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A RAND NOTE

Priority, Duality, and Penetration in the Soviet Command Economy

Richard E. Ericson

December 1988

40 Years
1948-1988

RAND

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PREFACE

This Note is part of a larger study whose purpose is to develop new methods and models for analyzing the Soviet economy. These new models are linked more closely than existing models to certain key characteristics of the Soviet system. In part, the study responds to some of the limitations of existing approaches that were identified at a conference on models of the Soviet economy.[1] The conference was held in the Washington offices of The RAND Corporation.

At the conference, it was argued that Soviet economic models have been based too extensively on Western economic concepts and constructs, and that certain features of the Soviet economy have not been adequately reflected in these models: the priority given the defense sector, its dualistic character, and its penetration into civil activities. In this Note, a theoretical basis for analyzing these features of the Soviet economy is proposed.

This research, sponsored by the Director of Net Assessment in the Office of the Secretary of Defense, is part of the International Economic Policy research program in RAND's National Defense Research Institute, a Federally Funded Research and Development Center sponsored by the Office of the Secretary of Defense. The Note should be of interest to those in the Departments of Defense and State and the intelligence community who are concerned with the key role of the defense sector in the Soviet economy.

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[1]Gregory G. Hildebrandt (ed.), *RAND Conference on Models of the Soviet Economy*, October 11–12, 1984, The RAND Corporation, R-3322, October 1985.

SUMMARY

This Note analyzes characteristics of the Soviet economy that are underemphasized in existing macroeconomic models of the Soviet Union. These characteristics include the existence of clear priority and nonpriority sectors, the "nonmarginalist" nature of decisionmaking, the distinct advantages of priority sectors during both planning and plan implementation, and the rigidities of administrative allocation in the face of random shocks to both needs and capabilities. The analysis is carried out in a series of simple two-sector macromodels of plan implementation in a priority-driven command economy. The structure of the models reflects, albeit in highly simplified form, the planned *dual* nature of the Soviet economy in terms of priority and nonpriority sectors, allocational and technological rigidities, and the effect of *priority* in determining the response to shocks during plan implementation. The Note also defines and formalizes of the concepts of *priority*, technological and economic *flexibility*, and the *dual-economy* hypothesis, and of priority-sector *penetration* of the rest of the economy.

A number of empirically verifiable implications that do not arise naturally in standard macroeconomic models stem from this analysis. In particular, the analysis shows that (1) the variance of output (plan fulfillment) is greater in nonpriority than in priority sectors; (2) there is more excess capacity in priority sectors; (3) priority factor/input use proportions are unrelated to economy-wide tradeoffs; (4) inputs into priority sectors are protected from fluctuations in economic activity; and (5) factor productivity is lower in priority sectors, perhaps because of flexibility considerations. These observations help rationalize aspects of Soviet economic behavior that require either irrationality or strangely changing preferences for explanation in standard models.

The analysis helps in understanding the impact of the high-priority military sectors on the macroeconomic performance of the Soviet economy. Priority is maintained by detailed centralized planning and administered implementation of resource allocation by GOSPLAN, GOSSNAB, and the defense ministries under the close supervision [*kontrol'*] of the VPK (Military-Industrial Commission). Special needs or changes in plans of priority sectors are handled by built-in flexibility and redundancy, by the right of first access to any resources, and by depriving other sectors, if necessary. Keeping tight central control over priorities makes this possible,

even though it leads to sometimes major, unintended consequences for the rest of the economy.

The purpose of the analysis is to formally capture this process and its consequences and ultimately to understand the burden of the military on the Soviet economy, to predict the impact of changes in Soviet policies and priorities, and to understand this structural source of inefficiency and deteriorating productivity in the Soviet Union. This Note is a first step to that end.

CONTENTS

FIGURES

I. INTRODUCTION

This portion of the Alternative Views of the Soviet Economy project provides a set of simple models that allow us to begin a formal analysis of the concepts of *priority, duality,* and *penetration* in the Soviet economy. These concepts are discussed in historical and institutional context by Badgett.[1] This analysis is motivated by a belief that existing economic models, based on *mirror imaging*, can be misleading in their implications, particularly when there are significant policy changes to be analyzed. Such models are built around neoclassical constrained optimization in a "generic" industrial economy that does not incorporate any of the noticeable institutional and structural differences between the Soviet economy and that of the industrialized West. Thus, when decisions or behavior are predicted from the optimal control solutions to such models, something important in understanding the Soviet economy is missed. This is particularly true regarding the role and effect of the military sectors in the Soviet economy, because of their unique structure, position, and priority in the Soviet economic hierarchy.

As a *preliminary* approach, our modeling focuses on some basic theoretical issues raised by the Soviet military economy's priority position and structure (the latter captured in the related concepts of duality and penetration). The objective is not to derive a complete theoretical framework, but rather to begin formalizing, in simple tractable models, some alternative ideas about how the Soviet economy functions. At a later stage, when we are more confident of our understanding of these models, we hope to apply them to explore substantive issues of Soviet economic change and development.

We try to model four ideas:

(1) Priority and its impact,
(2) Military intrusion/penetration and permeation in the economy,
(3) Flexible (dual-purpose) technology and its costs, and
(4) Dual-economy (near complete vertical integration) hypothesis.

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[1]Lee D. Badgett, *Defeated by a Maze: Modeling the Soviet Economy and Its Defense-Industrial Sector*, The RAND Corporation, N-2644-NA, October 1988.

These ideas are explored in a series of related models of aggregate economic activity under a number of very strong technical simplifying assumptions.[2] The models define the concepts of priority, penetration, flexibility, and duality, and begin to clarify their effect on economic outcomes. The models generate different kinds of optimizing problems from those typically analyzed and produce results that we find both interesting and suggestive of possibilities. Developing these ideas and insights may lead to an alternative theoretical framework to technologically determined mirror imaging.

The logic of our approach is as follows. As Badgett[3] cogently argues, something significantly different about Soviet economic institutions, broadly defined, invalidates standard neoclassical economic analysis. Indeed, we believe that difference is captured, in large part, by the four ideas outlined above. Building on Badgett's historical and institutional analysis, this Note provides a foundation for a more formal analytic development of the concepts he found relevant to an understanding of the Soviet military economy. We test those concepts, through their formal modeling, against both the intuitive reasonableness of their formulation and the consequences they imply for the economy. Thus we work with an extremely simple, graphically tractable, two-sector model reflecting the need for ex-post macroeconomic consistency. The only substantive assumptions required in this framework relate to the technological coefficients of the different sectors and the driving concepts of priority, duality, permeation, and flexibility. For example, the technical efficiency of a sector is reflected in its material and factor use coefficients, while the material use coefficients also reflect its assumed degree of dependence on the rest of the economy.

In this framework, we formally explore the results of explicit, yet intuitively reasonable, definitions of these four ideas. Their rigorous mathematical formulation almost immediately yields consequences that appear relevant to the Soviet economy, particularly in view of the ongoing discussion of Soviet reform. They support the intuition that imposing priorities—that is, goals overriding society's other objectives—is the source of much dysfunctional behavior. Our results point to

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[2]We study the very simplest case of two sectors and linear homogeneous technology. Under such assumptions one could get the same results from a neoclassical optimization framework by placing appropriate restrictions on the decisionmakers' preferences. But we believe that model to be more artificial and intuitively less satisfactory.

[3]Badgett (1988).

significant economic inefficiency, an opportunity cost borne largely outside the priority sector, as well as some *economic* waste within that sector. Thus the priority sector appears more efficient or "distinctly superior," because it effectively achieves results, while imposing much of the cost on others. These findings are fully consistent with greater *technical* efficiency within the priority (read, military) sector and overall economic inefficiency from the nature of its operation. Hence these models provide a partial explanation of Badgett's findings and show that priority mechanisms impose a potentially large opportunity cost.

Because of their simplicity, the resulting models will obviously be "inadequate" to Soviet reality. However, their purpose is not for prediction or policy analysis, but to elucidate some ideas about the essential nature of the Soviet economic system. The structure of the models, the "stylized facts" that lie behind them, rests on an understanding of the Soviet system as a priority-driven command economy, with significant intrusion into all other sectors by the defense/military sectors. If changes and reforms [*perestroika*] under Gorbachev change that nature of the system, these models will lose relevance. We do not consider this likely to happen in the near future, if only because of "brakes" on reform (e.g., state orders [goszakazy] and ceilings [limity]) in place for the transition period. Yet even in the case of true radical reform, the models may still be valuable as a theoretical benchmark, a formalization of priority, duality, and priority penetration in a command economy, and hence as a tool for analyzing Soviet economic history. Further, the qualitative results/predictions of these models, where they differ from those of standard neoclassical models, might be used for testing whether the reforms are real. Finally, these highly stylized models should provide a basis for developing more elaborate models intended for policy analysis, though we are still far from that stage.

II. THE BASIC MODEL

Most of the models that we present have a similar underlying structure. We interpret the two *interacting* production sectors (departments) as the heavy industry/defense sector, and all other sectors. These sectors supply output to several final uses: military/defense and other uses, including consumption and investment. Thus we are largely working with interpenetration models of the military and the civil economies, though reducing sectoral interdependence allows some preliminary exploration of the dual-economy hypothesis of a largely autonomous and self-sufficient military sector. The models deal with issues of priority, duality, and flexibility in *implementation*, and hence, basic capacity and output plans are taken as ex-ante fixed constraints. Technology and variable inputs, including materials, labor productivity, and availability, are taken to be stochastic, i.e., subject to random perturbation.

The first task undertaken in these models is to investigate the concept of *priority* and its implications, exploring the idea that the military has a near absolute priority in the Soviet system, as Badgett argues. The models investigate a number of closely interrelated potential priority uses or sectors: defense, net production of heavy industry (≈ defense plus investment), gross output of heavy industry, etc. Here it seems useful to distinguish between "priority in planning" and "priority in implementation," as the appropriate model seems quite different because of the various constraints that must be faced. During planning there are fewer constraints, but alternative claims on resources, other than the priority, must be considered more seriously. The priority, by its very nature, is better understood and its requirements more clearly perceived. But the time span (horizon)—length of time over which decisions are being made—is longer, and thus the claims of priority are less pressing. Therefore it may be reasonable to model the priority pursued as one argument in the optimand (the most heavily weighted objective) in a properly formulated constrained optimization problem encompassing the other social objectives. This approach is developed further in the Appendix.[1] During implementation, however, the demands

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[1] An alternative approach, more closely related to our model of priority in implementation, is presented below. It involves "needs-driven" satisficing during planning rather than optimizing with respect to a well-defined objective function. For a thorough discussion see R. Radner, "Satisficing," *Journal of Mathematical Economics*, Vol. 2, No. 2, 1975.

of any priority are immediate and urgent, and the constraints are more numerous and the alternatives fewer. The target/planned levels for any priority have already been chosen to be best, given other objectives and constraints. If it is a true priority, target levels must not be sacrificed in the face of unexpected contingencies or difficulties. Thus the best model for priority in implementation seems to be an almost surely binding constraint, a target level that must be attained at any feasible cost. In achieving priority outcomes, effectiveness is far more important than efficiency.

The concept investigated here is largely that of priority in implementation, though there is always an implicit planning problem behind the target level of that priority. We investigate the theoretical implications of defense/heavy-industry priority in the context of fixed capacities and output plans where system managers can adjust only intermediate product flows and the use of capacity. We study the kinds of production/allocation decisions that priorities imply and how they differ from those of a neoclassical world. Of particular interest is the effect of their interaction with uncertainty (surprises)—with respect to technology, factor productivity, and required priority output—on final economic outcomes especially in the nonpriority (residual) sectors. Here we can see the "costs" of enforced priorities, flexible technology supporting priorities, and the priority sector's permeation of the economy in terms of the economy's expected net output and its resulting allocation/distribution.[2] Remember, however, that we are merely illustrating, and to some extent elaborating, some basic and simple ideas about these issues. We derive the necessary consequences of our assumptions about the nature of priority, permeation, duality, and flexibility. The models are extreme and unrealistic, as they attempt to highlight aspects and questions previously slighted in formal modeling of the Soviet economy.

