BOOK REVIEWS

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Network Economics: A Variational Inequality Approach, by Anna Nagurney. 1993. Advances in Computational Economics, Vol. 1. Boston: Kluwer. 326 + xxi. $89.

Anna Nagurney uses networks as a paradigm for treating problems of economic equilibrium. While equilibrium concepts, and thus economic thinking, are central to the problems she presents, her focus is tools. Some may consider the approach a bit confining,

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but this is more a matter of nomenclature than anything else. In any event, it is not her fault. I suspect that questions of nomenclature are an occupational hazard of life on the cutting edge of truly important research: What does one call what one does? Nagurney's work spans disciplines, so her context provides her with few cues.

The mathematical sophistication Nagurney presumes is likely to be a bit daunting, even among motivated scholars. Still, her discussion of variational inequalities includes enough variations on the theme that almost any member of the regional science community who picks up the book is likely to encounter an application s/he considers relevant.

Nagurney's applications are built around the equivalence of the convex optimization problem

(1.3) "Minimize $f(x)$

subject to: x in K

where f is continuously differentiable and K is closed and convex" (p. 5), and the finite dimension variational inequality problem

(1.4) "$\nabla P(x^*)T \cdot (x - x^*) \geq 0$, for all x in K"

where $\Delta P(\cdot)$ is the gradient of $f(\cdot)$:$\mathscr{R}^n \rightarrow \mathscr{R}$. The solution to both (1.3) and (1.4) is an optimal vector x^*. In coarsest terms, the key is to use the insights provided by the variational inequality relationship to iteratively adjust any x satisfying the constraints in (1.3) such that it approaches the solution to (1.4). Where the initial feasible solution comes from is unaddressed, but this is not unusual for discussions of convergent algorithms.

There are many ways these adjustments might be undertaken, and Nagurney explains the most relevant in standard terms. The methods Nagurney describes are likely to be important to any scholar in the systems area. But Nagurney is sophisticated, and as a result the book requires at least a year of graduate training in economics or engineering if it is to be followed carefully. The book includes several numerical problems of various degrees of difficulty, but these are presented only in summary form. An appendix covering the relevant fundamentals of mathematical economics would broaden the market considerably, as would at least one detailed numerical example, though her large scale computational results are impressive. While these large applications are best described summarily, she could make better use of her small examples.

I took Nagurney's comments in the Preface seriously, proceeding on the assumption that "Each of the chapters is meant to be self-contained for an individual's own interest and use" (p. xviii). Being selfish, I first read Chapter 4, "Traffic Network Equilibrium." This was a mistake. A detour through the first few pages of Chapter 1, "Variational Inequality Theory," and the relevant sections of Chapter 2, "Algorithms," is the price of admission, even for initiates.

Notation plays an important role throughout the book. Most of the really challenging notational details are in Chapter 1. Chapter 2 is a mostly successful attempt to summarize Chapter 1 for the masses, operationalizing the general iterative scheme for the solution of the variational inequality problem, and adapting the scheme for a variety of special cases (projection, decomposition, linearization, relaxation, and others). Nagurney lavishes a little extra attention on equilibration algorithms that exploit network structure. She notes that

> variational inequality algorithms proceed to the equilibrium iteratively and progressively via some equilibration procedure, which involves the solution of a linearized or relaxed substitute of the system at each step. If the equilibration problem encountered at each

> step is an optimization problem (which is usually the case), then, in principle, any appropriate optimization algorithm may be used for the solution of such embedded problems. (p. 57)

Which is to say that the variational inequality approach is not the whole story. Rather, it is a way to break down problems into equivalent subproblems the investigator already knows how to handle easily. The tools used to solve the subproblems may be drawn from any relevant body of theory.

Nagurney augments Chapter 2 with a series of examples applying these techniques in the context of trade flows. These have the quality of a tutorial. She devotes subsequent chapters to various other applications, including spatial price equilibrium, traffic network equilibrium, migration equilibrium, oligopolistic market equilibrium, Walrasian price equilibrium, financial equilibrium, and constrained matrix problems. This is an ambitious array, but Nagurney succeeds in making the case that the variational inequalities approach is broadly applicable, and that it offers considerable computational advantage. Her theoretical and numerical examples are not always drawn from the mainstream of the literatures to which she refers, but they are sufficiently representative.

Chapter 3, "Spatial Price Equilibrium," includes the first mention of policy, but references to policy are fleeting. This is not a book about policy. This is a book about using new techniques to compute the equilibrium states of large economic systems made up of many rational, informed economic agents. Most often, Nagurney's agents compete. On rare occasions, they cooperate. Sometimes they are taxed, and the tax might be negative. Sometimes the prices associated with their choices are perturbed, and sometimes their transactions are restricted. But in Nagurney's network universe, exchange triumphs. The modest market imperfections are not sufficient to prevent Nagurney's markets from equilibrating. How the interventions come about and what the misguided souls who imposed them might be trying to accomplish are not part of the discussion. We have to settle for what the interventions do.

