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**OPTIMAL PRICING,
INFLATION, AND
THE COST OF
PRICE ADJUSTMENT**

EDITED BY

EYTAN SHESHINSKI

AND YORAM WEISS

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Optimal Pricing, Inflation, and the Cost of Price Adjustment

edited by Eytan Sheshinski and Yoram Weiss

The MIT Press
Cambridge, Massachusetts
London, England

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This book was set in Times Roman by Asco Trade Typesetting Ltd., Hong Kong, and was printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data

Optimal pricing, inflation, and the cost of price adjustment / edited
by Eytan Sheshinski and Yoram Weiss.

p. cm.

Includes bibliographical references and index.

ISBN 0-262-19332-9

1. Pricing. 2. Inflation (Finance) I. Sheshinski, Eytan.

II. Weiss, Yoram.

HF5416.5.067 1993

338.5'2—dc20

92-35198

CIP

Preface

The chapters in this volume provide an analysis of nominal price rigidities in an inflationary environment. A basic observation, which is in the background of this work, is that economic decisions are often characterized by periods of inaction followed by an abrupt change. Thus, in an inflationary economy, firms change nominal prices intermittently. The frequency and size of price changes by each firm and the degree of synchronization among different firms determine the aggregate dynamics of the economy. The common methodological feature is that firms follow rather simple pricing policies in which the real price floats freely between two predetermined bounds and action is triggered only if one of the bounds is reached. Such *S-s* policies yield tractable models of dynamic adjustment. The main purpose of the analysis is to evaluate the effects of inflation on aggregate output and on welfare.

The volume begins with two introductory surveys that are intended to motivate the collection. Yoram Weiss surveys the empirical studies of pricing policies by individual firms. His chapter documents the prevalence of nominal rigidities and the systematic impact of inflation on the size and frequency of price changes. