A Theory of Supply Chains

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PREFACE

This work was stimulated by a comment made by a former student (Prof. Alan Erera of Georgia Tech) in connection with an inventory stability game he was going to play in one of his logistics classes. This was the well-known "beer-game" that is often played in business schools to illustrate the "bullwhip" effect in supply chains. Al had said to me that he did not have to tell his students how to reorder replacement parts from the other members of the supply chain because he knew from experience that the order sizes the players would generate as the game progressed would become chaotic anyhow. Since I had not played the beer game, his assertion was intriguing to me. Why would such an unstructured game always lead to the same undesirable effect? Did it have something to do with psychology? What is it that players did to generate instabilities? I posed these questions to other people but could not get completely satisfactory answers. Thus, the bullwhip mystery remained, at least in my mind.

Since inventory chains are "conservative" systems analogous to a traffic stream, and since traffic flow models exhibit similar effects (the instability of automobile platoons and of certain numerical methods being two notable examples) I suspected that traffic flow theory might shed some light on the puzzle. This possibility became very intriguing to me because it meant that efforts to solve the puzzle might unify two research areas dear to my heart, "logistics" and "traffic flow". At the very least, they could show a strong connection between the two.

After several months of study, the results by mid 2001 were encouraging. Not only there seemed to be a strong connection between "logistics" and "traffic flow", but it appeared that "queuing theory" was a third leg of the stool too. In addition, three main findings stood out: (i) the apparent cause of the bullwhip effect; (ii) an efficient way to stabilize supply chains without centralized control; and (iii) a way to choose an optimum control policy subject to stability constraints. These ideas formed the basis for an extended "theory of supply chains." Because the results were obtained with methods rarely used in inventory analysis they had to be presented in an unconventional way, requiring new notation and terminology. Therefore, I needed feedback to figure out how best to proceed.

I gave a series of four lectures at U.C. Berkeley in the fall of 2001. They were attended by three colleagues (professors Mike Cassidy, Phil Kaminsky and Samer Madanat from the CEE and IEOR departments) and by 12 of our most advanced PhD students. The comments of this select audience

helped me refine the rough lecture notes into something resembling a monograph. They convinced me that a comprehensive, self-contained document would be the best publication venue for the complete work, and that one or two journal articles could then be used to summarize the main results. This monograph is the self-contained document.

Phil Kaminsky and (PhD candidate) Alejandro Lago offered valuable comments on preliminary versions. A brief paper summarizing the first half of the monograph was also circulated to key colleagues, and its highlights were presented at a few universities (U. Dresden, Georgia Tech, U. Montreal, and U.C. Berkeley (twice)). The comments of everyone who helped me are gratefully acknowledged. The perspective of professors Anton Kleywegt (Georgia Tech) and Paul Zipkin (Duke University) was particularly helpful. I also wish to thank PhD students Anne Goodchild, Jorge Laval, Juan Carlos Muñoz, Yuwei Li and Yanfeng Ouyang for drawing most of the figures and helping put the manuscript in its final form. The work was partly supported by grants from the University of California Transportation Center.

I should finally note that these lecture notes have not been used in the classroom in their final form. Therefore, they may contain errors; hopefully not too many. It goes without saying that all errors are exclusively mine. When found, they will be posted on the publications section of my web page: http://www.ce.berkeley.edu/~daganzo/.

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TABLE OF CONTENTS