine Building, 3 rather than 7 years for the Ministry of Electrical Equipment, and 4 rather than 7.5 years for the Ministry for Tractors and Agricultural Machinery. In the last ministry two plants are still under construction, one after the passage of 10 years and the other after 18 years (Silayev, 1988).

To continue with the textile example, one of the simplest ways to reduce yarn breakage is to allow the raw fiber to sit in storage for several days so its internal moisture content will equilibrate to the humidity of the weaving plant. A Soviet textile producer may not be allowed even this simple expedient to use the new shuttleless looms more effectively. Delivery schedules for inputs from quasi-monopolistic "upstream" suppliers are uncertain and output guidelines are monitored by higher authority. When stock arrives, it must be used immediately to meet enterprise output targets.

This is a derivative symptom of a more fundamental dysfunction. It is not clear that a sufficiently strong incentive exists for the machine-using firm to engage in the profound dislocations necessary to adapt to the requirements of newly adopted machinery. Textile enterprises do not possess sufficient sovereignty over their production processes or output decisions to be able to utilize these means. For example, operating production machinery more slowly and taking extra steps would lengthen the time of production runs, adversely affecting the enterprise's quantity indicators. Similarly, changing the production recipe by altering the preparation schedule, and incidentally modifying the technical characteristics of the ensuing output, would place the enterprise technically in violation of the quality norms and lead to problems with the state inspectors.⁵ Using what the enterprise is given in a flexible fashion and making local decisions to produce what is best suited to the means at hand would mean altering the enterprise output profile, the prerogative of the supervising ministry.

The lack of sovereignty is caused in part by the omnipresence of administrative control by supervisory organs outside the enterprise. Even after the string of reforms announced so far, this *de facto* control remains large.⁶ Ambiguities exist in the new Law on the State Enterprise. Although target figures given by the ministry are "not directive in character," state orders "must be included in the plan."

Nowhere does it say that a state order that has no material technical support and is economically disadvantageous for the enterprise is not binding. Without this, however, switching from predominantly administrative to predominantly economic methods of management will remain wishful thinking. (Kurashvili, 1988.)

⁵The output derived from the use of new technology may be different from the traditional output, but the ministry wants it to be the same because it is easier to account for within the traditional assortment guidelines. This created great problems for the designers of a new spinning technology who had to redesign their apparatus many times to ensure that the yarn produced was not only as good as the old, but identical (Biryukova, 1987).

⁶An article by the director of a tire-manufacturing enterprise in Sverdlovsk asks when will it be possible for enterprise directors to shift from being "managers" in name to managers in deed (Yefimenkov, 1987).

N. I. Ryzhkov, the Chairman of the Council of Ministers, has noted that the "most important" task for the latter half of the current five-year plan is the full implementation of the Law on the State Enterprise. This is the major document seeking to reform relations between enterprises and ministries in Soviet industry. According to the Premier it is being blocked by economic leaders, who still do not know how to manage production through economic levers and "business partnership," and ministerial bureaucrats, who do not believe in economic forms of management and insist on administrative forms (Ryzhkov, 1988). That is, the lack of response to the call to operate under a new system of incentives is ascribed to resistance from those in a position to recognize the ambiguities in the law,⁷ are most likely to suffer adverse consequences from implementing the new system before conditions are adequate for it to function properly, and still somehow must persevere and meet formal and informal targets set by higher authorities. The strong implication is that the Law on the Enterprise must be viewed more as a statement of direction and intent to reform than as the enactment of a new order in Soviet industrial management.

This discussion leads to a simple point worth elaborating: The Soviet-type enterprise is not the equivalent of the Western firm. A *perestroika* calling upon enterprises to make more of their own decisions and to be more "enterprising" but stopping its restructuring at the factory door is unlikely to achieve full realization of its expectations.

Both the firm and the enterprise may be defined by the number and type of decisions under their exclusive control.⁸ This sphere of authority is larger for the Western firm than for the Soviet enterprise. The firm has more decisions under its immediate control. Further, the boundaries of the firm's decision authority are well defined and may be protected through legal means. In the Soviet instance, the presence of the external management group makes this boundary indistinct. Not only is this boundary porous, inhibiting independent action by enterprise managers, it also lacks rigidity and so a degree of uncertainty exists over precisely which decisions will be left to the judgment of the enterprise and which will be subject to prior, or retrospective, review by higher authority.

Finally, when looking to the external economic environment, the Western manager perceives a coherent background to the activities of the firm. Interest rates move in step, there is a consistent vector of

⁷See, e.g., V. Arkhangelskii (1988).

⁸These include, but are not limited to, setting the output assortment, determining the marketing niche, deciding when to invest, deciding what processes to invest in, deciding when and where to relocate, and deciding when to go out of business.

prices based upon information about real resource costs and the nature of demand, and the rules for taxation and other unpleasant intrusions by government bodies are reasonably intelligible. More important, the environment permits movement to allow flexible decisionmaking. The Soviet enterprise, however, faces a dearth of information on the external environment while being confronted with incongruities, inconsistencies, obstructions—both known and unknown—and frequent change. This is most true during a period of reform when some institutions are modified while others remain the same, norms for profit retention and fund formation are subject to frequent change and are individually tailored by branch and by enterprise, some prices are decontrolled while others remain fixed, and superior authorities are learning new rules of the game while unpredictably lapsing into atavistic behavior. The Soviet manager of an enterprise in a period of reform is subject to more uncertainty, retains less control, and faces less well-specified performance criteria than does his counterpart in the Western firm whose actions he is now being asked to emulate.

A fourth difference, and a further reason for inefficient utilization, lies within the enterprise itself. All of the expedients for improving output quality mentioned above suggest the need for an efficiency in the generation and use of the enterprise's store of information, as well as an ability to decentralize decision authority, both lacking in the typical Soviet manufacturing enterprise. The organization of the Soviet enterprise is not conducive to generating and accurately assessing information on the manufacturing process and implementing decisions based upon that information. Neither is its operating environment conducive to generating satisfactory information flows.

Existing forms of enterprise organization have usually been left unmodified by most formal attempts to reform Soviet-type economies. Reform efforts are concentrated on redressing inadequacies existing in the relations between enterprises, between enterprises and consumers, and between enterprises and the state authorities. Enterprises purposefully constructed to operate as integral units in a hierarchic system of command management will have to undergo changes making them better suited to the new environment before they can meet its challenges.

Soviet enterprise organization internally recapitulates the hierarchic model of the orthodox system for sectoral and national economic management. Information flows are pronouncedly vertical, which is fitting where a prime purpose of the information is to keep external authorities well informed of the enterprise's activities (and true produc-

tion possibilities). It is less fitting for a self-financing enterprise intended to operate in an entrepreneurial fashion.⁹

Accounting practices are also designed with external auditors rather than local managers in mind. The purpose of the current system is more to enable superior organs to track the activities of most interest to them than to provide managers of the enterprise with the information required for efficient operation. This affects the type of information sought and the manner in which it is collected. Enterprises have difficulty in determining the true cost of individual operations.¹⁰ Further, plants are granted little flexibility in how to monitor performance; those using nonstandard equipment, nonstandard techniques, or low production runs are ill served by the standard documentation to which they are required to adhere (Noble, 1988). In addition, the torrent of data required by higher authorities reduces the attention paid to aspects of plant operations most crucial in ensuring efficient utilization of capital equipment. These problems are exacerbated in plants working under individual orders. Machine builders have little interest in satisfying the particular needs of individual end-users. In most cases, the performance of individual machines or even shops cannot be accurately assessed.

Similarly, decision authority also tends to follow the drift of information up the organizational tree, not necessarily stopping when it reaches the highest levels of enterprise management. Horizontal information flows are constricted and local decisionmaking reduced. Higher levels of management are confronted with a large range of decisions. Information generated within the plant to be acted on promptly at the appropriate level is not sufficiently available to the typical Soviet industrial enterprise.

The situation is further complicated for the users of new machinery by the dearth of information sources outside the enterprise, particularly from that most valuable of intelligence-gathering mechanisms, the market. New students of economics quickly grasp the value of the competitive market to consumers who usually face better selection and lower prices than they would if forced to buy from a monopolist. Less easily grasped is the concept that such a market can also be of value to the producers by providing what might be termed "the invisible

⁹A residual of this organizational paradigm is the large number of supervisors present in enterprise management. A reduction of as much as 40 percent in administrative staff would be in order (Leshchevskii, 1988).

¹⁰This problem manifests itself most strongly when numerical control equipment is introduced. A call for redrafting accounting practices usually accompanies the diffusion of this technology in Soviet-type economies. See Vasilyeva (1988) and Popper (1988).

foot"¹¹—information that the producer might be doing something wrong compared with his competitors.

In a market-type economy a firm adopting new machinery will often receive a painful lesson if it is utilizing that machinery less efficiently than the rest of the industry. Inefficiencies soon manifest themselves in the form of lost market share and other phenomena of noncompetitiveness. Most Soviet firms are insulated from this sort of learning. Protection from import competition, high levels of concentration, output profile restrictions and other administrative barriers to entry (and perhaps as important, exit), and the underdeveloped transportation and retail infrastructure keep many enterprises ignorant of best practice for operating newly acquired equipment. Soviet machine users may feel satisfaction at their increasing rates of production using new, expensive capital while remaining ignorant about how far they are from achieving truly efficient utilization. The result, again, is greater losses for the national economy.

This is not unique to the Soviet setting. Enterprises, as complex social units, will tend to be conservative of organization and established practice unless compelled to be innovative. New technology will be reinterpreted in the light of past experience in each new setting where it is placed. Only the example of others, backed by the spectre of punishing losses, will cause an enterprise to engage in the often painful process of seeking efficiencies through reorganization of manufacturing and management procedures.

The forces that would impel reassessment of capital utilization are highly attenuated in the Soviet enterprise. The idealized Western firm also has many aspects of command guiding its internal operations. There is no inherent economic reason why a large Western corporation operating as a perfect monopolist over the long run, shielded from domestic and foreign competition, should be a more efficient user of new technology than the typical Soviet-type firm.¹² The nature of the challenge confronting the corporation will determine whether it is forced to reevaluate its internal regime and confront its current shortcomings. But few firms in market economies are guaranteed their market position; and whereas both the Soviet and the market-type firm may have an internal regime of "command," the latter enjoys richer sources of information, a tighter loop between signal and response, and greater exposure to explicitly disillusioning experience. There are more

¹¹This evocative phrase has been ascribed to Joseph Berliner.