This exercise yields two general kinds of results. First it provides an analytically tractable way to analyze the consequences of the priority and intrusion of the military sector into the civil economy. Hence it provides a substructure for empirical analysis, a basis for organizing and questioning data. It also clarifies and operationalizes what we mean by the concepts of priority, duality, and intrusion or permeation of the military in the Soviet economy. Second, the exercise provides

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[2]We do not deny that there are some benefits, in terms of achieving priority objectives, to a flexible technology, for example. Those benefits relate to the effectiveness of pursuing largely political objectives, and not its economic efficiency. They, indeed, are better understood than the costs we focus on.

some interesting tentative conclusions that need to be developed as the models become more cohesive and systematic. For example, in these models priorities are always met when feasible and are planned so as to be almost surely feasible. Further, the priority sector carries the excess capacity of the system to deal successfully with uncertainty. This imposes an economic cost despite the presumed technical superiority of the priority military sectors. When the priority sector permeates (intrudes into) the rest of the economy, it imposes additional real current resource costs. In particular, exogenous shocks are fully passed to the nonpriority sectors, while endogenous uncertainty in the priority sector is shared with the rest of the economy. The priority sector absorbs resources independent of true opportunity costs, thus lowering current production potential and imposing flexibility costs on the economy. In addition, priority coupled with intrusion imposes excessive capital costs on the economy both through excess capacity and the costs of dual-purpose, flexible technologies and organizational forms.[3] To achieve the desired priority outcomes in a technically efficient manner imposes system-wide efficiency costs largely borne by other sectors. Each of these conclusions is a more natural consequence of the type of model investigated here than of a neoclassical mirror image model, where rather peculiar neoclassical preferences (utility functions) must be assumed to rationalize them.

Before turning to the formal models in the next section, we need to better define some of the driving concepts behind this research. As discussed above, *priority* is used in two senses. At the ex-ante planning stage, it may refer to the emphasis in the objective function of a well-defined optimization problem or to a perceived needs-driven choice with economic, opportunity-cost considerations decidedly secondary. In the latter case, it consists of near lexicographic satisficing with respect to clearly defined *needs* (priorities), followed later by consideration (perhaps optimization) of the rest of the economy. At the ex-post implementation stage, a priority is a constraint on choice that *must* be met, almost regardless of the economic consequences. That is because it has been chosen optimally, taking full

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[3]Examples of such costs include hardening costs, costs of extra-wide aisles, strategic location costs, cost of dual-purpose equipment and redundancy, extra administrative overhead (e.g., first department), joint production of military and civil output, etc. On joint military-civil production, see J. Cooper, "The Civilian Production of the Soviet Defense Industry," preprint, Centre for Russian and East European Studies, University of Birmingham, U.K., May 1985. We do not attempt to model such capital costs here, though some of their consequences are reflected in the "flexibility" models discussed below.

account of those consequences, at the ex-ante stage. In either case, it characterizes the choices made at the highest levels of decisionmaking in the Soviet Union, the Central Committee, the Council of Ministers, and their central planning and coordination organs (e.g., GOSPLAN, GOSSNAB).

By *duality* we mean the perception that the Soviet economy consists of two largely isolated and self-sufficient parts, the military economy and the civil economy. A pure duality model would be one of full vertical integration, with sectoral interaction and interdependence occurring only at the most basic factor and resource level and current production taking place independently in the dual sectors.[4] Below we consider weaker versions of the duality model where there is some limited interaction between the two sectors. Finally, a model of *penetration* or *intrusion* is one with essential interdependence of all economic activities, a quintessential "complex social economy."[5] In such an economy, no priority can be met without detailed cooperation with the rest of the economy; intersectoral trade is significant and essential. Therefore, the pursuit of any priority, as defined above, in a world with any uncertainty implies extremely serious disruption of nonpriority economic activity because of the random load imposed on other parts of the complex social economy. Thus it allows much of the inefficiency generated by priority mechanisms to be hidden, because it is borne by other sectors. These ideas are further elucidated through their implementation in the models that follow.

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[4]In an extreme version of such a model, the only constraints tying the system together are those reflecting the long-run allocation of land (natural resources), labor, and capital inputs. There is little or no essential trade/exchange between the sectors, and basic factor allocation is handled at the highest political levels.

[5]This kind of penetration, coupled with the clear distinction of the military economy, is the type of model that Badgett finds most compelling. On the concept of a complex social economy see G. Grossman, "Notes for a Theory of the Command Economy," *Soviet Studies*, Vol. 15, No. 2, 1963.

III. ANALYTIC MODELS

THE NEOCLASSICAL MODEL

We now turn to a formalization and analysis of the various related models, deriving the results attainable in such a simple framework. We start with the neoclassical model to illustrate the mechanics and geometry of the analysis that follows and introduce a benchmark against which to compare the results of the models that we consider more relevant. The primary source of explanation in this model is the decisionmaker's preferences as reflected in an indifference map. The slope of the indifference curve at any point (commodity bundle) shows the relative value placed on incremental changes in that bundle, and thus reflects the decisionmaker's priorities. A steep indifference curve (in the xy-plane) shows a rather large marginal valuation of the first good (x-axis) relative to the second, thus revealing its "priority." Because of this, we should expect a rational decision, equating this tradeoff rate to marginal rates of economic or technical transformation, and generating a relatively large amount of this good. As the environment changes, that choice should also change to maintain the equality of those substitution rates.

The first model is of this neoclassical response to a productivity shock. Two versions of the same situation are presented in Figs. 1 and 2, the difference lying in the commodity space measured along the axes. In Fig. 1, vectors of net output, y, of each of the (aggregate) products form the axes (an orthogonal basis for the commodity space), while in Fig. 2 the axes measure gross output, x. These figures illustrate identical technologies for transforming material inputs into outputs, and two different states of factor, e.g., labor and productivity. In the normal "high productivity" state, factor/labor inputs are more efficient in producing output than they are in the state subject to a "low productivity" shock. The graphs also contain an indifference curve representation (U') of identical neoclassical preferences showing a possible "implementation priority" (i.e., generally low MRS_{12}) for the net output of good 2, y_2. That is, the outputs become equally desirable only at the margin when substantially more of good 2 is available.

Letting A be the input coefficient matrix and ℓ the vector of factor use coefficients of the given technology, and letting L be the limit on factor availability,

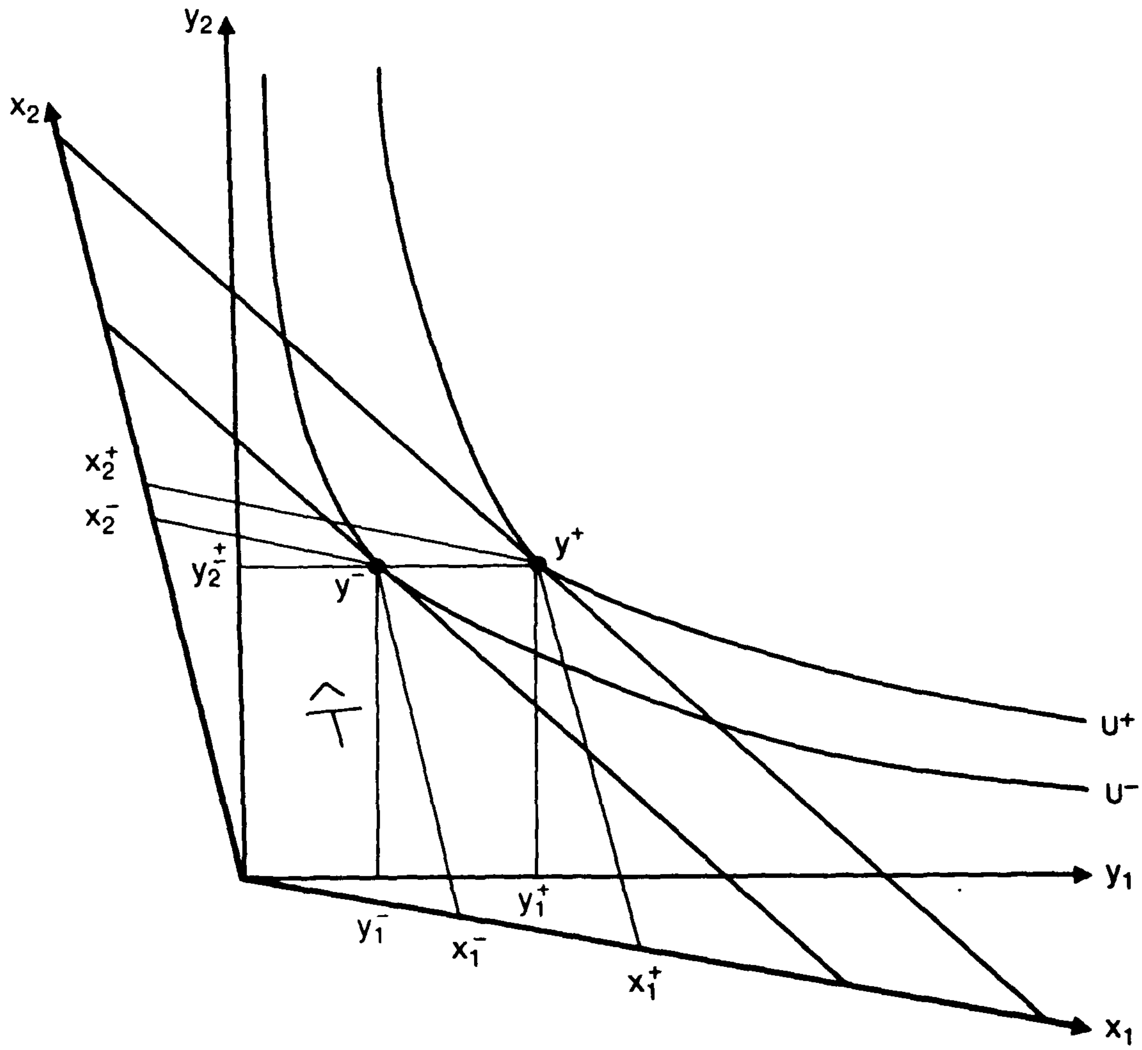

Fig. 1—Productivity shock response in net output space: The neoclassical approach (priority to good 2)