Given the breadth of Nagurney's agenda, this might seem a reasonable trade-off. Unfortunately, it is at the core of the work's only real weakness. Nagurney's unstated position is that most policies tend to hobble markets and supress the benefits market mechanisms might otherwise deliver. This may well be so, and it is clear that Nagurney's techniques might be used to determine the aggregate impacts of policy intrusions. However, there is nothing in Nagurney's allusions to policy that helps the planner to identify groups of winners and losers, which is a little surprising. In Nagurney's network universe, cost functions are monotonic, differentiable, and completely general. Constraint sets are (usually) convex. Demand and utility functions are known. They are linear when they need to be linear and they are quadratic when they need to be quadratic. In this context, the rationale for computing where the system is going to land is to determine whom, if anyone, it is likely to land on. These considerations are absent from the work. Given the level of detail that Nagurney's networks afford agents, accounts, and regions, this is a missed opportunity.

Despite the absence of welfare elements, Nagurney does provide a few policy insights. After disassembling Braess's (network design) paradox in Chapter 4, Nagurney draws an interesting distinction between path and link toll collection policies, identifying additional objectives admissible only if tolls are attached to paths. In some cases, this path flow orientation would not be effective. This is significant, because the variational inequalities approach presumes that there is a tractable approach for any sufficiently simplified problem. If network variables are represented in terms of paths instead of links, this may not be so.

It is clear that Nagurney's favorite problems are the most general ones. Her treatment of fixed travel demand formulations is presented almost grudgingly, as if to give transporta-

tion planners something familiar to relate to, and maybe to let policy wonks catch their breath. Still, she is restive, and cannot resist suggesting relevant generalizations of the conventional static model.

Chapters 1 through 4 account for most of the foundation Nagurney wants to introduce. The value of Chapter 5, "Migration Equilibrium," is not the further exposition of the variational inequalities approach, but the conceptualization of migration networks. Nagurney is especially detailed in this chapter, and the net effect is to provide the reader with more insight than usual into formulation decisions. The other sections of the book would benefit from more of the same approach. Chapter 6, "Oligopolistic Market Equilibrium," and Chapter 7, "Walrasian Price Equilibrium," are mere elaborations by comparison. Much of Chapter 7, for example, is organized around the observation that "the pure exchange model is isomorphic to a network equilibrium problem with special structure" (p. 221).

Chapter 8, "Financial Equilibrium," is particularly interesting because it is less abstract. Nagurney marries her techniques to the sort of institutional structure that is less articulated in her other applications. As a result, Chapter 8, and related sections of Chapter 9, "Constrained Matrix Problems," provide a sophisticated blend of institutions, algorithms, and computational processing strategies. She applies variational inequalities in two ways in this context. In Chapter 8, she computes the financial market equilibrium that yields asset and liability volumes, and instrument prices, while simultaneously making the case for a decomposition approach that yields network subproblems perhaps best addressed on parallel processing architectures. In Chapter 9, Nagurney uses her Splitting Equilibration Algorithm (SEA) to revise a Federal Reserve Board dataset in a way that makes it consistent with the accounting framework required for general equilibrium modeling of financial markets.

This numerical exercise is preceded by a more general treatment of matrix estimation, which includes her most detailed use of duality theory. Nagurney pauses only momentarily to dispense with Kruithof's RAS algorithm, but lingers long enough to bury the Bachem-Korte algorithm under an avalanche of vastly superior results. In short, she takes no prisoners on the matrix estimation front, and Chapter 9 has something for anybody whose matrices come with marginals.

Throughout the book, Nagurney provides a steady stream of references to Stella Dafermos's work. Taken individually, these references merely credit Dafermos's key contributions to the variational inequalities literature. Taken collectively, they go a subtle step further. It is clear that Nagurney is acknowledging Dafermos's contribution to her own scholarship. It is a generous gesture, particularly for an investigator as gifted as Nagurney. In the end, it is helpful too. She succeeds in providing a thorough, factual acknowledgement that is at least as relevant to the reader's understanding of the variational inequalities literature as it is to Dafermos's legacy.

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Chinese Economic Planning and Input-Output Analysis, edited by Karen R. Polenske and Xikang Chen. 1991. New York: Oxford University Press. 377 + xxiv. $65.

This long-awaited book is the result of an incredible five-year effort of the two editors. It opens a window to the English-speaking world on Chinese scholars' efforts in input-output (I-O) analysis over the past thirty years. Compiled in three parts and nineteen chapters, the construction and research of I-O models are presented at the national, regional, and