¹²There may be noneconomic reasons, however: a cultural propensity toward tinkering, more positive connotations attached to the concept of "change," better supply and more general dispersal of technical information, a less authoritarian system of hierarchic control within the enterprise, and so forth.

adaptive structures to information use and decisionmaking in Western firms than in Soviet types of systems.¹³

To put it in other terms, the warning signs of inefficient utilization will come later to a Soviet enterprise than to a competitive Western firm, if they are not lost altogether. It is for this reason, and the others raised in this section, that one might predict identical machinery will be operated with lower productivity in a Soviet plant than in a Western one. Anecdotal information from several industries corroborates this contention.¹⁴ Even if the Soviets succeed in meeting the extremely ambitious output targets set for the modernization program and adhere to an accelerated schedule of removing obsolescent equipment from production, only changes in the current economic system will prevent dissipation of the potential effects.

¹³Recent changes in the nature of intra-enterprise organization in the West have been characterized by a tendency to reduce the rigidities and "height" of internal hierarchies, and to generate internal manufacturing *cum* profit centers. This may be an implicit recognition of the inability of more classic enterprise structure to generate sufficient information to maintain competitiveness in the face of increasingly rapid change. Not only does the enterprise as a whole seek information from external sources, but discrete manufacturing "cells," as distinct from functional departments, are doing so as well.

¹⁴In spite of the policy goal announced in the 10th Five-Year Plan of increasing the shift-work factor for production equipment (the intensity of operation stated in shifts per day) by 20 to 30 percent, there was no change through 1985. Indeed, in the 20 years preceding 1985, the shift-work factor for metal-cutting machine tools in basic production fell from 1.64 to 1.39, down 15.3 percent (Ilyshev and Ilysheva, 1987). Although many factors enter into these figures, personal communications with vendors of Western machine tools who have had experience in selling to the Soviet Union suggest that failure to operate machinery in the appropriate manner is a partial cause. Some findings along these lines may also be found in Hanson (1981, Chap. 11).

V. THE ROLE OF ADVANCED MANUFACTURING TECHNOLOGY

ADVANCED MANUFACTURING TECHNOLOGY AS A DIAGNOSTIC

Soviet plans for using current state-of-the-art technology, grandiose as they are, may affect little manufacturing capacity. Much of what will actually be put in place will not correspond to that level of complexity. Yet the utilization problems associated with this type of productive capital are of interest because this is where the Soviets themselves have placed the emphasis. They believe this type of investment will profoundly alter the performance characteristics of Soviet industry. As quickly as possible they want to reach a stage where such ultramodern installations do account for a substantial share of their manufacturing capacity. Therefore, the actual machine types produced will have been heavily influenced by Soviet perceptions of where the leading edge does, and will, lie. The likelihood that this strategy will be successful needs to be assessed.

Although the phenomena of inefficient utilization are aggravated by the introduction of technologies as complex as those represented by the leading edge, they are still present, and in substantially the same form, with "simple" forms of advanced technology such as numerically controlled machine tools, or even with traditional processing machinery. Indeed, Western experience has shown that one of the most beneficial aspects of having a manufacturing organization plan for the introduction of advanced manufacturing technologies is that the experience itself provides a useful diagnostic device. It brings the existing system's sources of inefficiency in production into the open.¹ Therefore, to speak of the difficulties likely to be encountered in the course of applying advanced manufacturing technologies, the prized fruits of the modernization program, is to address fundamental problems in the efficient utilization of the widest range of productive capital throughout the Soviet economy.

¹"The problem of Flexible Manufacturing Systems has brought to light many general shortcomings in our economy, and especially in the economics of scientific-technological progress" (Vasilyeva, 1988).

THE NATURE OF ADVANCED MANUFACTURING TECHNOLOGIES

The Relevance for Soviet Industry

During the first three decades after World War II, the trend in design of manufacturing equipment emphasized increasingly faster rates and a declining share of labor input; since the mid-seventies, however, greater emphasis has been on controllability and flexibility, integrating machines into manufacturing systems.² There are at least three reasons for the emergence of this phenomenon.

First, for many machine types there are physical limitations on the theoretical maximum speed of operation.³ These maxima are close at hand. Other characteristics must be developed to seek the competitive edge.

Second, machine rates and capabilities have increased so rapidly that production managers often found themselves on a technological toboggan ride. For example, when digital encoders were applied to metal-cutting machine tools, the resulting machinery was capable of far higher rates of production than the traditional machine tools they superficially resembled, creating new problems of management. Old manufacturing processes needed to be substantially modified to take advantage of the capacity of the new equipment. As an aid to redrafting manufacturing systems, a premium is placed upon obtaining reliable information on the "state" of individual machines, information that may be acted upon promptly to maintain the flow of materials through the plant at a maximally efficient rate.

Third, the tasks set for manufacturing and machine-building industries to perform are changing. The quantity and assortment of output are increasing. In the broad sweep of history the first stage of manufacturing may be characterized by the artisan creating one-off copies of his work and the second by the assembly line with specifically designed machinery mass-producing a fixed output. The current trend is toward a middle ground with highly flexible machinery, connected by well-defined information and decision flows, producing an ever-varying and constantly evolving assortment of goods. This may be seen in many globally connected markets from textiles to consumer electronics to military hardware, where the competitive edge is becoming less one

²There have been advances in other areas but the dramatic qualitative changes in the flexibility and controllability aspects of manufacturing technology have come to be viewed as the essential elements of modernity.

³Much of this discussion is based upon conversations with equipment vendors and users held at the International Machine Tool Show, Chicago, Illinois, September 1988.

of output volume than of being able to rapidly respond to, and take advantage of, changes in consumer tastes or in the ability to develop and incorporate new functions in tangible form. Developments in this direction are intensifying the trend toward innovations providing a greater degree of control.

This trend would not yet appear greatly relevant to Soviet industry if it were merely an alternative means for exceeding physical limits. The Soviets may still have some distance to travel in bringing up to speed the types of manufacturing equipment they currently produce. However, the other points suggest it may already be time for the Soviets to pay attention to the issues of flexibility and control.

A system for machinery design lacking a means to consider the mode of utilization by the end-user will lead to efficiency losses and suboptimal utilization. This is partly what the emphasis on controllability attests to. Such consideration is also a *sine qua non* for a modernization effort employing a concept of technological sufficiency. The assurance of efficient use of existing technology provides the means for achieving greater productivity while solving problems within the region bounded by the technological frontier. To ignore, or fail to draw the appropriate lessons from, the trend toward controllability is to cast aside a valuable tool in achieving higher rates of productivity with the existing capital stock. One remarkable aspect of the shift in machinery design is its applicability to earlier vintages of manufacturing equipment to achieve higher levels of utilization.⁴ Cognizance of this will allow the Soviets to run their race of technological catch-up along a path representing the hypotenuse rather than along the dog-leg course following the two adjacents. This is especially important in an era when the future trend in manufacturing technology is unclear or might be veering from a previous trajectory.

Further, an emphasis on controllability holds relevance for a Soviet Union attempting to create a machine-building sector capable of answering the full range of needs of a developed industrial economy. The need for flexibility does hold less importance for the classical Soviet type of economy than it does for a market type, but it is precisely this aspect of the Soviet economy that Gorbachev wishes to change. He wants an economy capable of giving the consumer a varied assortment of goods to provide an incentive for increased labor effort, while making a wide variety of export-quality machinery for use at home and abroad; he also wants the military to have the means to compete effectively in the increasingly heady race of weapon and

⁴This may be applied to the hardware as well. Western metal-working trade periodicals display advertisements depicting machines formerly ready for the scrap heap that have been refurbished and fitted with numerical control apparatus.

counterweapon. The mark of such an economy is the ability to maximize its productive capacity. To do this it must be adaptive. Gorbachev's modernization program is designed to decrease the technological gap while making the economy more efficient in every sense.

Discerning this trend in manufacturing technologies would provide a useful source of information to the Soviets. Accurate assessment of changes in the nature of Western manufacturing management could help make more apparent the need for substantial economic reform to further the cause of modernization.

A Hornbook on Modern Manufacturing Technologies

The term *advanced manufacturing technologies* covers the wide range of equipment associated with these changes. Much of the remaining discussion rests upon the efficient utilization of machinery of this type, so it will be useful to discuss its nature. The justification for adding another term to the already confusing menagerie of modern manufacturing acronyms is to emphasize the common nature of different types of equipment and systems and the similarities in the requirements for efficient utilization.

The characteristics of complexity and flexibility are the common threads. The more technologically complex a machine, the more information flows must be considered along with the more typical energy and material flows across the boundary of the machine system to satisfactorily describe its function. The theme of information management will be dealt with more thoroughly below.

A "flexible" machine may be described as one designed to be adapted to several manufacturing processes. The processes themselves become more amenable to modification because of the presence of the flexible machinery. The machine may be modified through programming to fit into a production process rationalized for its use. Flexible machinery may be contrasted on the one hand with machinery designed to do only a limited range of specific tasks, such as one might find on a typical continuous transfer line, and with general purpose machinery on the other. Proper use of a flexible machine requires the manufacturing process be structured so the machine can perform several tasks, thus conferring a greater degree of manageability over all the other steps of the process.

The bedrock of advanced manufacturing technology is the numerically controlled (NC) machine tool. The first of these were traditional machine tools to which digital decoders had been attached. A punched paper tape directed the machine through a series of machining steps without the need for direct human intervention. Not only could

complicated pieces be machined at a rapid, fixed rate, but overhead costs were reduced because the paper tape program, rather than a ready stock of warehoused parts, was stored for use as needed. The subsequent development of machine tools specifically designed for NC applications has also resulted in the ability to machine parts to very exacting tolerances.

The economic niche occupied by NC equipment is illustrated in Fig. 1. A general-purpose machine operated by a skilled machinist is best suited to producing unique parts or parts needed only in small numbers. Specifically designed machinery on a continuous transfer line is the key to low-cost mass production. Numerical control occupies the middle range. An NC installation will be asked to machine a large variety of pieces, intermittently, in small lot sizes.