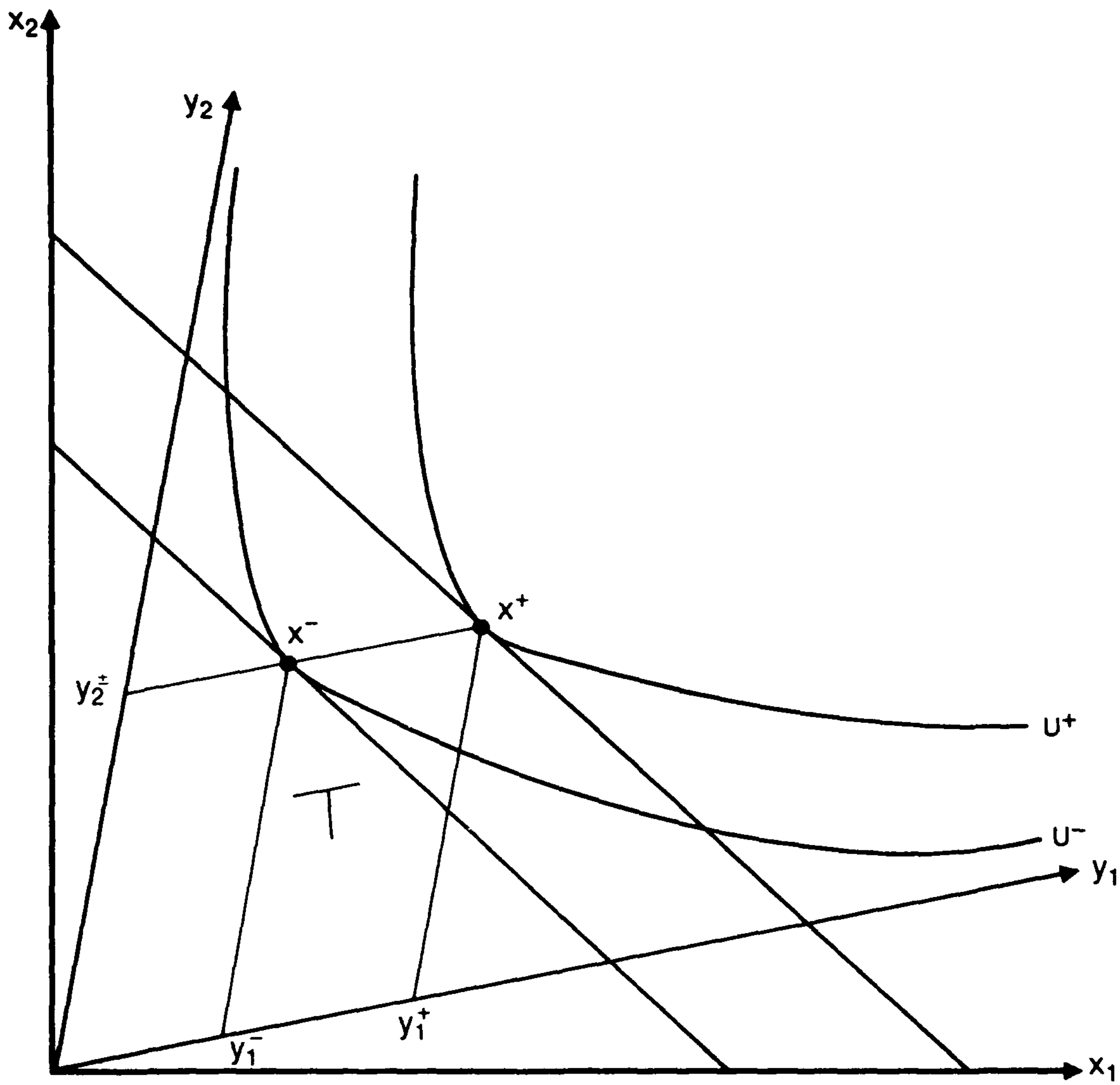

Fig. 2—Productivity shock response in gross output space: The neoclassical approach (priority to good 2)

we can algebraically formulate both versions of the model. In Fig. 1 we have

$$y = (I-A)x \tag{1.a}$$
$$\ell'(I-A)^{-1} y \leq L \tag{1.b}$$

with the truncated technology cone, $\hat{T} \equiv \{ y \mid \text{equations (1) hold and } x \geq 0 \}$, showing all nonnegative feasible gross outputs. The "planners' problem" in this model is to maximize a social welfare (planners' preference) function, $W(y)$ by choosing y subject to the constraint $y \varepsilon \hat{T}$ and $y \geq 0$. The optimal choices in the different states of factor productivity are y^- and y^+, where $-$ and $+$ refer to the low and high productivity states, respectively. These determine, through materials input requirements (along the boundary of $\hat{T}$), the gross outputs, x^- and x^+, necessary to support this net production, and the welfare levels generated by this optimal choice, $W(y^-) = u^-$ and $W(y^+) = u^+$. Notice that $y_2^- = y_2^+$, with all the loss of productivity realized in the net output of sector 1.

Similarly, in Fig. 2,

$$x = (I-A)^{-1} y, \tag{2.a}$$
$$\ell' x \leq L \tag{2.b}$$

determine the gross outputs necessary to maintain nonnegative net output given in the truncated cone $T \equiv \{ x \mid \text{equations (2) hold and } y \geq 0 \}$. Here the optimal decisions are x^- and x^+, which in turn determine y^- and y^+ on the boundary of T (projected on the axes) and optimal welfare levels u^- and u^+.[1] This representation in gross output space is the one that we shall maintain for most of the analysis of this Note, though identical results could be derived in the net output framework.

In this and the models that follow, we consider the second sector as the priority sector, and the first as all other sectors. Hence $x_2\,(y_2)$ represents the gross (net) output of the defense/heavy industry sectors, while $x_1\,(y_1)$ represents the gross (net) outputs of all other sectors. It is interesting to note the impact of the negative productivity shock depicted in Figs. 1 and 2, as it reflects the priority accorded sector 2 in the social welfare (utility) function of this neoclassical model. First note that

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[1]The formal problem solved here is: $\max_x \{ W([I-A]x) \mid x \varepsilon T \}$

gross output falls significantly farther in the nonpriority sectors, despite the equal reduction of productivity in all sectors of the economy. This nonpriority output loss is further aggravated by the maintenance of net output in the priority sector, due to that priority. Finally we remark that this result depends critically on the assumed shape of the preference map; quite different results would come from different preferences. Were the slopes of the indifference curves steeper, showing less of a willingness to sacrifice sector 1's performance to maintain that of sector 2, this model could generate precisely opposite conclusions. Indeed, any response to the productivity shock could be generated by an appropriate choice of planners' preference map. This indeterminacy, essentially depending on inherently unobservable characteristics, is, in part, why we believe the neoclassical model inadequate for analysis of priority-driven economic behavior.

Notice that here we have a class of models that can be interpreted as reflecting either a "dual" or an "intrusion" interpretation of the Soviet economy. The degree of duality (vertical integration) is reflected in the slopes of the boundary of the feasible technology cones: the closer they approximate the axes of the positive orthant, the less mutual interdependence there is in the economy. Indeed, for our purposes, only the vertical boundary (zero gross or net output in the nonpriority sectors) need approach the vertical axes for the model to incorporate a nearly self-contained, self-sufficient military sector. This is the sense in which our models address the issue of duality: very little output of the nonpriority sectors is required to support economic activity of high priority.

PRIORITY IN A (NEAR) DUAL-ECONOMY MODEL

We now present a model of priority in implementation as a constraint on the minimum level of activity/net output of the priority sector that must almost surely (a.s.) be met. This captures the operational impact of a priority expressed in preferences at a higher level. In the Soviet case, this reflects the right of the military to commandeer, as needed, any capital, labor, or material inputs in order to meet its assigned targets. This priority is seen in the operation of GOSSNAB, the Defense Ministries, and the *voenpredy* and quality control at the factory level. The objective of the economic system assumed here is to maximize net output of the nonpriority sectors, subject to the constraint of meeting priority needs in all anticipatable circumstances. Formally,

$$\max_{x} y_1 \qquad \text{subject to:}$$

$$\begin{aligned} y_2 &\geq D \\ (I-A)^{-1} y &= x \\ \ell' x &\leq L \\ x &\leq \bar{x} \end{aligned} \tag{3}$$

where D is the required level of priority (military/defense) output, $\bar{x}$ fixed (in the short run) capacity/plan limits on gross outputs, ℓ the realization of a random variable $(\omega): \Omega \rightarrow R^{2}_{++}$, and A the realization of a random variable $A(\omega): \Omega \rightarrow R^{2x2}_{++}$. These random variables formalize stochastic factor productivity and stochastic sectoral interdependence (material input needs), respectively. For expositional clarity, we separate the analysis of their impact, depicted in Figs. 3 and 4. In both figures we work only in gross output, x, space.

In Fig. 3 we see a range of variation in factor productivity, which, due to the necessity of maintaining $y_2 \geq D$, is fully transferred to the nonpriority sectors, generating $y_1 \in [\underline{c}, c]$. Notice that we have assumed $\bar{x}$ to be *optimistic*; capacity or plan levels are never strictly binding in the sense of rendering the factor constraint L irrelevant.[2] Indeed, to the extent that $\bar{x}$ is an ex-ante object of choice, we shall see that the optimal plan is always optimistic in just this sense. For, in this simple framework, we might model the choice of D as solving the intermediate stage "priority in planning" (see Appendix) problem:[3]

$$\max_{\bar{x}} y_2 \qquad \text{subject to:} \qquad \Pr\{ y_1 \geq \underline{c}, (I-A)^{-1} y = x \leq \bar{x} \} = 1, \tag{4}$$

$$\text{and} \qquad \Pr\{\ell' x \leq L\} = 1,$$

---

[2]To the extent that $\bar{x}$ is binding the problem of implementation becomes trivial. Indeed, as long as it is consistent with $(y_2 = D)$, it becomes the optimal choice for gross output and $\bar{y} = (I-A)\bar{x}$ the optimal net output. If $y_2 \geq D$ in this situation, then some additional nonpriority output Δy_1 can be generated by holding excess capacity in the priority sector, while still meeting all priority requirements. Easy calculation shows that $\Delta y_1 = (1-a_{22})^{-1} a_{12}(\bar{y}_2 - D)$.

[3]This should not be interpreted as treating consumption as a priority. As seen in the Appendix, $\underline{c}$ is a lower bound arising from the maximization of welfare defined over both types of output. Many other formulations also suggest themselves as reasonable for this choice. In the Appendix, we also consider a problem in which the choice of $\bar{x}$ is subject to a "capacity possibility frontier," $G(\bar{x}) \leq K$, in a more general programming formulation.

