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A Computational Model of Industry Dynamics

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The economics literature on industry dynamics contains a wide array of empirical works identifying a set of stylized facts. There have been several attempts at constructing analytical models to explain some of these regularities. These attempts are highly stylized and limited in scope to keep the analyses tractable. A general model of industry evolution capable of generating firm and industry behavior that can match the data is needed.

This book endeavors to explain many well-documented aspects of the evolution of industries over time. It uses an agent-based computational model in which artificial industries are created and grown to maturity *in silico*. While the firms in the model are assumed to have bounded rationality, they are nevertheless adaptive in the sense that their experience-based R&D efforts allow them to search for improved technologies. Given a technological environment subject to persistent and unexpected external shocks, the computationally generated industry remains in a perennial state of flux. The main objective of this study is to identify patterns that exist in the movements of firms as the industry evolves over time along the steady state in which the measured behavior of the firms and the industry stochastically fluctuate around steady means.

The computational model developed in this book is able to replicate many of the stylized facts from the empirical industrial organization literature, particularly as the facts pertain to the dynamics of firm entry and exit. Furthermore, the model allows examination of cross-industry variations in entry and exit patterns by systematically varying the characteristics of the market and the technological environment within which the computationally generated industry evolves. The model demonstrates that the computational approach based on boundedly rational agents in a dynamic setting can be useful and effective in carrying out both positive and normative economic analysis.

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To the memory of my father

"[T]he central idea of economics, even when its Foundations alone are under discussion, must be that of living force and movement."

Principles of Economics, Alfred Marshall

Preface

The computational model of industry dynamics presented in this book evolved out of several generations of earlier primitive versions that went through the usual process of natural and artificial selection in the academic setting. The very first version focused solely on the shakeout dynamics in an infant industry with no external technological shocks. The results from this preliminary version were reported in an article published in the *Journal of Economic Interactions and Coordination* (2009). The second version allowed for external technological shocks but with no adaptive R&D by the firms. The results from this model were reported in a chapter in *Oxford Handbook of Computational Economics and Finance* (forthcoming). The third version of the model with exogenously specified R&D by firms was presented in *Eastern Economic Journal* (2011).

The most general version of this line of models is reported in this book and allows firms to adapt to external technological shocks by autonomously performing R&D in search of improved technologies. Making the process of R&D endogenous has enabled a re-examination of the issues explored in the earlier publications under richer market and technological conditions. More importantly, it has created the ability to address a new set of questions that are unique to Schumpeterian competition with innovative and imitative R&D.

I have two goals in this book. The first is to model a set of well-known stylized facts in empirical Industrial Organization, involving entries and exits of firms over time. While various attempts have been made to understand these patterns as part of the "industry equilibrium" in the context of profit-maximizing firms with perfect foresight, the scale and scope of investigations have been rather limited due to either the restrictive nature of the assumptions used to foster tractability, or the formidable analytical difficulties resulting from less restrictive assumptions. The computational model developed here eschews the standard

behavioral assumptions in the tradition of "orthodox" economic theory. Instead, the dynamic patterns arising at the level of an industry are viewed as the result of continuing interactions among myopic and heterogeneous firms which are motivated by profit and engaged in R&D as a way to improve their profits. The ultimate objective is then to understand the stylized facts as patterns that arise endogenously as firms make adaptive moves against unexpected external shocks as well as to each other in their search for improved profits.

The second, more general, goal of the book is to explore and demonstrate the capability of computational modeling in making theoretical advances in those areas of economics traditionally thought to be the exclusive domain of analytical methodology based on equilibrium theorizing. As I hope to show in the following chapters, questions not easily answered using orthodox equilibrium models can be resolved and examined in some detail within a computational model of boundedly rational agents.

Although the present study does not go further than to offer positive analyses for explanatory purposes, the further challenge for the approach will be the extent of its capacity to offer normative prescription through policy experiments performed on a platform sophisticated enough to capture the finer details of the real industries. I hope to have made a preliminary contribution to this endeavor by writing this book.

Acknowledgments

The research reported in this book was presented at several national and international conferences: 2010 International Industrial Organization Conference (Vancouver); 2010 International Computational Economics & Finance Conference (London); 2011 International Industrial Organization Conference (Boston); 2012 Eastern Economic Association Conference (Boston); 2012 Workshop on Economic Heterogeneous Interacting Agents (Paris); 2012 International Computational Economics & Finance Conference (Prague); 2013 Eastern Economic Association Conference (New York). I have benefitted from the comments and suggestions of the session participants from these conferences. In particular, I would like to thank Jason Barr, Johannes Koenen, Chris Ruebeck, and Robert Somogyi for their detailed comments.

At the home front, I have received helpful comments and assistance from a number of colleagues both while working on the model and on various drafts of this book; I am especially grateful to Ed Bell, Jon Harford, and Doug Stewart for many stimulating conversations that proved valuable in refining the model presented here. Both Jon Harford and Doug Stewart made useful editorial comments on earlier drafts of the manuscript. In particular, Jon was gracious enough to read the manuscript in its entirety and offer invaluable advice. I have incorporated the substance of nearly all of his suggestions in my text.

I have also been assisted by a number of capable graduate assistants over the years. Although not included in this book, Amanda Janosco carried out the data collection effort for the study of firm turnovers in the East Liverpool (Ohio) pottery industry, which substantially improved my understanding of the entry and exit process. Charlotte DeKoning, Endrit Meta, and Chris Cox provided editorial assistance at various stages of the writing process. Endrit deserves special thanks for transforming the entry/exit data from the US auto industry (Smith (1968)) into a manageable dataset as visualized in Chapter 5.

I am pleased to acknowledge the institutional support I received from Cleveland State University during the project. I was granted a sabbatical leave in the spring of 2009 to work on the initial development of the project. Dean Greg Sadlek of the College of Liberal Arts and Social Sciences allowed release time during the summer of 2014 to complete the manuscript. Finally, this research was partially funded by the Faculty Research Development Grant (0210-0382-10) from the College of Graduate Studies at Cleveland State University. The groundwork was laid during the grant period of 2008–2011. This book is the final product.

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