The trend of the last decade has been to replace simple digital decoders with internal microprocessors: computer numerically controlled (CNC) machine tools. CNC machine tools have rapidly become the standard embodiment of this technology because they may be

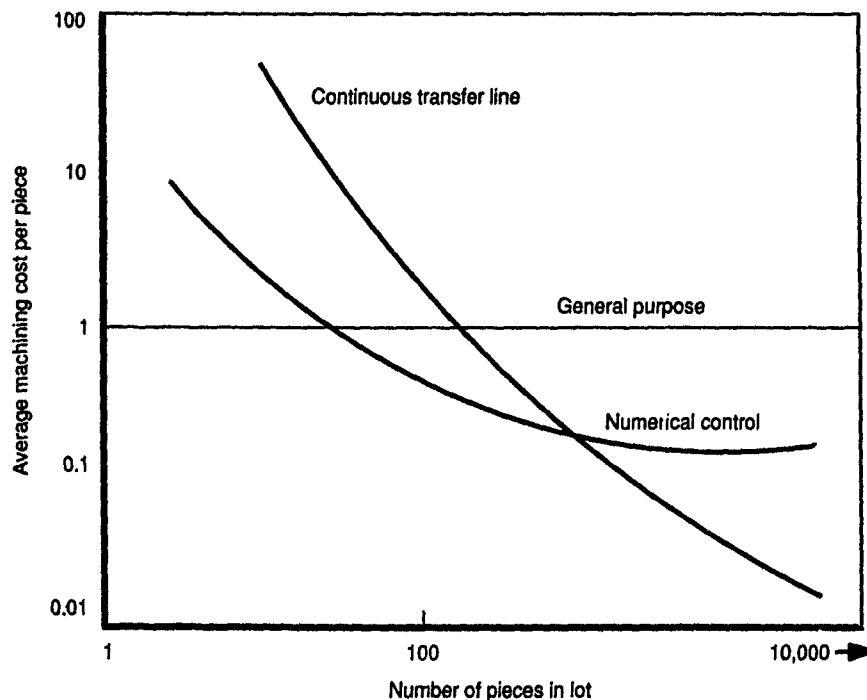


Fig. 1—Cost/quantity tradeoffs for three manufacturing technologies

directly programmed. The next step is direct numerical control (DNC): linking several CNC computers to a central processing computer from which they all can receive separate, detailed instructions.

Direct numerical control is the first step in achieving what is coming to be seen as the logical culmination of advanced manufacturing technology: computer integrated manufacturing (CIM). This currently takes several forms. The basic building block is the flexible manufacturing cell. The core of the cell is a CNC machine tool. The machine tool is supported by automating the steps preceding and following the actual machining by adding automated materials transfer, robotized manipulators, automatic testing procedures, and so forth.

To successfully link several flexible manufacturing cells together with a system of automated materials and integrated information flows is to create a flexible manufacturing system (FMS). A successful FMS will be more than a series of linked flexible manufacturing cells. It will be an integrated system of manufacturing allowing the completely automated production of complex, differentiated assemblies by arranging the passage of jobs from machining center to machining center without direct intervention by the operators. Ideally, complete CIM is achieved when an FMS will allow the computer-assisted design team to pass its finished designs directly to the FMS as a ready program of instructions for manufacturing.

The Comparative Management of New Manufacturing Technologies

In the experience of the West, successful application of even the simplest forms of advanced manufacturing technology, NC machine tools, requires considerable change in management roles, production processes, and plant practices.

The most obvious difference between modern machinery and the earlier vintages it replaces is the great cost. An NC machine tool may easily cost ten times as much as a traditional machine tool. Such a machine cannot merely "replace" the old machine in an unchanged production schema. To do so would be to underutilize its potential. As a greater share of the productive assets of a plant come to be composed of such high-cost assets, fixed costs come to dominate variable costs.

Because a large share of total costs are in the form of initial capital investment,⁵ and because the justification for expense of this

⁵Certain industries, such as petroleum refining, have long been characterized by sunk costs being a great share of their total costs. What sets the new applications of advanced manufacturing technology apart is that the equipment is not intended to be used in a static manufacturing framework, producing continuous runs of a narrow selection of products, but is designed to be applied in a dynamic fashion to face a constantly changing set of desired output.

magnitude rests upon an appraisal of the output desired and the ability of the production plant to utilize the advanced manufacturing technology equipment appropriately, the ultimate success of this equipment is determined before production, or even investment, begins—in the preliminary planning stages. The introduction of advanced manufacturing technology, no matter where applied, is inherently difficult because of the complexities of planning and management.

WESTERN EXPERIENCE WITH ADVANCED MANUFACTURING TECHNOLOGY

What Is To Be Done?

The consistent message coming from Western experience with advanced manufacturing technologies is that inefficient utilization is likely if there is a failure to adapt existing manufacturing systems to the new technology. The prominent role of advanced technologies in changing manufacturing practice masks the fact that the new equipment in itself is not so much the essence of these changes as are the new approaches to management it accompanies. To use the machinery in the absence of these changes could well lead new equipment to display productivity characteristics below the level of the machinery it replaced (Jaikumar, 1986).⁶

Comprehensive Planning. Before adopting new technology, the enterprise strategy must be reviewed. This requires an analysis of products, both present and prospective, available technologies, likely competition, and so forth. A strategy should be in place before any funds are spent on new equipment. Middle managers must be trained.

The most common mistake is to think of [advanced manufacturing technology] as a set of tools, an off-the-shelf solution to solve what is really . . . a problem of poor management. . . . It is nothing more than an attitude of mind, a dedication to a few worthwhile principles—like simplicity, collaboration, quality, and zero-defects. . . . The object is not total automation, but running a profitable business. (*Economist*, 1987.)

The advanced manufacturing technology itself is not the sole source of all the benefits it confers upon the firm. Rather, in planning for the successful implementation of its adoption a plant may obtain a clearer perspective on waste generation and control, more information

⁶The findings in the Jaikumar study were based upon a three-year analysis of 95 FMSs, over half the FMSs installed in the United States and Japan, and included interviews and examination of company records, as well as observation of operations.

on tool wear leading to changes permitting greater adherence to tolerances and precision, and as a result of this, an improvement in product quality.

Information, Organization, Accounting. A firm planning the adoption of advanced manufacturing technology must develop a database of information on current production practice. This, in turn, means drawing upon all departments and cutting across proprietary lines of "turf" definition. It is an obtrusive process in itself affecting the way people conceive of and perform their jobs. Under traditional systems of management, manufacturers have sought to control complex operations through hierarchies. Organizational distance, however, has made it difficult to keep close track of labor and plant resources, scheduling, and priorities. Institutional barriers hinder information flows and give rise to antagonistic localized interests within the plant. This leads to sluggish response and large stock inventories.

Extensive internal hierarchies are a potential barrier to successful adoption of new manufacturing technologies as well as a source of other problems. To increase response and reduce inventories, many firms have looked to FMS and other advanced manufacturing technology. But that treats the symptom rather than the cause. The prerequisite for successful introduction is to have available the detailed information that will allow for its success. A detailed study by planners at Hewlett-Packard found production included informal procedures that were not supposed to be there. A good deal of "fixing" was done by people on the line and never formally appeared on any organizational chart. A firm must have this sort of information available to it if it is to design the layout of its suite of advanced manufacturing equipment effectively.

Successful implementation of advanced manufacturing technology requires an interdepartmental task force approach to manufacturing. This means conferring a good deal of decisionmaking authority on local managers and work teams who possess the particular bits of information necessary for efficient utilization of the new technology. Further, accounting practices must be established to generate the type of information the organization needs for planning the operation of the new equipment. By no means the least important aspect of this will be to devise means for tracking the results stemming from the plant's reporting units to determine if the new equipment is actually achieving its full potential in use. Accounting systems need to be adjusted to assess true costs and benefits of advanced manufacturing technology.

The problem is not trivial. In the industrialized West, labor accounts for only 5 to 15 percent of manufacturing costs. In a plant utilizing FMS it is the fixed costs rather than the variable costs that

dominate, amounting to perhaps 70 percent of the total bill (*Economist*, 1987). Often, the bulk of accounting activity goes to tracking 20 to 30 percent of the production plant's activity. The problem is how to account for the factors of quality, variety, flexibility, response time, and appropriate use of expensive capital in a traditional accounting framework. A cost tracking method to capture the benefits of FMS will be attuned to such factors as market share capture and optimal pricing schemes.

Communications and Training. As more complex systems are envisioned, the software and communications problems become extraordinarily difficult. Adoption of advanced manufacturing technology may be compromised. This has both technical and human aspects. It is a difficult problem to write programs for an array of different machines, often produced by different manufacturers, to communicate with each other and to send information to and receive timely instructions from a central data processing facility. More often than not, inadequate software causes a complex FMS to degenerate into a series of uncoordinated flexible manufacturing cells.⁷ Although the Japanese lead the world in the number of FMSs deployed, no Japanese firm has yet attempted to move completely over to total CIM, as have several in the United States (*Economist*, 1987). This may be a comment on the state of Japanese software development. More likely, it should be taken as a judgment by critical observers of the poor results likely to ensue from investment in technical means lying beyond the ability of current communications software to support.

Integrating different types of advanced manufacturing equipment with computers may be the easy part. Integrating workers with differing skills and backgrounds is perhaps harder. The early view that new manufacturing technology is labor saving is not correct; it places a greater reliance upon more costly skilled workers and increases the need for them. Since software development provides the foundation for appropriate use of NC technologies and information-intensive manufacturing, "the technical literacy of a company's workers is critical" (Jaikumar, 1986). In Japan, three times as much time is taken in training to upgrade skills as in the United States, apparently affecting comparative success rates with advanced manufacturing technologies. This theme is stressed by all commentators: training the work force to operate the new equipment. "Flexible manufacturing systems work at full capacity only if production workers are able to take complex scheduling decisions about which [job] they. . . should work on at any one time" (*Economist*, 1988). Thus the efficient operation of advanced

⁷Personal communication with representatives of FMS vendors.

manufacturing technology often means efficiently preparing and managing the people who will operate it.

What Has Been Done Wrong?

The most frequent misstep is a failure to recognize that a different approach to manufacturing must be taken after the adoption of advanced manufacturing technology.

Management [at a prominent U.S. producer] treated the FMS as if it were just another set of machines for high-volume, standardized production—which is precisely what it is not. . . . These executives separated the establishment of procedures from their execution, replaced skilled blue-collar machinists with trained operators, and emphasized machine uptime and productivity. In short, they mastered narrow-purpose production on expensive FMS technology designed for high-powered, flexible usage. . . . Not surprisingly, the flexibility achieved by this FMS was much less than that of a stand-alone CNC machining center. (Jaikumar, 1986.)

Failure occurs at the planning stage. Often, the team planning the system is not the one to operate it. Indeed, the system may be planned for more flexibility than the firm can use. Pressure is then placed upon the system operators to provide quick software or hard-wire fixes to problems that emerge. These may then ultimately reduce flexibility. "If anything, the complexity of the FMS [may force] operators to stick more rigidly to procedure than they did at the stand-alone CNC machining centers" (Jaikumar, 1986). Investment in complex new technologies may lead to further institutional paralysis and a reduced willingness to reexamine enterprise procedures and manufacturing processes—especially if lack of information inhibits detection of inefficiencies in production. The result is a tendency to use FMSs the wrong way. Firms have found themselves unable to break away from using them for high-volume production of a few parts rather than for high-variety production of many parts at a low cost per unit.