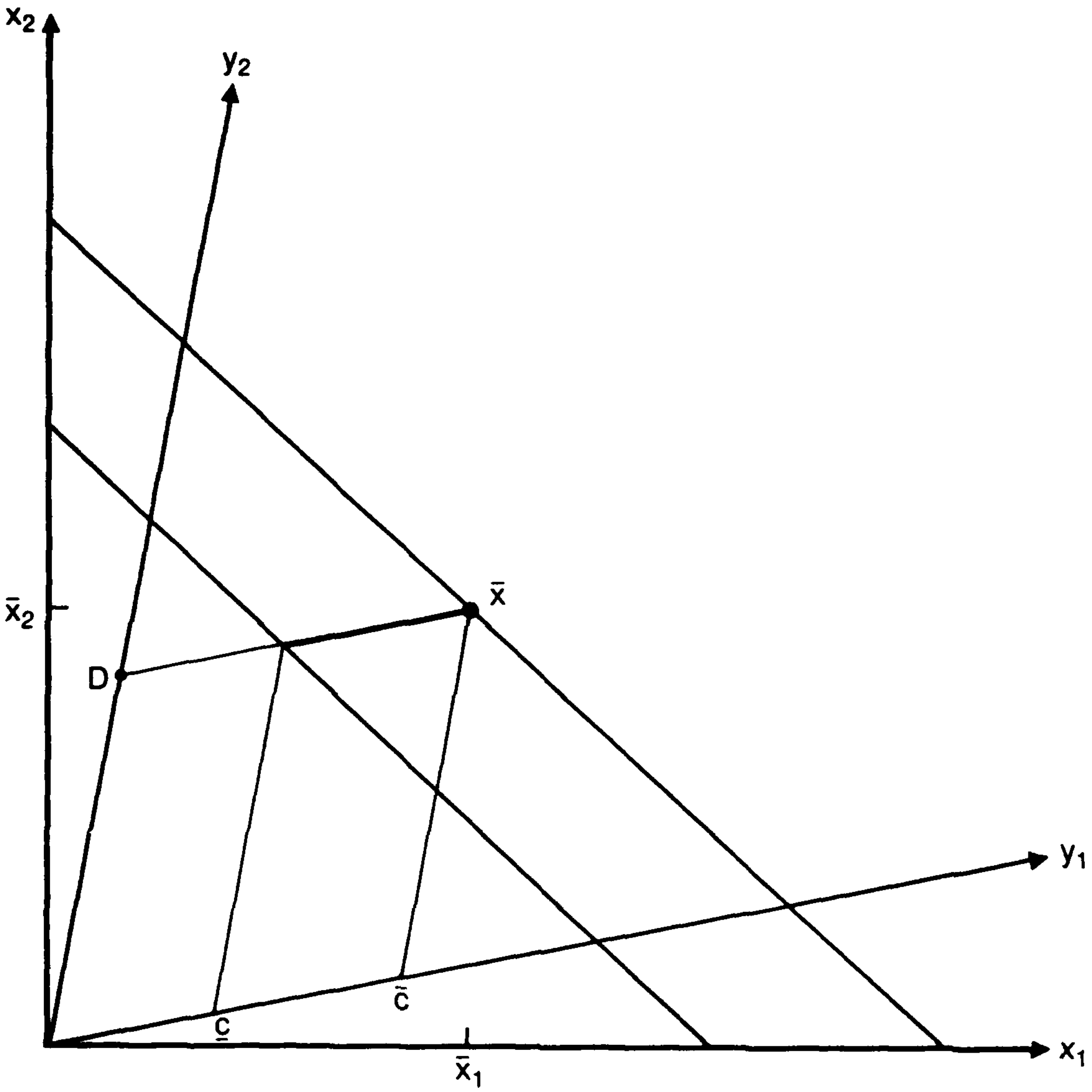

Fig. 3—Factor productivity shock in a priority model (priority to good 2)

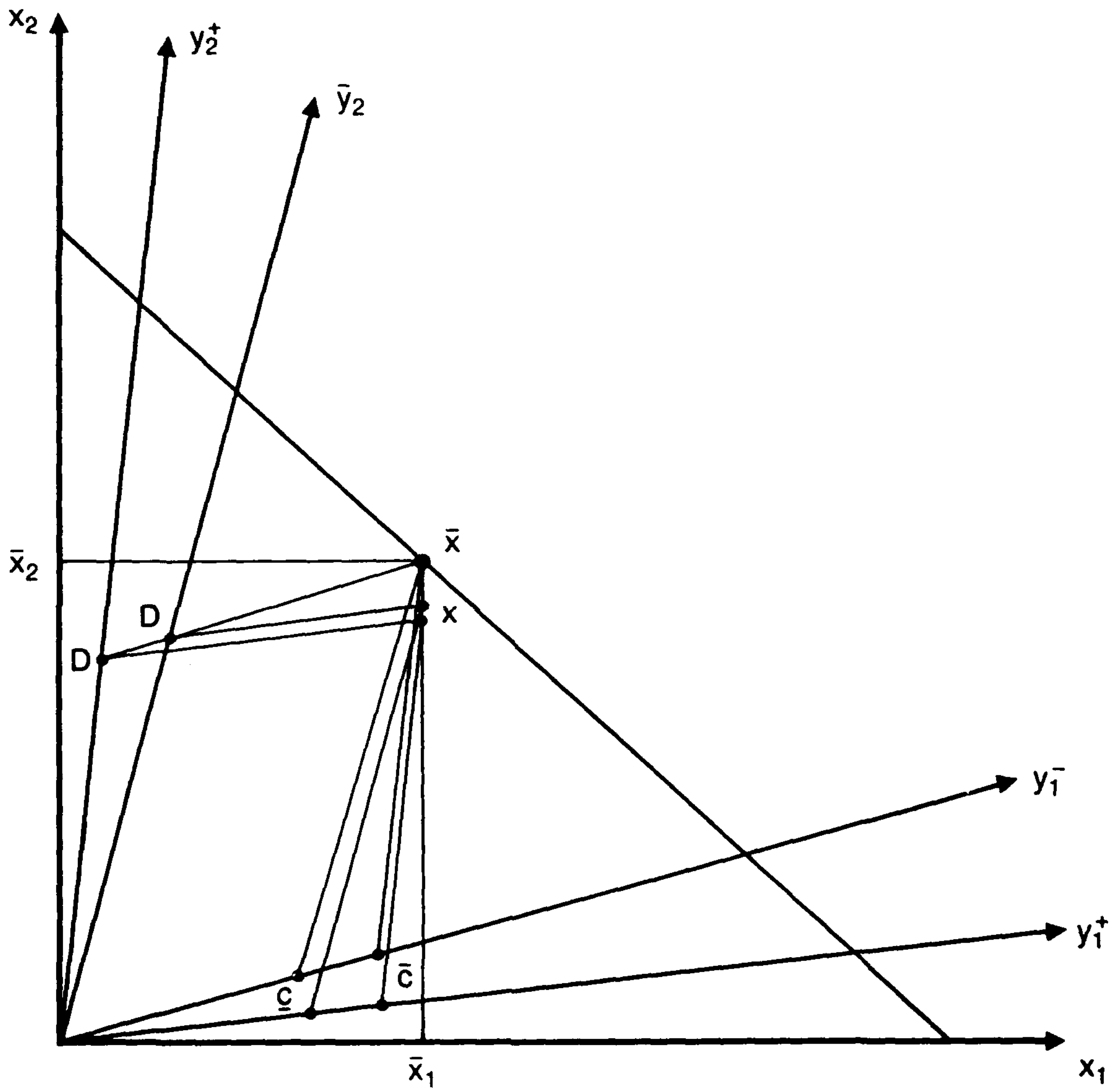

Fig. 4—Technology shocks in a priority model (priority to good 2)

yielding as an optimal value, $y_2 = D$. Notice that while this yields a definite y_2^*, the problem has no definite solution $\bar{x}^*$; $\bar{x}$ sufficiently large does not affect the solution. However, there is a minimal $\bar{x}$ allowing the solution ($y_2 = D$) that we might take as the planned choice as it is less costly than anything greater. This $\bar{x}$ ensures that capacity (binding plan ceiling on gross output) is chosen to guarantee the attainment of the necessary priority net output even in the worst anticipatable situation. Of course, it begs the question of how $\underline{c}$ was chosen, and that ultimately determines D. Thus there is implicitly a higher level of decisionmaking at which the (ultimately) political tradeoffs between $\underline{c}$ and D are made. At that stage, this model faces the same difficulties of preference observability as the neoclassical model. We do not attempt to model that stage here, though one possible formulation is presented in the Appendix, as we are more interested in priority during the operational stage of plan implementation.

In Fig. 4, we see the impact of fluctuations in mutual material input needs and intersectoral interdependence. Here maintaining priority final output, D, both transfers all randomness in the economy to nonpriority sectors but also typically generates (require) excess capacity in the priority sector. That is, at the optimum, $x_1 = \bar{x}_1$, $x_2 < \bar{x}_2$, $y_1 \in [\underline{c}, \bar{c}]$, and $y_2 \equiv D$. As in the case of stochastic productivity, it is assumed that $\bar{x}$ is chosen to ensure the achievement of D even in the least (anticipatable) favorable situation (4), and that is consistent with some rational (unmodeled) choice of D and $\underline{c}$. In addition, Fig. 4 depicts the impact of variations in labor productivity as the loci of gross outputs in two extreme situations of the variation of the dependence of sector 1 on sector 2.

The results of this simple analysis can now be summarized. First, by virtue of being priority, the planned net output levels of the heavy industry/defense sector are always met exactly. This implies that the variance in economic activity is thrown fully on the nonpriority sectors. Further, optimal planning will result in having more excess capacity, indeed all in this simplest formulation, in the military than in the nonpriority sectors. It also implies that capacity (the constraining plan) is set to ensure attaining the priority in the "worst" reasonable (anticipatable) situation.[4] Finally, this model also allows exploration of another definition of the priority output

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[4]While the response to risk is crudely modeled here, we consider it reasonable in view of the "bounded rationality" of decisionmakers; only sufficiently likely situations are anticipatable, and one-in-a-million chances are typically ignored. See David Kahneman and Amos Tversky, "Prospect Theory: An Analysis of Decision Under Risk," *Econometrica*, Vol. 47, No. 2, 1979.

as gross, rather than net, without significant change in the analysis. In that case, maintaining $x_2 = \bar{x}_2$ reduces the variance in y_1 while allowing upward fluctuation in $y_2 \geq D$. It should be emphasized that all these results are an immediate consequence of our concept of priority, and the behavior that it implies.

PRIORITY IN A "PENETRATION" MODEL

The next model is based on an understanding of military strength/defense capability as depending on all sectors of the economy, rather than being the output of a (subset of) priority sector(s), although some sectors (e.g., y_2—heavy industry) are clearly more important for the generation of that priority output. This implies that the maintenance of a military/defense priority requires the permeation by military requirements of all sectors of the economy, since the generation of "defense" output depends on inputs from many other interdependent sectors. Again the Soviet institutions supporting the priority claims of the military sectors are those that administer this permeation by the military of the entire economy. We model that dependence through a final-good production function, $f:R^2 \rightarrow R$, showing how the net military/defense output, $D = f(y^D)$, depends on the bundle of net outputs of the production sectors that is committed to those ends, $y^D \varepsilon R^2$, in our simple two-sector world.[5] To simplify the analysis below, we assume $f(\cdot)$ to be smooth and quasi-concave. The remaining net final output, $y^C = y - y^D$, is used in the rest of the economy to generate social/planners' welfare. The priority of D is reflected in its status as an essential need, a constraint on other uses that must be met.

The generation of priority output in this model is a final stage of production that does not feed directly back into the production capabilities of the more basic sectors. Yet it places a load, y^D, on them, imposing very real opportunity costs in terms of overall net output, y, and civil net output, y^C, on the rest of the economy. How this load is determined and allocated and how it responds to the changing economic environment are critical to an evaluation of the performance of the system. In the Soviet Union, the acquisition of these inputs seems to be governed, in part, by an attempt at explicit "cost" minimization, subject to the constraint of achieving priority targets.[6] In this model we assume such an approach, implying technical

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[5]We owe this formulation to a suggestion of Scott Cardell of The RAND Corporation.

[6]For a discussion of this see David Holloway, "Technology and Political Decision in Soviet Armaments Policy," *Journal of Peace Research*, No. 4, 1974, and "Technology,

efficiency and allowing for economic efficiency if an optimal target D were to be chosen and true opportunity costs were to be minimized.[7] However, it also allows a clear representation of the costs of an arbitrarily imposed priority target and arbitrary unit evaluations (prices) of the inputs into the production of military output, as observation of the Soviet Union suggests to be the case. These costs go beyond those captured in the neoclassical model above due to the increased latitude for error in this more elaborate formulation.

The implementation problem solved in this model consists of two stages: first, inputs into supporting the priority y^D must be determined, and then total net output, y, including the optimal composition of y^C, may be planned. This timing emphasizes the priority nature of the output supported by y^D. Assuming, again for simplicity, that the planners' preferences outside the priority are well-defined and neoclassical, the problem can be formulated as follows:

$$\min_{y^D} p'y^D \quad \text{subject to} \quad f(y^D) \geq D \tag{5.a}$$

$$\max_{x} U(y-y^D) \quad \text{subject to} \quad (I-A)^{-1} y = x \tag{5.b}$$

$$\ell' x \leq L$$

$$x \leq \bar{x}$$

where p is the vector of unit evaluations used for cost minimizing within the priority sector, D is the required priority target level, y^D is the solution to the first stage of the decision problem, and $y^C \equiv y-y^D$ is the residual output over which social/planners' preferences are defined. As above, ℓ and A are realizations of the random variables $\ell(\omega)$ and $A(\omega)$, respectively. Again we separate these sources of uncertainty in the graphical analysis of Figs. 5 and 6.