Western firms that have taken a "campaign" approach to advanced manufacturing technology, investing heavily in new state-of-the-art plant, have often found the results disappointing. GM spent \$40 billion in eight years, staffing its factories with some 200,000 programmable tools of one form or another. To date, the results have been disappointing. This is illustrated by the experience of GM's Hamtramck facility with its \$500 million worth of robots (310 units), computers, and digitalized manufacturing and testing equipment. Its quality and productivity barely matches that of the traditionally equipped Fremont plant operating under Toyota-style management techniques (*Economist*, 1988).

This experience has been recapitulated to one extent or another by General Electric and IBM.⁸ These have not been obvious disasters, far from it: Productivity has increased (six times at the IBM facility), market share has expanded (from 31 percent to 43 percent for the products of the GE facility), and product quality improved (the required servicing interval has been increased by a factor of four for IBM) (*Economist*, 1988). But the cost of these improvements has been judged too great by these firms. Subsequent investment projects, planned after these advanced manufacturing technology plants had been placed into operation, have taken a more incremental, less grand approach.

What Has Been Done Right?

The record on utilization of advanced manufacturing technology has not been uniformly indifferent. There are instances, conspicuously in Japan, of success that spurred the diffusion of the technologies involved. Japan has 40 percent of the world's stock of CNC machining centers, two-thirds of them located in small- and medium-sized firms, and leads the United States in FMSs planned and deployed (*Economist*, 1987). From 1981 to 1985, 55 percent of the machine tools installed in Japan were CNC compared to only 18 percent in the United States (Jaikumar, 1986).

Japanese success has stemmed from several sources. The first has been to conceptualize advanced manufacturing technology as automation of the traditional, small, flexible job shop rather than introducing flexibility to rigid Fordian transfer lines.⁹ This has facilitated communications and information generation and utilization, and has clarified the conception of what a proposed FMS facility is intended to do.

The Japanese approach to advanced manufacturing technology has also been characterized by incrementalism. Rather than engaging in major campaigns and renovations, Japanese manufacturing firms have learned to value frequent incremental improvements to their processes rather than the occasional giant leaps favored by American firms.

When installing advanced manufacturing technology, Japanese firms have emphasized the need to prepare the auxiliary services, especially materials transfer and storage, to realize the full benefit of the inherent technology. At Toyota, for example, the emphasis is not so much on speeding up individual machining steps by seconds as on saving hours

⁸Discussions with the representatives of advanced manufacturing technology vendors suggest that many other examples could have been chosen.

⁹The gigantism that is a legacy of past industrial development could make this conceptualization difficult to achieve in the Soviet setting.

and days of waste by reducing idle time of operators and improving material handling and warehousing by reducing stored materials and subassemblies. Dies and molds are standard sizes with standard fittings, and quick-release fasteners have replaced nuts and bolts, reducing setup times, which reduces economical batch size. This modernizes manufacturing without heavy investment of capital. It also allows the introduction of advanced manufacturing technology to go more smoothly.

The Lessons of Advanced Manufacturing Technology

The Western experience yields two major conclusions with implications for the prospects of successful modernization in the Soviet Union.

The Secondary Role of the "Hardware." To concentrate upon developing a capacity for producing and diffusing advanced manufacturing capital goods is to emphasize the appurtenances of modern manufacturing rather than its essence. A failure to grasp this insight and use it to provide the bedrock for any program of modernization will seriously compromise the degree to which the capital investment can provide an appropriate return.

A large part of improved competitiveness stems from a scrutiny of manufacturing processes in minute detail. At Hewlett-Packard, for example, the formula for success has been to "first learn how [the] factories actually function, not how they are supposed to." The next job is to simplify all procedures: What is the minimum amount of information required for value-adding activities to be pursued successfully? Only then should any hardware purchases be considered. "Often, it results in very little automation going into the workshop itself" (*Economist*, 1987).

To carry this theme further

[Better use of new technology for competitive advantage] does not mean investing in more equipment; in today's manufacturing environment it is how the equipment is used that is important. . . . Success comes from achieving continuous process improvement through organizational learning and experimentation. (Jaikumar, 1986.)

A recent comparative analysis of 38 automobile assembly plants in 13 countries found that production management policy, regardless of the national parentage of the management group, greatly affected plant operating performance. The level of technology, as measured by a robotic index, had little effect on performance (Krafcik, 1988).

This does not mean that the impressive advanced manufacturing technologies, presented as the wave of the future, are in reality hollow giants with feet of clay. Only with advanced manufacturing technology

has it been possible for the manufacturer of discrete products to gain continuous control over, and information feedback from, his production processes in the same manner as the continuous process manufacturer could from his (Gunn, 1982). New machine types are also capable of performing at previously unattainable tolerances. But a firm need not spend a great deal to gain many of the benefits from switching over to this type of manufacturing. It is even technically possible to retrofit numerical control technology to traditional machine tools, using them as the core of a flexible manufacturing cell.¹⁰

The goal of a modernization process ought not be modernization of the stock of machinery at the disposal of an enterprise. This can only be an adjunct to the true purpose of modernizing the process of manufacturing itself. Technology is the tool that makes it possible. It is the most visible and tangible manifestation of change. But to concentrate on the machinery is to miss the essential. As an example, no single breakthrough in technology made assembly lines possible, although the incorporation of high-productivity, labor-saving equipment was an important adjunct. Rather, the revolution brought about by the Ford-style transfer line was owed to a change in attitude toward manufacturing and management style.

Evolution vs. Revolution. As noted above, whereas 30 or so plants in the United States are using a major investment push to attempt to recapture or sustain competitiveness by moving directly from traditional manufacturing arrangements to a full realization of CIM in its most advanced form, there are none in Japan. The Japanese approach has been more incremental. On balance, this appears to have worked out better in practice.

America's largest dozen or so firms that have embarked on costly CIM-like adventures have learned that the "moon shot" approach certainly gets results and provides useful experience, but at a price that few, if any, of them can afford to repeat. For a few brief years, America's brave high-tech form of manufacturing flared brilliantly across the headlines. Lately, however, it has fizzled back to earth—and the big guns of manufacturing in the U.S. are a good deal wiser for it. (*Economist*, 1987.)

The most successful users of advanced manufacturing in the United States are those that have taken a lean, incremental approach to technology.¹¹ This incremental approach provides the opportunity for

¹⁰The mechanical in-feed and regulating wheel drive mechanisms may be replaced by digital control servomechanisms. One then adds a robot to load parts and to remove the machined part to a testing bed.

¹¹Examples include Caterpillar, Allen-Bradley, John Deere, and Hewlett-Packard (*Economist*, 1987).

enterprises to form a realistic appraisal of where they want to go with advanced manufacturing technology and how the new approaches are actually operating at the various steps along the way.

VI. THE SOVIET ENTERPRISE AND ADVANCED MANUFACTURING TECHNOLOGY

In light of the experience of successful Western implementers, the philosophy guiding the Soviet modernization program, as articulated by such spokesmen as Agenbegyan and Silayev, is ill-suited to its purpose.¹ Further, current Soviet economic institutions will be inadequate to detect and rectify the arising conflicts.

The program is intended by its architects to be revolutionary, increasing the rates for scrapping existing plant and force-feeding machinery of a profoundly different character into Soviet industry. Its campaign aspect fixes priorities and attention on the hardware rather than letting investment be the last step in a comprehensive solution to the problems besetting Soviet industry. This has great force. It is the primary message the implementers of the program received from a central leadership that retains great powers in setting performance goals for enterprises and rewarding their achievement. Setting the world technological frontier as the standard for directing the practical implementation of the modernization effort focuses attention, as happened in the United States ten years ago, on the hardware. This fails to reflect the real change: reassessment of management techniques and changed perceptions of what manufacturing ought to be.

This point finds support from some Soviet commentators.

The desire to increase the production of diverse types of equipment, including basically new types, has decreased the importance of those questions concerned with radically restructuring machine building proper and especially its organizational structure. Meanwhile, it is precisely such restructuring that is considered to be the basis for qualitatively solving the tasks confronting this complex. The admiration being aroused by some items of new equipment is producing positive emotions among some leaders but it is not motivating us toward the creation of an optimum model for machine building. (Kheynman, 1988.)

The predisposition to emphasize the hardware is not difficult to explain. When time is of the essence in staving off a crisis, it is natural to concentrate on doing what past practice gives reason to believe the system will do well. In the Soviet setting the need for linkage between the hardware and the system for its management is not

¹See Sec. II.

readily apparent. Further, the increasing acuteness of civil/military tradeoffs may be stimulating the emphasis on the hardware aspects of modernization. This form of modernization as embodied in advanced manufacturing technologies, especially numerical control, is precisely the type that could allow for the production of consumer and defense goods on the same production lines. In theory, this could ease the material effects of the defense burden because there would be less necessity to develop two separate capital stocks; lines producing consumer articles then become the surge capacity for the military. Failure means greater demands to convert defense facilities to civilian use.

Leaving aside the fundamental problem of too great an emphasis on hardware, the Soviets may be fighting several problems in finding a successful approach to managing the application of advanced manufacturing technology. One is the tendency toward campaigns to maintain the objectives of the modernization program. This leads to major investments in large-scale projects, countervailing the wisdom in the West that step-by-step might be the way to go. Beyond this, there are also deficiencies of managerial resources, appropriate incentives, independence, organizational flexibility, and, above all else, a flow of information and the means to analyze it, that are necessary to turn the incremental approach into a virtue rather than a problem. This lack may be what suggests to the authors of the modernization program the need for thoroughgoing transformation in a single stroke if any modernization is to occur. However, given the character of the Soviet industrial enterprise, such a transformation is more urgently required in the area of management than in technical reequipment.

INTERNAL DEBATES

It is possible to identify four Soviet schools of thought on the proper role of advanced manufacturing technologies, particularly FMS. Those most in tune with Western thinking are strong proponents of the technology but believe its use should be limited. The director of the Faculty of Automation in the Institute for Improving Skills of the Ministry of Machine Tool and Tool Building, D. L'vov, emphasizes the need for economic planning and for guaranteeing the suitability of the FMS to the intended purpose. Drawing heavily upon Western practice, he believes that FMS should be used at first in self-contained, well-integrated small plants producing small batches of parts in a flexible manner (Vasilyeva, 1988).

L. Volchkevich is also a proponent, also of the go-slow stamp, but differs with L'vov on where the use of FMS is appropriate.² He believes the technology is not ready. Therefore, he argues, its use should be limited to large plants possessing the resources to see the development through during the eight to ten years it will require. These are the true centers of production in the USSR. If FMS were located in large plants, their experience could be most clearly scrutinized and they would be able to command the resources necessary to assure proper utilization. Conditions need to be favorable for perfecting the technical level of FMS before it is diffused more widely to smaller plants. There are already sufficient problems with specialization in Soviet industry. Most of the giant state enterprise produce their own parts rather than relying on specialty producers. Therefore, this is where FMS should be applied.

Then, there is the anti-FMS camp. One articulate critic is L. Koshkin. The prevailing sentiment of this school is that FMS represents a technological will-o'-the-wisp and will prove a costly dead end (Koshkin, 1988).

A fourth school is more taciturn than the first three and produces little scholarship. Its existence may be inferred because its views have provided the primary impetus to the modernization effort. Since FMS will be a way around many of the bottlenecks in Soviet industry, they would argue, it should be diffused as quickly and extensively as possible. This, of course, accords well with the spirit of the world technological frontier approach to technology choice. Studies showing the increased utilization rates of NC machine tools when used in an FMS system³ incline the advocates to see this as a panacea without considering that there needs to be the antecedent of proper planning, among other things, before incantation of the trigrammaton "FMS" and the accompanying expenditure will work its magic.

The illusion emerged that [FMS] introduction would be capable of almost automatically, regardless of the technical level and actual use conditions, providing enormous economic and social dividends. At the same time, the high efficiency of the FMSs . . . has been claimed to be already attained. As a result, the increase in the efficiency of flexible readjustable production by its automation has been replaced by the pursuit of the most rapid expansion of FMSs. . . . In order to obtain [the desired results of FMS,] it is necessary to have an integrated automation of planning and design operations and the technological preparation of production, of the entire multi-operation manufacturing process and the assembly of the produced articles. At

²See Volchkevich (1988a, 1988b, 1988c).

³See, for example, Belov (1985).

present, we do not have such FMSs in our country. (Volchkevich, 1988b.)

The consequences of this approach, and the systemic inability to assess the net effect of FMS use, have had predictable effects on Soviet performance.

THE SOVIET EXPERIENCE

It is not possible in this study to provide a detailed analysis of the Soviet experience with advanced manufacturing technology. The particulars of how this type of capital operates in individual enterprises are difficult to garner through secondary sources; further, it is a hypothesis of this study that not even the enterprises themselves possess sufficient information to make this assessment. However, a few recent articles by Soviet observers lend credence to the supposition that Soviet industry is poorly poised to make efficient use of advanced manufacturing technology, and certainly not in the volume projected to be produced under the modernization program.

D. L'vov, when speaking of the higher end of the advanced manufacturing technology spectrum, says that FMSs have failed to bring the expected changes in the enterprises in which they have been placed. By the end of 1987, there were about 300 FMSs installed in the Soviet Union, but the consensus is that these have been a "total loss."⁴ The result, in L'vov's opinion, has been ruinously wasteful for society (Vasilyeva, 1988). Flexible manufacturing systems are installed in a thoughtless manner and merely increase the buildup of unfinished products, further slowing the turnover of working capital (*oborachivae-most' oborotnykh sredstv*). L'vov states that in the Soviet Union this stands between 50 and 70 days, compared with 3 in Japan.

The Soviet Union is also becoming a world leader in industrial robot production. While the pool of robots in the United States stands at about 20,000 and in Japan at 64,000, fully 71,000 have been produced in the Soviet Union and the annual production has reached 15,000 units per year. However, many of these are only simple manipulators while two-thirds of those in the United States are more complex, self-adjusting mechanisms. Even so, "a number of studies have revealed

⁴In 1986, the People's Control Commission examined the operation of 16 existing FMS installations. "All the examined FMSs were considered to be the best of scientific and technical achievements, with millions of rubles in savings and hundreds of freed-up workers. The reality turned out to be otherwise. Thus, for five FMSs with a total cost of 26.9 million rubles, instead of the promised annual gain of 3.5 million rubles, there were losses amounting to 260,000 rubles. Only 24 people were freed up" (Volchkevich, 1988b).

that a considerable number of domestic robots continue to remain inactive. The amount of robot idle time exceeds to a considerable degree the idle time of traditional equipment" (Kheynman, 1988). L. Koshkin, the director of the Intersectoral Science and Technology Complex [MNTK] "Rotor" says, "Each robot causes economic harm. It is minimal . . . if the robot remains in the warehouse. If it is used, the damage increases as a result of service and reduction of the productivity of the equipment that is being operated."⁵

In the case of NC machine tools, the lower end of the complexity spectrum for advanced manufacturing technology, the Soviet experience has not been uniformly positive. Nonproductive down periods account for too much time (Belov, 1985). According to an article dealing with the shipbuilding sector, NC machine tools have not fulfilled expectations in some enterprises of the branch (Glukhov, 1987). The problems are extensive enough that brigade leaders in plants judged to be effective users of NC technology have been asked to relate their experiences to higher levels of economic management.

Upon closer analysis, these instances of apparently effective utilization may well be the exceptions proving the rule. A brigade operating NC equipment at the Kirov Shipbuilding plant in Khabarovsk was praised for solving the pernicious small batch problem, inherent in shipbuilding. The brigade gathers together similar parts from different orders and machines them together to reduce the time required for readjusting the equipment, thereby increasing its productivity. However, this appears to defeat the major purpose of installing flexible manufacturing machinery: conferring the ability to machine quite different parts, as needed, as part of a continuous process. The solution developed by the brigade is a true innovation in management and job scheduling but would not require the use of NC machine tools. Indeed, this is a situation where the management solution obviates the need for heavy investment in advanced manufacturing technology. Because the indicator of labor productivity subsequently increases, the branch authorities judge the manner of utilization a success. But the success comes at the cost of using equipment too elaborate for the production process, and of having too much metal tied up in warehoused parts. If that is indeed the much-touted solution of the brigade, it illuminates the limited degree to which management solutions have been

⁵This might be dismissed as a self-serving polemic. After all, Koshkin's organization, in a sense, is dedicated to producing a technology that competes with the robotic approach to materials handling. Yet in 1985, the People's Control Commission found that the economic effect of 600 installed robots was 0.2 percent of cost (18,000 rubles/year at a cost of 10 mR). In 1987, the average payback period for robots in the enterprises attached to the Ministry of the Automotive Industry was 38 years, and 196 years in the Ministry for Heavy Machine Building (Koshkin, 1988).

employed in the Soviet Union, and the limited means available for measuring the cost effectiveness of machine use.

The arguments raised in Secs. III and IV, especially when viewed in light of Western experience with advanced manufacturing technology, suggest some reasons for these difficulties. Machine builders are insufficiently attentive to the needs of end-users, pre-investment planning of potential adopters is not thorough enough, the information available to decisionmakers is inadequate, solutions are planned for and imposed upon enterprises by external authority, and enterprises do not possess sufficient incentive or control to readjust production processes to gain the advantages embodied in the new machinery. These conditions are the antithesis of those prescribed in the West for firms seeking to use advanced manufacturing technologies in the most efficient manner.

Producers of domestic advanced manufacturing technology are not sufficiently attentive to the requirements of their customers. As the R&D/production cycle is applied to the design of more complex manufacturing technologies, "the greater the degree to which scientific-technical and design problems are replaced by economic and organizational-administrative ones" (Zaichenko, 1988). But these problems are not easily addressed in the absence of meaningful information on costs and in the presence of institutional rigidities and effective monopolies. The experience of the past two decades has shown that "the failures of all attempts to accelerate" the cycle are explained by the lack of development of cost-accounting relations in the national economy, and the existence of a rigid bureaucratic apparatus for management of production "which has its own . . . system of values and interests." Even after planning for the introduction of 2,000 new FMSs during the current five-year plan, no scientific center for flexible automation was established to assist enterprises with the introduction of FMSs. Instead, enterprises had to develop their installations on their own (Volchkevich, 1988a).

In the absence of meaningful prices, the current solution being favored by Silayev for generating excellence in machinery design is wider competition between domestic machine design bureaus within and across ministerial branches (Silayev, 1988).⁶ But compartmentalization appears to proceed unabated, and although solutions may be multiplied, they are often not in active competition. Different

⁶There is no clear reason to believe that calls for wider competition will have, under present conditions, an effect other than multiplying problems of opportunism and monopoly. Silayev himself notes "The passive position of the ministries and their head development institutes, whose products the competitions are intended to improve. Under constant pressure from above, they delay in preparing the technical specifications and conditions for conducting the competitions. . . . The real assistance and support the innovators need drown in the bureaucratic whirlpool."

development approaches are not forced to be cognizant of one another other than by bureaucratic prompting. Robot production went forward under the auspices of some 20 different ministries, usually as self-contained programs, each prepared for an isolated branch. The programs were planned without thorough consideration of the conditions of subsequent use, such as determining whether work stations were appropriate for multishift operations (Kheynman, 1988). The proliferation of alternative approaches could lead to competition under certain conditions, but given current institutions they must be interpreted as symptomatic of, among other things, chronic problems of unresponsiveness by suppliers in one branch to the demands of end-users in another.⁷

Soviet experts have called attention to the low reliability of domestically produced advanced manufacturing technology and its comparatively high price as reasons for the lack of success in practice. L'vov, however, stresses imperfections in the methods used to determine economic effect. Even highly reliable imported equipment has failed in the Soviet setting (Vasilyeva, 1988). In his opinion, the key problem with the use of FMS in the Soviet Union lies in the faulty approach to its introduction. A scientifically based conception of flexible automation is lacking. In the words of another commentator,

You cannot obtain good products without excellent machine tools, but the experience of VAZ and KamAZ [two large manufacturers of automobiles], which have mainly imported equipment, shows that we have learned quite well how to produce poor products with excellent equipment. (Yelekoyev, 1988.)

The type of planning required for successful design and installation of an FMS is at a rudimentary level in the Soviet Union. The director of the Uzbek Science Production Organization *Kibernetika* says there is not a single production facility in the republic where modern machining centers, machine tools, and robots would operate without a loss. Instead, they would be used to mass produce basic parts not characterized by labor intensiveness or precision; they would be used in fewer than three shifts; actual equipment would not be fully appropriate for the production task; there would be a shortage of skilled specialists in programming and in electronics troubleshooting; and even if all goes well, few enterprises would need to produce as many highly machined parts as the NCMTs would be capable of producing (Muminov, 1988).