In Fig. 5 we see in gross output space the impact of priority under variation in factor productivity. The permeation of the military (priority) throughout the civil economy is reflected in the isoquant f_D of net outputs that might be used to

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Management and the Soviet Military Establishment," *Adelphi Papers*, No. 76, April 1971. Also see Arthur J. Alexander, "Decision Making in Soviet Weapons Procurement," *Adelphi Papers*, Nos. 147–148, Winter 1978–1979, and Arthur J. Alexander, *Modeling Soviet Defense Decisionmaking*, The RAND Corporation, P-6560, December 1980.

[7]Thus, in this formulation, priority procedures need not be inefficient as long as uncertainty does not affect the social utility of an "optimally" chosen D.

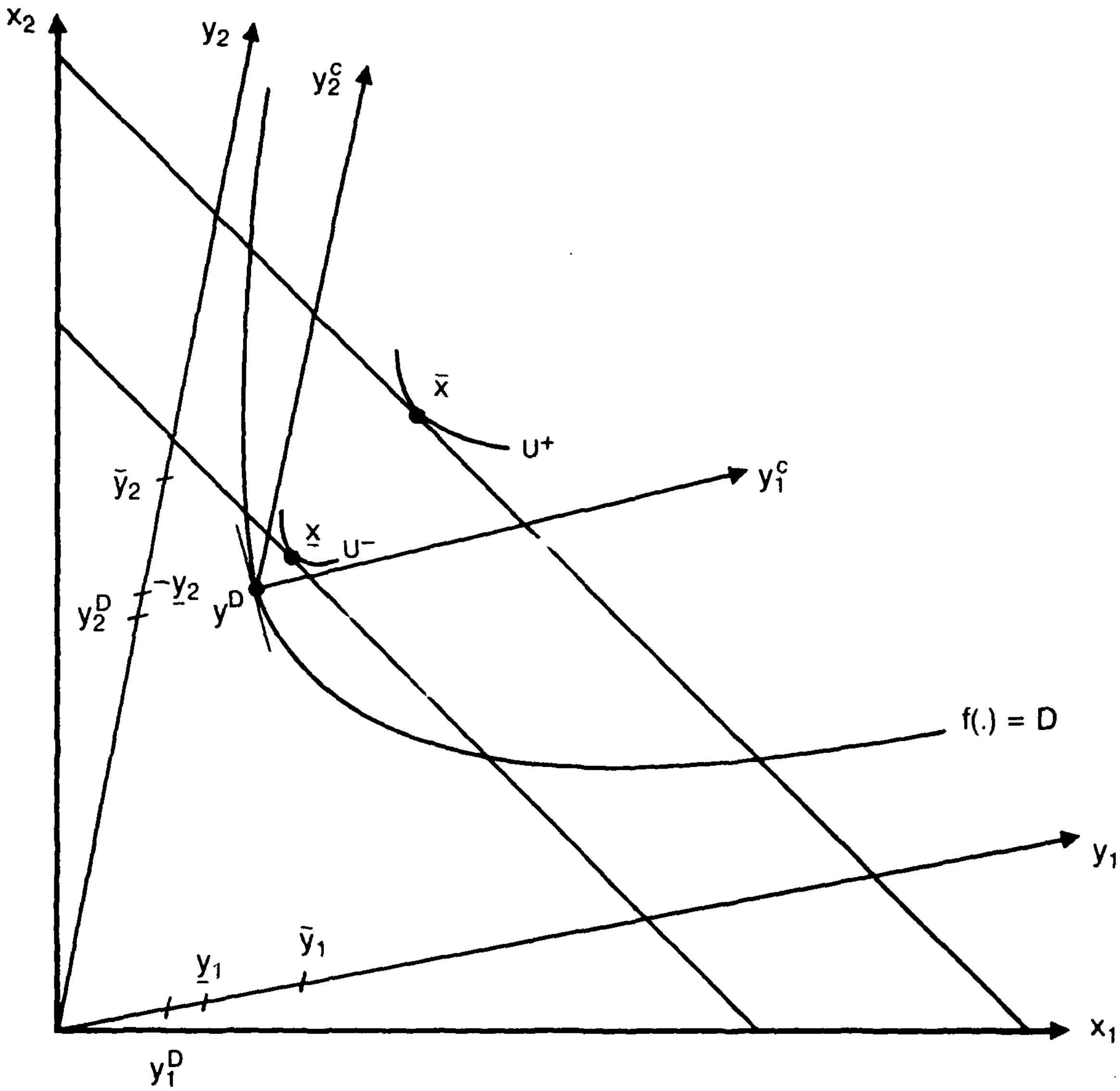

Fig. 5—Factor productivity shock in a priority penetration model (priority to defense and supporting sectors)

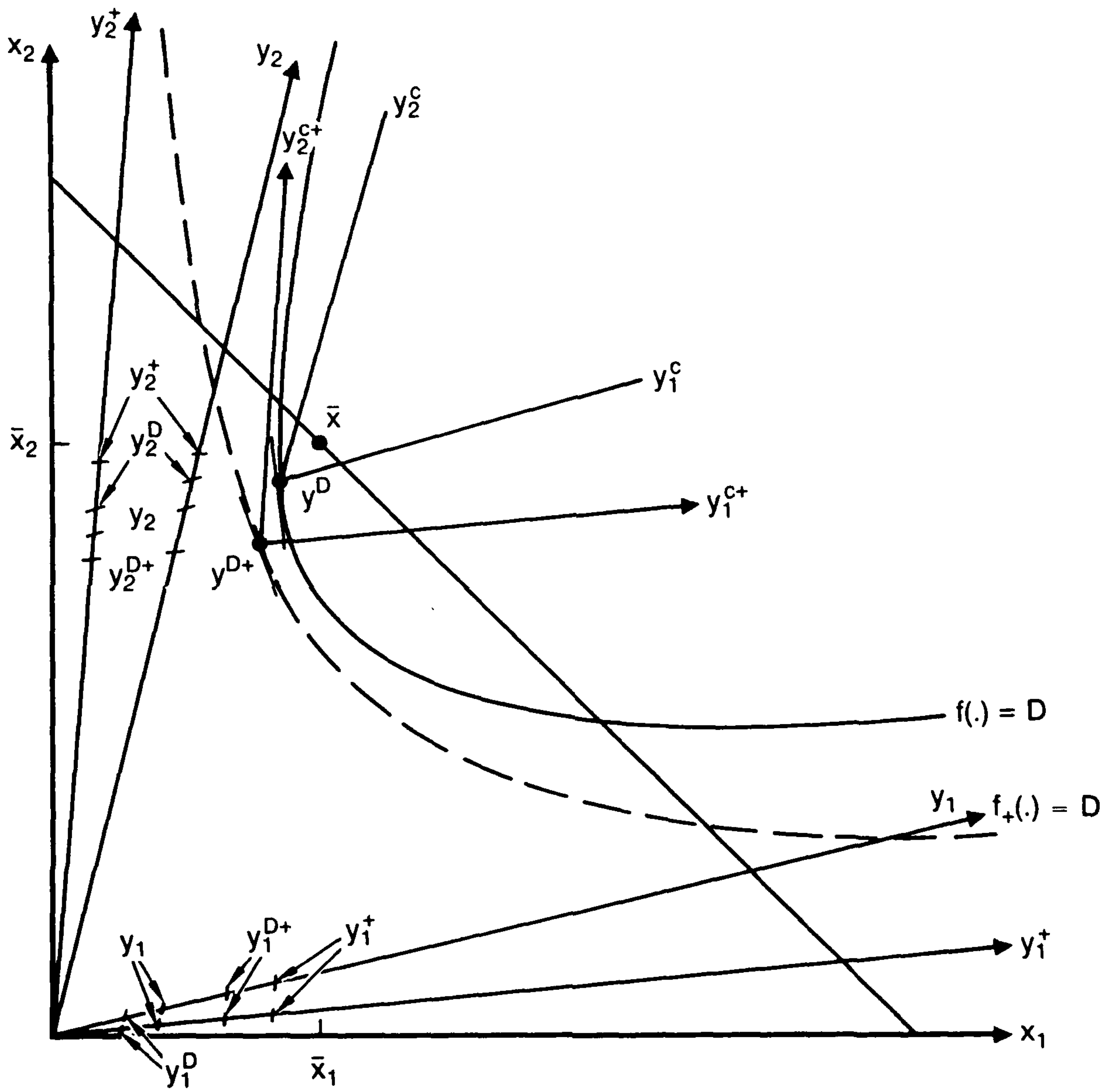

Fig. 6—Technology shocks in a priority penetration model (priority to defense and supporting sectors)

support military requirements. The optimal bundle, y^D, depends on the fixed "prices" p and is unaffected by fluctuations in factor productivity as long as it remains feasible; it has become a derived implementation priority, just as in the preceding model. The residual, y^C, depends on capacity/plan constraints, factor productivity, and social preferences, U, and hence absorbs all of the uncertainty in the economy. This variation is shown in Fig. 5 by the boundaries of such fluctuation along the axes, $\underline{y}_i, \bar{y}_i$, $i=1,2$. Thus we have the same costs and consequences of the implementation priority as in the previous model, but with one additional problem. Here an additional social loss is imposed due to improper tradeoffs (according to planners' utility, U) being made in providing inputs to the military/defense sectors: $p \neq U'(y^*) \equiv \ell(\omega)$, the marginal social tradeoffs between the two sectors at the optimum. The problem depicted in Fig. 5 is of heavy industry output, y_2, being underpriced relative to other sectors, as seems to be the case in the Soviet Union. Hence locally optimal (cost-minimizing) decisions in the defense sector aggravate the social loss imposed by the maintenance of a priority in the defense sector.

The solution to problem (5) in the face of varying interdependence (i.e., mutual material inputs requirements) of the production sectors is presented in Fig. 6. *Notice that the input requirements for military/defense activities are also changing in* that picture, as can be seen from the variation in y^D to y^{D+}. Here we again see the immutability of the priority level D, the relative stability of its supporting inputs y^D, and the preservation of excess capacity in the heavy-industry sector when capacity constraints bind in the nonpriority sectors. Again this is the consequence of the concept of a priority as a constraint that *must* be met in all reasonable circumstances. As in the preceding models, plan/capacity constraints are best set optimistically with respect to factor productivity and pessimistically with respect to material input requirements so as to maintain priority activity levels in the worst anticipatable case.

Finally, it should be noted that the richer structure of this model allows the introduction of a hierarchy of priorities. In particular, we can, without over-determining the model, impose a secondary implementation priority of x_2 (gross output target for heavy industry) or y_2 (net output of heavy industry), thus implicitly establishing an investment goods target/priority beyond the requirements for the military, y_2^D. This extension is developed geometrically in Fig. 7.