⁷An example: There is a lack of progressive Soviet equipment for producing polymer pipes, and major tasks have been set for the Ministry of Machine Building for the Chemical and Petroleum Industries. "In addition, it is deemed necessary for the USSR Ministry of the Chemical Industry to actively develop its own machine-building" (Baklanov, 1988). Similarly, there have been recent calls for larger enterprises to produce their own microcircuits because of the insufficiencies of the supplying enterprise.

Indeed, even in a showcase enterprise like the Leninist Komsomol Automobile Factory in Moscow, cited by the Minister of the Automotive industry as "the leader in the business of robotization,"⁸ the FMS installation, introduced at a cost of some 1 billion "gold" rubles, is capable of producing only one-quarter of its planned output (Ivanov and Shogin, 1988). The plant suffers from poor equipment and shortages, and many robots were obsolete at the time they entered production. More fundamentally, because of the chronic excess demand for passenger vehicles in the Soviet Union, there is no need for the continuous changes in style and models that FMS technology is designed to provide; and, indeed, the equipment is not used in that fashion. This flexibility will not be realized in the foreseeable future, while the high costs of production are passed on to the consumers (Vasilyeva, 1988).

This example deserves closer attention. Figure 2 illustrates the main point. It modifies Fig. 1 of Sec. V by pushing out the "Numerical Control" average cost curve.⁹ This line, termed "Flexible Manufacturing," represents the tendency in the West for more advanced manufacturing technology, building upon the foundation of numerical control, to expand into the domain previously held by general-purpose machinery at one end of the range of batch size, and by continuous-production machinery at the other.¹⁰ Soviet machine builders, in the absence of adequate domestic sources of information, observe the shifting dotted curve for cues to the direction Soviet developments should take. In this example, it would represent the much-prized "world technological frontier" and so provide the objective for Soviet modernization standards as well. But while the Soviets may identify the capital types associated with this shift, they are not well-positioned to observe or implement the changes in management that are the *sine qua non* for success. Neither have they access to the market information indicating whether such an investment project is advisable in any specific case, nor does Soviet management economics adequately recognize many of the realizable benefits. Soviet FMS installations operate inside the region bounded by the lower dotted line and are thus more expensive than they need be. As the example of the FMS in the automobile plant suggests, they may be operating at some point ("A" in the figure) short of where they had intended to be (point "B"). Machining costs may be greater than they would be with less expensive, more tractable

⁸See Shlemin (1988).

⁹This represents machining cost per piece, not total cost, and the scale is logarithmic.

¹⁰This is done by adding more control and flexibility to the other production steps besides direct metal working. Additional savings stem from lower inspection costs, greater ease of replication, higher quality, reduced inventories, and the like.

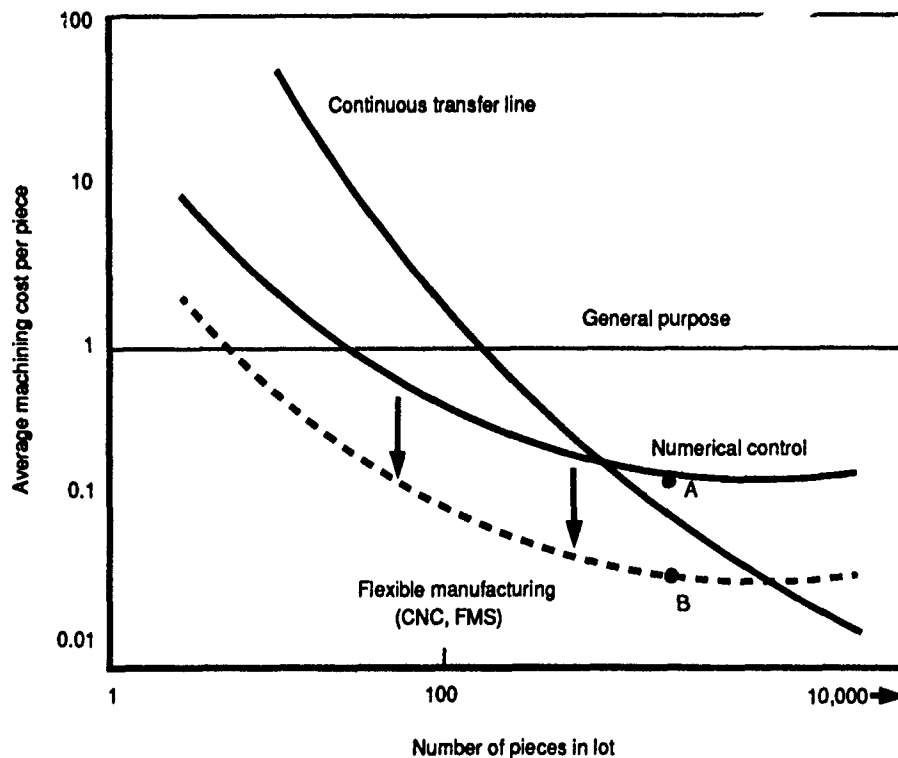


Fig. 2—Cost/quantity tradeoffs with advances in technology

technology. Indeed, it may take a good deal of time before it is ever suspected that they are not at "B." Given that they have neither the capacity to operate nor the need to install FMS in this instance, a different technological approach would have been more appropriate and less costly.

In the West, there was a sequential process in learning how to use more advanced manufacturing equipment properly. First, old jobs were duplicated with new equipment. Next, explicit advantage was taken of the qualitatively different character of this equipment (e.g., inventory costs were lowered). Finally, production was completely reorganized in a manner to better suit the nature and capacities inherent in the machinery. The suggestion raised by this analysis is that in the present circumstances the Soviets will have difficulty moving beyond the first of these steps.

Flexible manufacturing fails in this setting because of the narrow terms in which its use and effect are conceived. L'vov states that the majority of producers consider their main assignment to be increased

output quantity. New technology is viewed as a means of raising labor productivity, although as a rule only in selected segments of the production scheme. In particular, the main production activities are likely to receive more support than auxiliary services, the areas given most attention by successful Western adopters.¹¹ The result of raising the efficiency of production of some subassembly is often to increase the level of unfinished goods in the warehouse with little effect on final results. Instead, for an incremental approach to proceed rationally there must be an economic approach to the planning of investment.

The economic approach [to the introduction of FMS] breaks through fixed notions, compelling a different perception of the essence of complex automation. For us this by no means [implies] the 100 percent saturation of the enterprise with automated equipment. Integration [*kompleksnost'*] is achieved not through the quantity of such equipment, but to the degree that automation affects the final results. It may turn out to be more efficient economically to derive a solution guaranteeing the combination of both automated and non-automated aspects of production into one system. Therefore one must consider the complete modernization of production by means of partial automation with the help of FMS. (Vasilyeva, 1988.)

Unfortunately, according to V. Serebrennyi, also of the Machine Tool Building Ministry's Institute, the present approach is purely technocratic. The role of economics is that of a servant, entering in at the end of the design cycle for the purpose of calculating the economic effect of the engineering decisions already taken. A new approach would require that economics be the beginning of the process (Vasilyeva, 1988). But such an approach is frustrated by the limited means at the disposal of enterprises planning capital investment.

These limitations are, in part, material. An enterprise finding itself the sudden, if perhaps unwilling, beneficiary of a modernization campaign may be in a position to ask few questions of its superiors, nor really be in the same position as a Western firm for effectively planning adoption.

The realization of scientific and technical achievements in our country is complicated primarily by the fact that we do not have the necessary material conditions for the introduction of new technical equipment. The majority of enterprises do not have the necessary experimental and testing base and through their own forces cannot provide for a high level of organization of work for introducing new technical equipment within short periods of time. (Zaichenko, 1988.)

Enterprises are to agree to allocation lists for FMS components, then perform a series of integrating tasks, such as writing software, best

¹¹Compare with the description of the Toyota approach cited in Sec. V.

performed by specialists. Suppliers of components provide what they wish, not what is needed. "After this, try not reporting on [the FMS facility's] high degree of efficiency [to the ministry]!" (Volchkevich, 1988b).

A major shortcoming is the scarcity of computing and monitoring facilities. In the Western experience, proliferation of the computer hardware and the skill to use it throughout the plant permit the collection of information from various enterprise departments. This is the prerequisite for eliminating redundancies and allowing a different approach to material and information flows to transform the production process.¹²

In the case of machine builders, limitations also take the form of inadequate support from machine designers.

Once the enterprise has received technical documentation and an experimental model of a new item, it frequently cannot begin series production since the developing organization, as a rule, does not take into account the specific technological capabilities of the given enterprise. As a result, when it introduces new technical equipment through its own forces it practically repeats the entire complex of work included in the experimental development, the technology for the manufacture changes radically, and the technological fittings are designed and manufactured all over again. (Zaichenko, 1988.)

This applies, in turn, to users of advanced manufacturing technology since the team designing the installation usually will not be the one eventually operating it.

The most serious limitation is on the information and opportunity available to the enterprise to plan for the effective utilization of advanced manufacturing technology. L'vov believes, as would a Western analyst, it is necessary to begin with a definition of enterprise goals. This should be framed in terms of a question that "is today not generally considered during the preparation of expensive designs. I have in mind marketing—studying the demand and creating the market for the products of the enterprise" (Vasilyeva, 1988). This prescription is based upon the recognition that investment in advanced manufacturing technology, if carried out properly, will change the enterprise's manufacturing process. This may further indicate a need

¹²Among the domestic specialists who recognize the inadequacies of Soviet performance with advanced manufacturing technologies is a school that attributes these shortcomings to insufficient automation of data flows (see, e.g., Chumachenko and Aizenshtein, 1988). While undoubtedly true, such views also reinforce the predisposition to concentrate on hardware, hence costly, solutions. Although part of the solution may be to increase computerization of existing data flows, this will certainly not help to compensate for the absence of data flows that do not currently exist within the Soviet enterprise in any form.

to change the old output profile to one that takes better advantage of the new realities and capabilities. The flaw, of course, is that the quality of market information is degraded by the lack of market mechanisms in the Soviet economy. There is also low incentive for producers to pay heed to what signals there might be. Economic reforms have not yet advanced far enough to suggest the authority governing the connection between investment and output decisions will change, nor what the extent of enterprise authority over these matters will be.¹³

But the information available to enterprises on their own internal processes is not markedly better. In these circumstances, even if good domestic machinery is produced, it may not have much greater effect than the old. The lack of an accounting system to suit the purpose of an enterprise needing to track equipment performance is coming more sharply into focus as advanced manufacturing technology finds its way into Soviet enterprises.¹⁴ Coupled with the difficulties of cross-departmental information sharing and task-forcing, and the local management's limited authority to redraft production processes, the chance for a Soviet enterprise to do the type of preinvestment planning required for rational choice and use of advanced manufacturing technology is quite limited. This problem is not susceptible to technological quick fixes.