Here we depict a situation with fixed military/defense technology, f(•), and fixed industrial capacities, $\bar{x}$, that are derived from a longer-run production

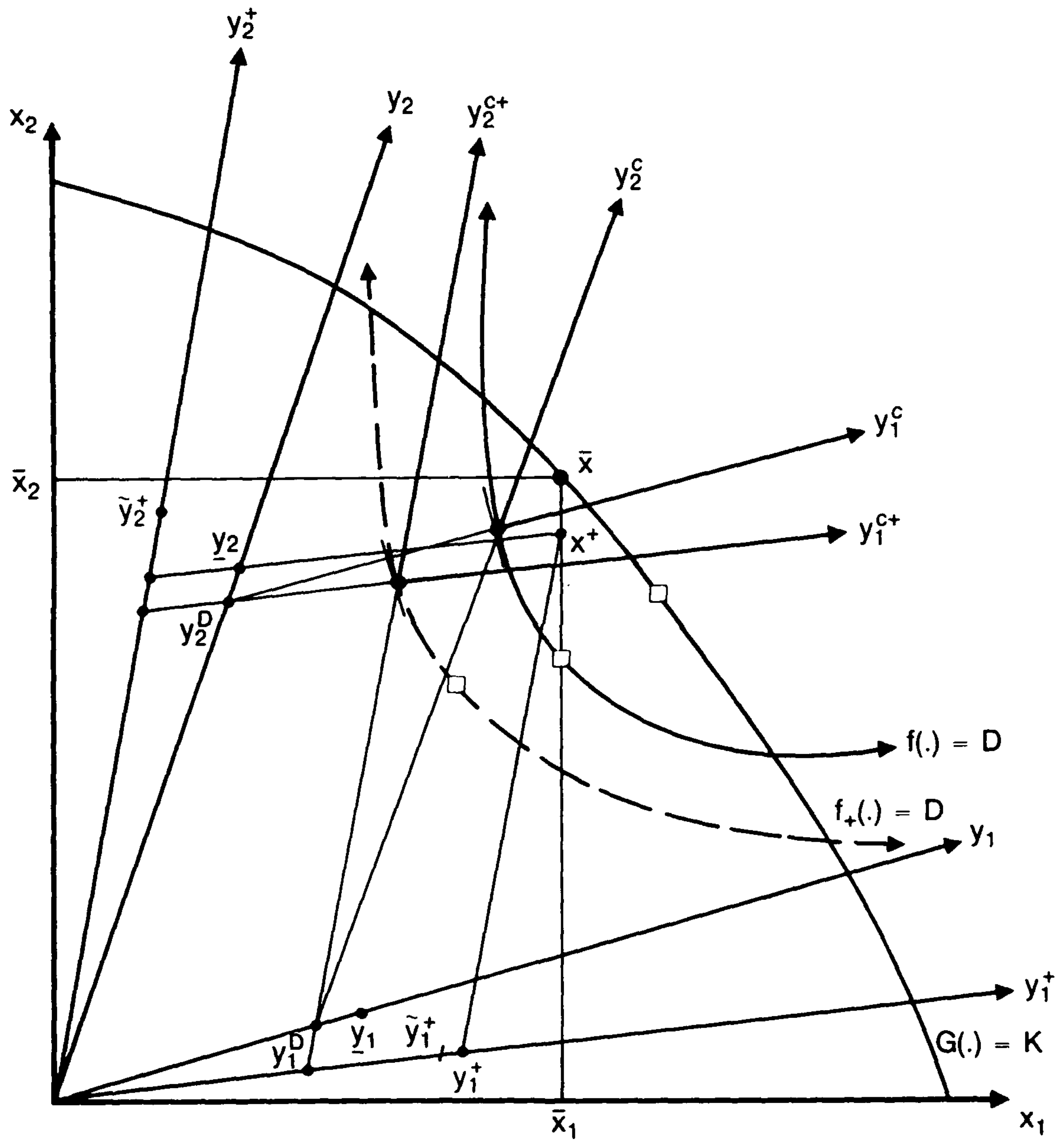

Fig. 7—Priority penetration model with a hierarchy of priorities ($[D, y^D]$ — main priority; x_2 or y_2 — secondary priority)

possibility frontier. As the isoquants of $f(\cdot)$ are defined in the net output space of the rest of the economy, they will vary as intermediate input requirements (sectoral interdependence) change. We identify two extreme cases, with the more "productive" state indicated with a superscript +. Two types of secondary priorities are investigated: $\bar{y}_2$ as an implementation priority, and $\bar{x}_2$ as a priority gross output target. These priorities are secondary in the sense that they are pursued only after $f(\cdot) \geq D$ is satisfied. Notice the interpretation here: with D, $f(\cdot)$, and p fixed, y^D is given and $y_2 - y^D$ becomes an investment priority determined by $\bar{y}_2$. Similarly, $\bar{x}_2$ places the priority not only on investment but also on all other uses of heavy industry output including intermediate input.

As expected, priorities $(D, y^D, \bar{y}_2$ or $\bar{x}_2)$ are always met exactly, and variance is always thrown on the nonpriority output of other sectors, y_1^C, and on the nonpriority uses of y_2 when $\bar{x}_2$ is the secondary priority. This is clearly seen in Fig. 7 where y_1 varies between $\underline{y}_1$ and y_1^+ (when $\bar{y}_2$ is the secondary priority) or $\tilde{y}_1^+$ (when $\bar{x}_2$ is a priority). Further, x^+ becomes capacity use when $\bar{y}_2$ is the priority, and $\tilde{y}_2^+$ is the upper bound on the fluctuations of the net output of heavy industry when $\bar{x}_2$ is the secondary priority. Finally, for completeness, we have also indicated with a □ in Fig. 7 the "second best" social optimum, given a priority constraint of meeting defense levels D. This highlights the two kinds of loss (costs) engendered by the pursuit of priorities, in addition to those from the possibly inappropriate choice of D: (1) the wrong tradeoffs are made in choosing y^D; (2) excessive variance in sector 1 and overall inappropriate output levels due to the imposition of secondary priorities. The first might be ameliorated if correct prices/tradeoffs were used in defense production cost minimization, yet the second is unavoidable in view of the nature of priority. Of course, these costs must be weighed against any advantages that priority procedures might have in attaining final results.

MODELS OF PRODUCTION FLEXIBILITY

The next set of models addresses, in an even more preliminary fashion than above, the costs and benefits of dual-use or flexible technologies that are suitable for both civil and military production or are rapidly and easily convertible from civil to military uses. The consideration of such technologies is necessary for either dual or penetration models of the Soviet economy, as there is a growing body of evidence indicating their importance in the Soviet Union.[8] Such technologies include not only dual-use plant and equipment but also location choices for defense/military purposes, hardening of sites, widening of production lines, and the administrative apparatus in plants (e.g., "first departments") providing preparation and potential for rapid mobilization.

All of these impose "costs of flexibility" in return for providing the natural benefits of effective surge capacity (being able to mobilize more rapidly and cheaply).[9] Among these are the costs of:

- Lack of specialization in equipment and personnel,
- Lack of specialization in capabilities and tasks,
- Near autarky (i.e., providing own production support and subsidiary services),
- Increased administration and overhead, (associated with increased operational complexity),
- Greater inventory due to larger variety of required inputs,
- Increased complexity of interaction with the rest of the economy,
- Increased capital for design, construction, and setup of flexible technologies.

In our simple models, such costs might be captured as (1) losses in output, reflecting current production cost increases, or (2) increases in capital/fixed costs that *must be borne* if technology (output structure) changes. Below we explicitly describe only the first kind of costs, though the shape and location of some production possibility frontiers depicted implicitly incorporate some capital costs. At this stage, we restrict ourselves to geometric analysis as we are still developing proper analytic formulations.

Production flexibility (dual-purpose technology) is modeled here, under some extremely strong simplifying assumptions, at both the microeconomic (firm) and the

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[8]For some of the evidence see Charles Wolf, "The Costs and Benefits of the Soviet Empire," in H. S. Rowen, C. Wolf (eds.), *The Future of the Soviet Empire*, ICS Press, San Francisco, 1987; J. Cooper, op. cit., and the CIA report, "The Soviet Economy Under a New Leader," presented to the Joint Economic Committee, U.S. Congress, March 19, 1986.

[9]Surge capacity may be extremely important from the perspective of national security, and hence its social value may be beyond question. However, it still carries a natural economic (efficiency) cost as long as there are increasing returns to specialization.

macroeconomic (economy-wide) levels. There are two key assumptions that lie behind these models. The first is that there are increasing returns to specialization of both technologies and organizations. The second, and closely related, assumption is that flexibility imposes a loss of current output, i.e., lower current productivity, as well as requiring higher capital (investment) costs. Therefore, independent, specialized operations, without the capability to rapidly alter their output mix, are more productive as well as less costly to set up.[10] Flexible, joint-product technologies (forms of organization of economic activity) are less productive as well as more costly to establish. However, the latter allow the economy to meet a wide range of rapidly changing priority demands, while providing significant "surge production" potential, if at a fairly high opportunity cost.

These considerations, costs, and benefits are illustrated in the highly stylized production possibility frontier (PPF) models of Figs. 8 and 9. Figure 8 presents a micromodel of net production possibilities within a single organization. As before, y_1 represents net civil (nonpriority) output, while y_2 shows net priority (heavy-industry/military) output. Complete specialization by the production organization involves producing at a or a' for military or civil production, respectively. Using such technologies allows no flexibility in the short run. An *inflexible* joint-production technology might be represented by the PPF dBd where B is the maximal joint production possible. The set of all such inflexible joint production technologies is reflected in the possibility locus aBa'. Notice that this locus is strictly inside the "convex combination" locus of aAa', the PPF for two independent, linear homogenous, specialized operations using the same resources. This reflects the assumed costs of dual-purpose capabilities as well as the increasing returns to specialization. The obvious benefit is the ability to produce more than one kind of output.

Joint production technologies that are flexible in the sense of permitting rapid changes in output structure are even less productive/efficient (more costly) in their use of available resources; flexibility is not "costless." One such technology is represented by the PPF cc. The PPF envelope for flexible joint-product technologies must lie within that for inflexible technologies, if flexibility is not to be a "free good," and hence is depicted here by the curve bb. The compensation for this lesser output

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[10]There is evidence for this wherever cost-conscious producers have control over their own investment decisions.

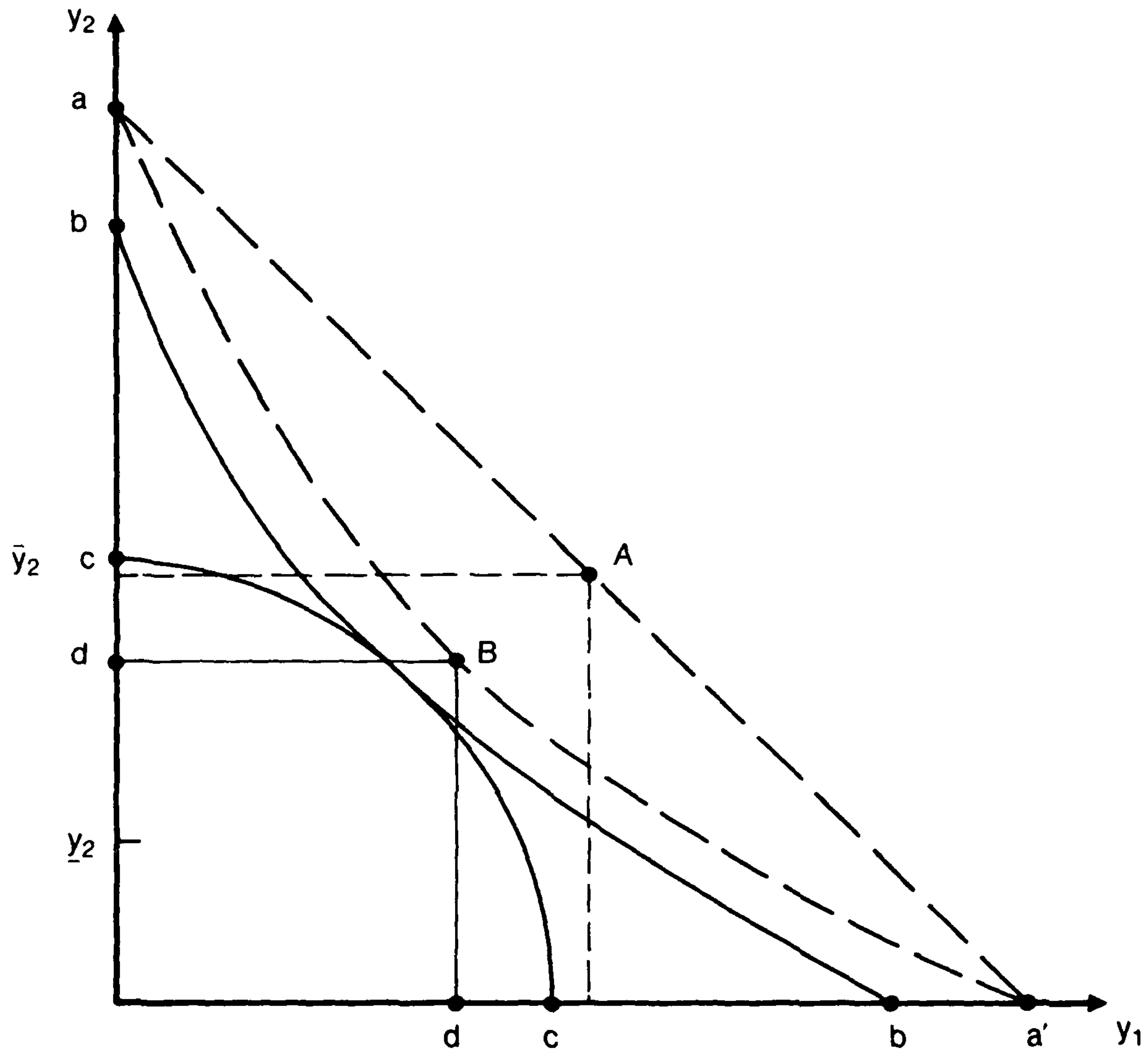

Fig. 8—Organization PPFs with increasing returns to specialization and costs of flexibility

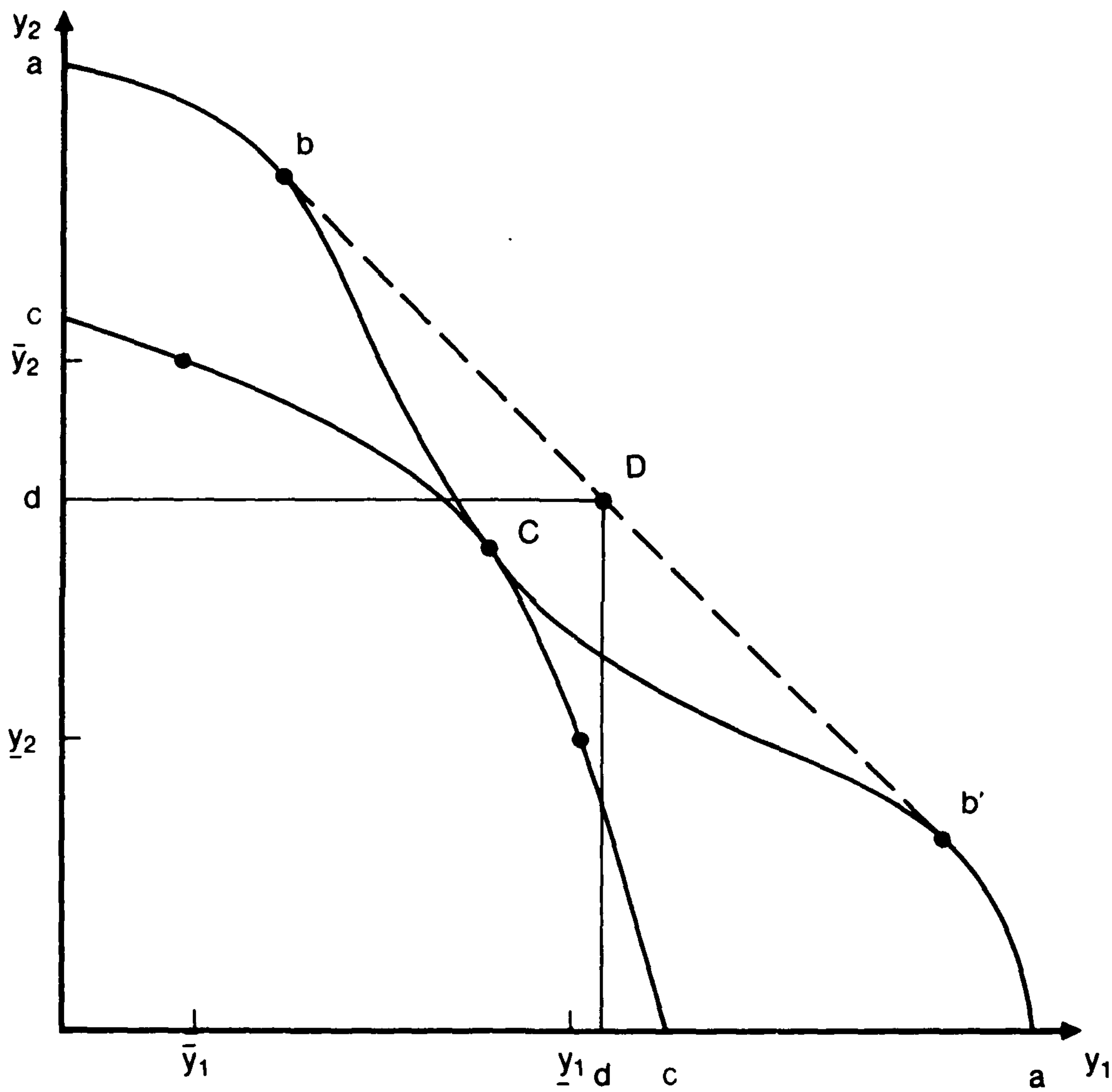

Fig. 9—Economywide PPFs with increasing returns to specialization and costs of flexibility

from a given bundle of resources lies in the ability to immediately meet, without loss of technical efficiency, a wide range of changing priority demands, for example between $\underline{y}_2$ and $\bar{y}_2$ in Fig. 8; short run adjustment along the PPF is possible. This allows meeting demands that would be infeasible with a (statically) more productive inflexible technology.

A macromodel of economy-wide *net* production possibilities, embodying the same considerations, is presented in Fig. 9. Here the increasing returns to specialization must necessarily be limited; not all social resources are suitable to either purely military or purely civil production. However, we hypothesize that there is an intermediate region over which there are increasing returns to society-wide specialization, giving a social PPF for flexible organization of economic activity and technology such as abCb'a' in the graph. This is hence an envelope PPF for economic structures and technologies allowing short-run flexible adjustment of output patterns, as depicted by the short-run PPF - cCc.

Over the region of increasing returns to specialization, inflexible output structures can be generated as convex combinations of efficient fixed, specialized technologies. This increases potential output at the cost of flexibility as represented by the PPF dDd: D >> C. The PPF envelope for such inflexible "social technologies" is given by abDb'a'. For fixed or stable demand for net social output, such inflexible technologies are clearly optimal. However, in the face of uncertain, fluctuating priority needs (e.g., threat of war), say from $\underline{y}_2$ to $\bar{y}_2$, the flexible technology/structure might be desirable, despite the perhaps substantial loss, from $d-\underline{y}_1$ to $d-\bar{y}_1$ of nonpriority output; the benefit of technically efficient surge capacity may be substantial. With these considerations in mind, we might interpret some of the depicted organizational/technological structures as follows:

b — An efficient war economy,

b' — An efficient civil economy,

C — An efficient military-industrial economy, with flexibility from penetration,

D — An efficient "mixed" economy with a fixed, inflexible, military-industrial complex.

We are now in a position to summarize this highly tentative and still ill-formulated modeling effort. This last set of models has attempted to capture the *current*, as opposed to capital, costs of (a) technological flexibility with respect to military output, (b) the maintenance of military output "surge potential," and (c) the military intrusion, in pursuit of flexibility, into the civil economy. By flexibility in these models, we mean the capability for short-run adjustment along a production possibility frontier, while inflexibility means that only "free disposal" adjustment is possible in the short run. The principal conclusion illustrated here is that changing short-run military/defense needs imply that flexible technologies can generate greater benefits than the opportunity costs of forgone output. This is particularly true as the output lost is only in nonpriority activities and sectors by the definition of priority. The verification of this conclusion and the elaboration of further results await the development of a formal analytic model amenable to rigorous mathematical analysis.

There are a large number of issues relating to production flexibility and dual use that we have not yet begun to address. Of particular importance are the relative capital costs of flexibility, dual-use, and joint production, hardening and location considerations, etc. They include not only the fixed costs of setting up production processes of varying flexibility characteristics but also the adjustment costs that must depend on the speed of adjustment as well as the flexibility of the technology. Indeed, the analysis of capital costs should explicitly depend on the time span over which the change of output structure, of priority requirements, must occur. These can be dealt with rigorously only in an analytic mathematical formulation of this model, on which we are still working. We have also not yet formulated an appropriate planning framework within which we might formally analyze the choice of degree of technological/production flexibility; our discussion of tradeoffs is so far purely heuristic. As timing is crucial to the decision, an explicit dynamic programming model—incorporating an appropriate conception of priority—is called for. The model must further include consideration of expectations of planners and the very real uncertainty and risk that they face in choosing the constraints on production possibilities over a long period, as they must inevitably do in making any investment decision. Finally, we see a need to distinguish in these models the costs of excess capacity, as a source of flexibility, from the costs of dual-purpose, inherently flexible, technologies including organizational forms.

IV. CONCLUSION

At the present stage we have a number of rather incomplete models on which we hope to build a more realistic analysis of Soviet short-run macroeconomic response to changes in their economic environment or needs. These models exhibit a number of the recommendations highlighted in Badgett: (1) Broad security related objectives are pursued through their reflection in the composition of economic output; (2) the military sectors (sector 2 here) are functionally distinct from the general economy; (3) marginalism and the maximization of a function with smooth tradeoffs are eschewed at the operational stage. They also incorporate Badgett's idea that outcomes in centrally administered economies reflect "physical equilibrium and arithmetic consistency with little evidence of any conscious maximizing behavior." The models are, however, still too simple to capture other Soviet objectives such as the independent social value of centralization and central control, or the preservation of the power of the Party and the State, beyond its military component. Despite their many manifest shortcomings, these models are simple enough to be tractable analytically, with implications crude enough to be observable in the available data.

Among the implications consistent with much of what we know about Soviet reality are the following:

- Variance in output (plan fulfillment) is greater in nonpriority than in priority sectors,
- There is more excess capacity in priority sectors,
- Priority factor/input use proportions are evidently unrelated to economy-wide tradeoffs,
- Inputs into priority sectors, especially defense-related, are protected from fluctuations in economic activity,[1]
- Factor productivity is lower in priority sectors, perhaps due to flexibility considerations.

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[1]This observation is not contradicted by the apparent slowdown of Soviet military procurement in the mid 1970s. That is better explained by a change in perceived needs, D and $\underline{c}$, at a higher level of planning than the operational implementation addressed in our models. The reasons for that change need to be studied in the context of models of national security and "power maximization" beyond the scope of this Note.

These are the direct consequences of the logic of our model, of our assumptions about the nature of "priority." If priority targets must be met in bad times as well as good, and bad times are impossible to forecast with perfect accuracy, extra capacity and specialized inputs must be kept on hand for priority production. Naturally, controlling for input quality, productivity will tend to be less in the priority sector than in the nonpriority sectors. Given the inelastic demand for the priority good, it is clearly true that variance will be higher in nonpriority output, that priority costs will be passed on to the rest of the economy. This is the intuition behind the analytic models presented above.