The most insidious aspect of the problem of skewed and inadequate information is that a Soviet enterprise employing advanced manufacturing technology has limited means for receiving adequate warning when its utilization is inefficient. In the context of Fig. 2, it might be using the machinery in such a fashion that it can achieve no greater efficiency than represented by point "A," while believing all the while that the mere fact an investment has been made in a costly FMS installation means the plant is operating at point "B." Consider again the examples of General Motors, General Electric, and IBM. How

¹³During the first 15 years of the reform effort in Hungary, the model that comes closest to the type of reform Gorbachev seems to have in mind for the Soviet Union, enterprise investment decisions were circumscribed by central checks (designed to rein in investment cycles) to such an extent that enterprises could not do the type of thorough preinvestment planning L'vov calls for. This did affect the nature of planning for, and efficient utilization of, advanced manufacturing technology (Popper, 1988).

¹⁴Current assessments of FMS utilization are based on the "efficient time fund" (*effektivnyi fond vremeni*) method, which is unaffected, for example, by the actual number of shifts the equipment operates, whereas experience has shown that efficient three-shift operation is crucial for achieving the technology's potential. Further, few plants perform continuous monitoring of operations. Rather, necessary reports to higher authorities are based upon 24-hour spot checks, which are then recalculated to cover the entire reporting period. The object, clearly, is to come up with a mandatory figure rather than to actually track performance. Monitoring of indicators, when not obligatory, is rarely done (Chumachenko and Aizenshtein, 1988). Also see Ilyshev and Ilysheva (1987) for a more detailed discussion.

would the results of their investment have been evaluated in Soviet terms? If after investment in FMS a Soviet enterprise were able to claim increased product reliability that achieved world levels, higher labor productivity, and more output for both domestic and foreign markets, laudatory stories would undoubtedly appear in the Soviet press, extolling its management for being on the forefront of modernization, rather than having it be fairly common knowledge that not all was well on the shop floor.¹⁵ Only the most perceptive of trained specialists might harbor some doubts about how effective the FMS installation actually was. Taken in aggregate, enough investment of this type would lead to favorable trends in the comparisons between the Soviet capital stock and the world technological frontier—accompanied by further increases in Soviet capital/output ratios.

We are faced with a dilemma in its full magnitude: Do we learn to solve harmoniously the social, technical and economic problems of flexible automation or do we automate without regard to the costs? (Volchkevich, 1988b.)

The discussion of Soviet experience with advanced manufacturing technology should not be taken to mean this type of machinery will work unequivocally well in the West while uniformly failing in the Soviet Union. Efficient utilization is inherently problematic wherever it is tried. "With few exceptions, the FMSs installed in the United States show an astonishing lack of flexibility. In many cases, they perform worse than the conventional technology they replace. The technology itself is not to blame; it is the management that makes the difference" (Jaikumar, 1986). However, the strong implication for Soviet attempts at this form of modernization is that the prospects for their success at an inherently difficult process will be further compromised by a lack of the information and organizational tools available to local management in the West.

Some Soviet commentators are aware of these pitfalls. This report has, as much as possible, utilized the writings of Soviet critics to suggest the inadequacies of the main course of the modernization effort. This has been done purposefully to indicate the existence of a sophisticated level of awareness in some parts of the Soviet system:

¹⁵The question need not be posed hypothetically. In 1984, the Kirov machine-tool-building plant reported an annual gain of 91,300 rubles with their ASK-01 flexible manufacturing installation. Actually, the installation was not producing a single part at the time. By 1986, in full three-shift operation, the installation produced losses of 170,000 rubles annually. "Despite this, the former leadership of the Ministry for the Machine Tool and Tool Building Industry ordered the compulsory introduction of FMSs of this design at all subordinate enterprises" (Volchkevich, 1988b).

When we see someone juggling swords at the circus, we do not hurry to repeat his trick. We understand: It requires practice, training, and props. The history of FMS shows that we were oblivious to such healthy thoughts. When the plans were imposed, we lacked experience, personnel, and scientific purpose. (Volchkevich, 1988a.)

It remains to be seen how much attention will be paid to these eloquent voices. At the national level, the possibility for improved performance with changes in incentives and institutions will be missed if central authorities, however well intentioned, set output priorities and targets for insufficiently sovereign enterprises in the simple terms that lend themselves best to quantification ("More NC!").

VII. THE PROSPECTS FOR MODERNIZATION

LESS EFFICIENT OR INEFFICIENT?

Even if modernization does not achieve all it was intended to, even if it follows a path less efficient than if the institutional precursors were already in place, will the effort still make a difference to Soviet production possibilities? In particular, will the emphasis on advanced manufacturing technology provide a net benefit to the system, albeit a less substantial one than might otherwise have been gained? Future research will concentrate more on the details of particular aspects of Soviet modernization. However, some observations can be offered in keeping with the general treatment provided by this report.

To a certain degree, the answer to the questions above depends upon the nature of the demands placed on Soviet industry for consumption and producer goods. As long as assortments are narrow and product runs long, it does not pay to equip plants with the greater degree of flexibility that must be utilized for advanced manufacturing technology to justify its cost. However, the nature of the manufacturing machinery purchased today will in large part govern the Soviet ability to produce the goods demanded tomorrow.

A well-operated and efficiently planned CNC installation is capable of doing more, both quantitatively and qualitatively, in a shorter period of time, than is a well-operated traditional machine tool. It may also be the case that a poorly operated and inefficiently planned CNC machine tool may be capable of doing more both quantitatively and qualitatively in a short period of time than is an inefficiently operated traditional machine tool, but that is not clear if all costs are considered. It may prove to be more injurious to productivity, given the expense involved, if the indicators for measurement are properly chosen. Costly programs to produce domestic CNC equipment not well suited to the needs of the machine users could prove a large drain on national resources. The consequences of inefficient utilization are greater still and have the potential for being extremely large if even more advanced manufacturing technologies are utilized.

Figure 3 illustrates the main point, albeit in a highly simplified and abstract presentation. The three sets of curves in the figure demonstrate returns to investments in advanced manufacturing technology

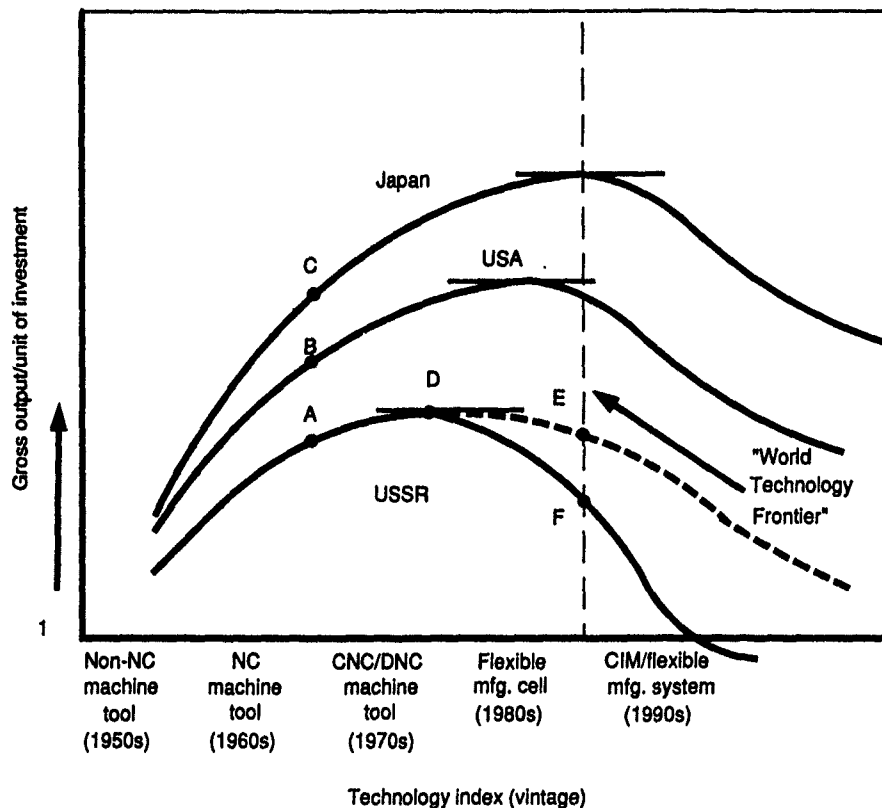


Fig. 3—Return to investment under several economic regimes

for three “countries.”¹ The vertical axis measures the gross output produced by industry per unit of investment in manufacturing capital.² This axis is set at the origin at 1, the point where each currency unit invested in manufacturing equipment returns one unit of output. It is certainly possible to pass below this point.³ The horizontal axis, although measuring technological vintage, is not interpreted as a time coordinate but rather as a hierarchy of increasing costs attending the

¹Although referred to as Japan, USA, and USSR, the representations are stylizations and were not derived from actual data series.

²This crude measure was chosen in preference to internal rate of return because the latter depends, in part, on starting position and investment patterns; a higher base level of efficiency stemming from previous investment will reduce the internal rate of return. The intention is to abstract from previous investment and use a measure that will be independent of starting positions.

³According to Soviet Finance Minister Pavlov, “One ruble invested . . . in heavy industry yields 84 kopeks” (Golovachev, 1989). As is usual with such statements, the underlying assumptions are not rendered explicit.

currently available investment choices.⁴ More advanced technology is achieved only with a greater outlay for manufacturing equipment and the other costs associated with refitting, retooling, and retraining. The broken vertical line represents the "world technological frontier" as it would be assessed in current Soviet usage: the technological level attained in practice by the leading industrial country. The figure, then, shows three continua of idealized investment choices and resulting technological levels that exist at a single moment.

The figure implicitly indicates that at each level of technology "Japan" is absolutely more efficient than is the "USA," which in turn dominates the "USSR." The shape of the curve marked "Japan" suggests that a nation constrained to follow its path would best be served by investing in leading-edge technology. This yields the maximum attainable output per unit of investment as represented by the flat slope of the short, horizontal line tangent to the curve. A greater efficiency of output is not possible in this setting. To pass beyond this point to the right would require even greater investment in untested or currently insufficiently understood technologies and would be unlikely to repay the investment costs as well as will the technological vintage represented by the point intersecting the dashed vertical line.

An industry possessing the characteristics inherent in the curve marked "USA" would achieve its optimal level of output return on investment at a technological level slightly below that of "Japan." Its return on investment would also be commensurately smaller. If it were to pass beyond this point to the section of the curve lying on or to the right of the dashed line, it will become apparent that the investment does not yield sufficient return; and future investment choices might then drift back across the line to the left. Material presented in Sec. V suggests that occurred with several investments in FMS systems in the United States. The systems could not be sustained efficiently as planned and were instead operated at a lower level, as a series of isolated flexible manufacturing cells. Subsequent investment planning took the negative experience into account.