Thus we find the strong implication of significant economic inefficiency in the use of priority mechanisms. While this may seem to contradict Badgett's finding of "distinctive superiority" (p. 41) in the functioning of the military economy, there is in fact no necessary contradiction. That superiority refers to the *technical efficiency* of the functioning of the military-industrial sector and its *effectiveness* in generating the results desired by the central authorities. Both of those properties are fostered by the advantages that the priority system gives to those sectors. Indeed, in our models, the military sector is fully technically efficient, as indicated by its highly productive technological coefficients and operation on the feasible production frontier, and absolutely effective, as the priority targets are always precisely achieved. Yet it is still economically *inefficient*, generating noticeable waste and misallocation of resources. Further, much of that waste is hidden from the perspective of the military-industrial sectors; they appear to have superior performance, as indeed they do if it is measured sufficiently narrowly. As we have shown, the inefficiency is transferred to the rest of the economy and only is revealed in the unsatisfactory overall performance of the whole economic system. Thus, in terms of central objectives, the military economy, as perhaps the rest of the Soviet economic system, is highly effective, yet inherently economically inefficient; objectives are achieved regardless of economic costs.

These observations provide a partial explanation of the use of priority mechanisms in the military sectors of all economies, and in times of emergency when there is some overriding objective, such as winning a war, that must be achieved at any cost. Priority mechanisms in practice, as well as our models, are effective, if inherently inefficient due to not allowing fine tradeoffs of objectives or means. In an emergency, or any situation where the well-defined objective is overwhelmingly desirable, there is no time or need to weigh all alternatives and opportunity costs, so a priority is imposed and pursued to its successful fulfillment. The costs imposed on the rest of the economy, including opportunities forgone as well as any direct costs, are decidedly of secondary importance and hence with some reason ignored.

These observations also help to explain or rationalize some aspects of Soviet economic behavior that we believe are important yet are extremely difficult, or indeed impossible, to capture in neoclassical marginalist models. In those models, the kinds of behavioral responses that we predict are either irrational or the consequence of strangely changing preference orderings. Further, we have Badgett's arguments as to why the neoclassical model may not be very relevant. Here we derive that behavior as the rational, optimizing response to the uncertain and changing environment. Hence we find this approach more satisfying both structurally and in its implications, despite its still primitive stage of development. We recognize, however, that much work needs to be done before it becomes a fully viable alternative to the standard models.

Appendix

THE PRIORITY PLANNING PROBLEM

Here we present one possible formulation of the planning difficulty faced in a priority-driven system that might lie behind our version of the plan implementation problem analyzed in the text. It formalizes the impact of the strong preferences, and their induced priorities, that are described in other research on this project.[1] It is an attempt to give an analytically tractable form to the objectives of the Soviet system described there. We work with the simplest two-sector model of Sec. III, where the second sector supports the priority of military/defense activities. The planning problem consists of three sequential stages, depending on the information available and the decisions that can be made in response to that information. Information available in the future is incorporated through the optimal response functions of later stages that can depend on that information. Hence the planning problem must be solved recursively, beginning with the last implementation stage and using the structure of those decisions in order to solve the prior planning problems that will constrain them.

In the first, most general stage, overall objectives are formulated including the requisite level of priority net output, D, and the minimum required level of civil (all other) net output, $\underline{c}$. Here the tradeoffs in the value of priority versus nonpriority uses are explicitly made, with priorities having a much higher, if diminishing, valuation, at least when nonpriority output exceeds some minimum feasible level. At this stage, resource constraints, $L(\omega)$, factor productivities, $\ell(\omega)$, and production technologies, $A(\omega)$, all remain uncertain, though there is some information about the distribution of their possible realizations. Thus we might conceive of the first stage as involving the maximization of the expected social welfare to be generated by the net outputs that will result from the optimal pursuit of the priorities in the actual situation that will result from the resolution of this uncertainty. Of course these outputs will depend on the capabilities of the economy, which must also be planned before the resolution of the uncertainty.

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[1] See Badgett (1988).

Hence, the second planning stage requires a commitment of capital, the generation of binding capacities, $\bar{x}$, that will allow the economy to best take advantage of the actual situation realized in order to achieve the objectives/priorities of the central authorities. While at the first stage largely political tradeoffs must be made between priority and other claims on resources, at this second stage the priority net output enters the problem as a constraint while the output of other sectors becomes the optimand as in the third, implementation, stage.[2] This choice will be further constrained by the capabilities of the economy to provide production capacities, though this was ignored in equation (4) where there was no upper bound on $\bar{x}$ (yet beyond a certain level extra capacity was useless).

The solution at both of these planning stages clearly depends on what will be done at the last, implementation, stage when the uncertainty has been resolved. Here the priority, optimally chosen in the planning stages, becomes a binding and taut constraint as illustrated in the text above (see Eq. (3)). The optimal, priority-driven, choices here depend directly on the realizations of each of the random variables, and thus from the perspective of rational planning become themselves random variables that must be incorporated, as constraints, into the planning problems of the first two stages. Thus our concept of priority must affect the decisions at all levels, including the most removed (political) choice of final output proportions, D and $\underset{\sim}{c}$.

To provide a clear and simple formulation of the problem, we assume (without loss of generality) that there are only a finite number of "states of the world," $\sigma = 1, \ldots, n$. The implementation problem, i.e., stage three, is precisely that of Eq. (3):

$$\max_{x} y_1 \qquad \text{subject to:} \qquad \begin{aligned} & y_2 \geq D \\ & (I - A^{\sigma})^{-1} y = x \\ & (\ell^{\sigma})' x \leq L^{\sigma} \\ & x \leq \bar{x}(D), \end{aligned} \tag{A.1}$$

[2]This formulation is consistent with our concept of priority in planning as optimization at the highest level, followed by satisficing to assure the achievement of the priority. The alternative of satisficing with respect to an exogenously given need at all levels renders the initial step redundant. Another alternative is to let optimization at the second stage determine the priority level, D, with only $\underset{\sim}{c}$ chosen at the highest levels, as was implicitly done in Eq. (4). All these approaches leave the implementation problem of the third stage, as analysed in the text, unchanged.

where D is from the solution to the first, highest planning stage, $\bar{x}(D)$ is the solution to the second stage, and σ is the realized state. The solution for any state σ will be a pair of vectors $\{x^\sigma(D,\bar{x}), y^\sigma(D,\bar{x})\}$ such that the constraints of problem (A.1) are met, $y_2^\sigma \equiv D$, and $x_1^\sigma \equiv \bar{x}_1$.[3] These optimal gross and net output decisions are (optimally) taken as part of the (stochastic) environment at the earlier stages of planning to ensure attainment of the military/defense priority.

The planning problem at the second, choice of capacity, stage then becomes the following. Letting π^σ be the planners' (subjective) probability of state σ occurring, we have:

$$\max_{\bar{x}} \sum_{\sigma} \pi^\sigma y_1^\sigma (D,\bar{x}), \qquad \text{subject to:}$$

$$y_2^\sigma (D,\bar{x}) \geq D, \forall\sigma \qquad \text{(A.2a)}$$

$$(I - A^\sigma)^{-1} y^\sigma (\cdot) = x^\sigma (\cdot), \forall\sigma \qquad \text{(A.2b)}$$

$$(\ell^\sigma)' x^\sigma (\cdot) \leq L^\sigma, \forall\sigma \qquad \text{(A.2c)}$$

$$x^\sigma (\cdot) \leq \bar{x}, \forall\sigma \qquad \text{(A.2d)}$$

$$G(\bar{x}) \leq 0, \qquad \text{(A.2e)}$$

where $G(\cdot) = 0$ is the production possibility frontier for capacity during the plan period. The solution to this problem will be a vector of capacities, $\bar{x}(D)$, that maximizes the expected value of the net output of the rest of the economy subject to the constraint of meeting priority requirements with probability one. Clearly, the Kuhn-Tucker conditions show that constraint (a) is met exactly, (b) and (d) imply that $\bar{x}$ is chosen pessimistically with respect to intermediate input requirements, and (c) and (d) imply an optimistic choice with respect to factor productivity, subject of course to physical feasibility (e). Further, (a), (b), and (d) together imply that it will frequently be optimal for $\bar{x}_2 > x_2^\sigma$, i.e., for all σ such that the slope of the

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[3]Of course this assumes that the priority is for the net output of sector 2. Clearly, for a priority in terms of gross output, $x_2^\sigma \equiv \bar{x}_2$ with $y_2^\sigma \geq D, x_1^\sigma \leq \bar{x}_1$, and less variation in y_1^σ is required.

y_1 ($y_2 = 0$) vector is less than its maximum value. Hence the diagrams in Figs. 3 and 4 are fully justified.

Once an acceptable and feasible priority level is given the latter stages of planning and implementation are fairly mechanical, with well-defined and easily derivable consequences. The true economic choices and tradeoffs have already been made at higher levels. When we turn to those higher levels, however, we find that those choices are severely constrained by the priority implementation behavior that takes place subsequent to them. For the rational central planner must consider how certain choices and decisions will affect subsequent behavior of the subordinates who implement the plans. This is clearly seen in a (neoclassical) optimizing formulation of the central planners' problem in our context. A welfare (planners' utility) function, U(·), representing the kinds of preferences assumed in the text would have $\partial U/\partial y_2$ large and only slowly diminishing in y_2 and $\partial U/\partial y_1$—small on the interior of the feasible "consumption" set. Only at the lower boundary of socially feasible nonpriority outputs would their marginal valuation grow to outweigh the value of priority outputs.[4] Assuming that the central planners have the same *a priori* information as their subordinates and are cognizant of those subordinates reactions, we have

$$\max_{(c,\,D)} \sum_{\sigma} \pi^{\sigma} U[y^{\sigma}(D, \bar{x}(D))] \qquad \text{subject to:}$$

$$\begin{aligned} & y^{\sigma}(D, \bar{x}(D)) \text{ solves (A.1)}, \\ & y_1^{\sigma}(D, \bar{x}(D)) \geq c, \forall\sigma, \\ \text{and} \quad & \bar{x}(D) \text{ solves (A.2)}. \end{aligned} \tag{A.3}$$

The solution to this expected "social welfare" maximization will be optimal net output targets, $\underline{c}$ and D, where the former represents the highest lower bound on nonpriority net output that can be guaranteed with probability one, and the latter the highest priority target that can be achieved with priority one.[5]

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[4]This boundary condition is used to define the constraining level of nonpriority output in the simple formulation of "priority in planning" discussed in the text.

[5]Another possible formulation of this problem would involve the central authorities maximizing $U[\underline{c}, D]$ subject to almost sure feasibility and their subordinates optimal reactions in (A.1) and (A.2), rather than maximizing expected utility. The solutions do not differ in any way

There may be an additional lower bound on c further constraining this problem, representing some minimal required level of nonpriority (civil) net output believed necessary for social/political stability. That, and the choice of the form of the "social welfare function" U, however, involve political issues beyond the scope of this Note, and ones that do not affect our use and analysis of the concept of "priority."[6] Finally, we note that this neoclassical maximizing formulation is not at all necessary to the rest of the analysis. Any arbitrary choice of a priority level D, based perhaps on historical, cultural, ideological, or other noneconomic factors,[7] as long as it is consistent with macroeconomic (and political) feasibility, will drive the same kind of decisionmaking at levels two and three as does this optimization. Problem (A.3) is just provided as one way to close the model analytically.

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significant for the analysis of the subsequent planning (A.2) and implementation (A.1) decisions.

[6]They naturally affect the precise $\underline{c}$ and D used in any practical application, and hence will have to be developed more carefully as this class of models begins to be applied.

[7]The significant effect of noneconomic factors is indeed suggested by the thrust of Badgett's analysis.