The curve marked "USSR" illustrates the main themes presented in this report. If the Soviet Union were currently at point "A," then the modernization program may be considered as movement to the right along the curve. If the Soviets invested enough to provide themselves with the technology represented by the horizontal coordinate of point "D," the effort would then make industrial production as efficient as possible given current institutions, practices, and incentives. To seek

⁴The capital types associated with points along this axis are also intended to be representations; the distances between them do not reflect real differences in relative costs.

the "world technology frontier" by investing the additional resources required would bring the economy to a point providing less return on investment than point "D."

Could such investment lead to actual net losses? If the curve continues from point "D" along the dotted line and achieves the world technological frontier at "E," the result will be a more effective industry in that it will produce more output per unit investment than at "A." The outcome is not efficient, however: More could have been produced with a smaller outlay if the Soviets chose to modernize to a technological level better suited to the ability of industrial management to operate it ("D"). However, the true curve may be the solid one lying below the dotted line, and a concerted campaign to achieve the technological frontier may lead industry to "F." After making vast claims upon national income to support a modernization drive of this type, the economy would be in a less efficient position than it was formerly because of the sums required and the underdevelopment of the means of efficiently utilizing the capital stock thus constructed.

It has not been possible, with the material presented in this study, to determine which outcome is more likely. The true outcome of the modernization program may well lie in the region bounded by points "E" and "F." But Fig. 3 suggests that in the long run this empirical question may not be as important as it first appears. Even if the resulting outcome lies closer to "E," a modernization program conceptualized in terms of improving the quality of machinery constrains the Soviet economy to choose a solution on the "USSR" curve that is absolutely less efficient at every point than are the two curves lying above it.⁵ Given the relationship among the three curves, this course is not sufficient for reducing the technological lag between the Soviet Union and the industrialized West.

Modernizing investment programs must be accompanied by institutional changes to permit modernization of industry in the broadest sense rather than of the production equipment alone. Improving the information available to enterprise managers, as to both external conditions and internal possibilities, and increasing the authority for such decisionmakers to act upon this information while providing them with incentives to do so will make it possible for the existing capital stock to be rendered more productive. In the idiom of Fig. 3, such changes would allow Soviet industry to move from the regime represented by point "A" to a more productive state such as those represented by "B"

⁵Indeed, differences in comparative advantage may make it more costly in real resource terms for the Soviets to keep pace with leading industrial countries while moving the same horizontal distance along the "USSR" curve as is travelled by the "USA" and "Japan" along theirs.

or even "C" without as great an outlay for new equipment.⁶ The second benefit from such a regime shift would be to make existing machinery more efficient and to make any subsequent investment in equipment of a higher technological level more efficient by yielding a higher return per unit investment.

Therefore, the question of whether the Gorbachev modernization program yields a result that is less efficient ("E," leading to nonoptimal resource utilization) or inefficient ("F," a calamity if pursued as a major national investment drive) is immaterial in the long run. Even a solution deemed efficient in local Soviet terms ("D") is absolutely less efficient than the results achieved by the nations the Soviet Union is in competition with.

It may be argued, however, that the extra abilities conferred by advanced manufacturing technology may be sufficient to prevent the precrisis situation from worsening and the technology gap from widening. In this respect strict cost accounting is not as relevant. Perhaps so. But the Soviets are currently in crisis because the policies of the past and the institutions of both the past and present have made the economy profligate of its resources. Goals were established by the central authorities based upon the limited understanding conveyed by available economic data, or in pursuit of ends other than the strictly economic; and the means of achieving them have been wasteful. It is difficult to imagine that exploring new, advanced means of being inefficient will prove to be of great benefit to the Soviet Union over the long run. Over the short run, the net result may be an increase in the overall output indicators or even an ability to produce new varieties of goods. This in itself could lead to further injury to the economy if the cost of investment in these technologies is so large that it crowds out other, perhaps even more effective, lower-cost solutions. These short-run benefits could prove dearly bought indeed if they distract attention from the urgent need to overhaul the system.

The Soviets should not necessarily confine themselves to producing and employing low-technology machinery, concentrating upon operating it as efficiently as possible, and deliberately avoid using advanced

⁶Such a move is not costless. New capital will still need to be produced and modified to better suit the needs of users, and the new insights gained by enterprise officials will need to be embodied in redesigned and better laid out plant. In addition, any shift to new institutions of economic decisionmaking will involve short-term dislocations and losses of potential output that may appear even more dramatic in a period of generally perceived shortages. Finally, there will appear to be considerable losses to those who derive rents or hold other forms of property rights within the existing economic institutions, although from an economy-wide perspective these will not be lost but rather transferred. What will be saved are the costs necessary for the horizontal move into a higher-technology regime and the gains accrued over time from shifting to a more efficient production regime.

manufacturing technology capital. It is difficult to say what would be the consequences of such a strategy or even if it would make any sense to try and apply it. But if even the current vintage of capital cannot be used efficiently, there may be greater capacity for efficiency losses the more expensive the capital being used.

THE NEED FOR ECONOMIC REFORM

The modernization program, as conceived and as waged as a priority campaign, addresses only the symptoms of inefficiency in the economy and not the root cause.

This conclusion seems at variance with events. After all, Mikhail S. Gorbachev has demonstrated a willingness to confront and modify long-standing Soviet institutions as has no other Soviet leader of modern times. The movement for *perestroika* has become the central theme of his tenure as General Secretary. Yet, as a practical matter, the campaign for modernization has been conducted as a policy distinct from the elements of reform intended to form the core of the economic restructuring. The modernization program was laid down in 1985 in substantially the same form as it is being currently enacted. The Law on the State Enterprise (Association) was not formally decreed until 1987 and has yet to have a substantial positive effect on the operation of the economy or the actions of economic agents in the state sector. The timing strongly suggests a perception among the senior Soviet leadership that stagnation can be ameliorated by changing industrial equipment before modifying the economic institutions in which they operate. There is not yet a general understanding among the leadership that the goals set for the modernization program depend crucially upon fundamental reform of Soviet economic institutions. Only this can render modernization an efficient process for redressing the system's inefficiencies.

An analysis of the problems of appropriate choice and efficient utilization of new capital brings the discussion full circle. The attempt at large-scale modernization of Soviet industry has largely preceded successful formulation and implementation of the reforms that would make it feasible. The urgency with which the leadership has perceived a need to address the hardware aspects of Soviet stagnation has prompted a response bearing less fruit than would have been the case if reform were carried forward more decisively.

Currently, modernization is made inefficient by the primitive mechanism governing technological choice at the site where new capital is produced, and by the insufficient means to inform and guide its

efficient use when put into place. Heretofore, the mechanisms employed to change the nature of these means have been insufficient to substantially affect the problems. Are the current reform proposals, moving in this direction, going to be sufficient even if fully implemented as drafted?

Several crucial areas remain untouched, or have been inadequately addressed in practice, by current Soviet law:⁷

- Reform of the price system
- Creation of competitive markets
- Reform of internal enterprise structure to conform with external changes
- Removal of ministerial control over output profile decisions
- Providing legal guarantees to enterprises for the free exercise of their newly found rights.

The first of these is fundamental. Only when the price regime does a better job of conveying the costs to the economy of engaging in various activities will it be possible to make efficient choices between alternatives. Such a system need not be perfect, merely better than the current practice of setting administrative prices on the basis of faulty criteria.

However, a system still predicated upon central administrators setting prices, albeit using new, improved, and presumably more apposite criteria, is not sufficient. Central authorities, even with the best will in the world, do not have the ability to gather sufficient information and analyze it rapidly enough to achieve the goals set for a more information-laden system of prices. And, of course, such bodies may not have the best of wills; they may be parochial, short-sighted, obtuse, venal, or have a messianic zeal for a pet project. Further, market competition against potential rivals also provides instructive lessons for a producer that would be forgone by such a regime. Only in a competitive context can information on best practice be pooled, performance judged, and adequate motivation provided for occasionally forcing hard choices upon enterprises.

For the information generated by a greater degree of competition to be utilized adequately, enterprises must be changed into better receptors of such information. They must also be better poised to make use of it once it is received. This implies a series of transformations ranging from the simple reshuffling of internal portfolios (e.g., increasing the size and presence of marketing departments, providing for more interaction between departments over investment decisions) to basic

⁷These may all be seen as variations on the problematic theme of assigning property rights, currently so ill defined under the Soviet system.

changes in enterprise structure by spinning off some plants into separate entities and altering the internal environment for information flows and decisionmaking. If enterprises are to be more enterprising and less responsive to command directives, they must be recast in an image that will allow greater response to new stimuli.

Part of this enlarged sphere of authority must include sovereignty over entry and exit decisions. The latter is the most problematic. Decisions over investment must come increasingly from an analysis of the type of output desired. Efficient utilization of capital implies that some activities and product lines should be emphasized over others. Indeed, it is by no means certain that all enterprises should continue to produce their present assortment. Who should have the authority to decide such questions? The reform proposals presented to date suggest this should fall within the province of enterprise decisions. This is a source for potential conflict; what is the role of the ministry when an enterprise ceases to produce a good for which it has responsibility? Should a ministry have the power to force an enterprise to produce something the enterprise judges to be unprofitable under the new conditions? The July 1988 clarifications to the Law on the State Enterprise say enterprises may not withdraw from existing supply connections. The fundamental conflict over the role of intermediate economic management, the whole elaborate ministerial structure, must be resolved if reform is to move toward realization of industry modernization.

Many of the decisions an enterprise might take to modernize by more efficiently utilizing new manufacturing capital may, in fact, be sanctioned by law but deviate from past and current custom. If the ministry stands poised to wield powers that can injure the enterprise if the ministry's perceived prerogatives are trespassed upon, the enterprise will be likely to alter its behavior to follow *de facto* rather than *de jure* practice. In such an environment, any reform decree will become a dead letter. The enterprise's legal standing with respect to the ministry must be clarified.

Modernization taking place in the substantially unchanged economic system leads to expensive, excessive, and often inappropriate use of advanced manufacturing technology in industry. To the extent that they decentralize decisionmaking, make goals other than simple-minded plan targets the objects for planning in enterprises, and provide more useful information to decisionmakers, the proposed reforms may lead to more appropriate and well-managed applications, profoundly affecting the capacity of Soviet industrial production. Thus, the success with which this technology is utilized depends ultimately on the nature of economic reforms in the Soviet Union and the extent to which they are successfully realized in practice.

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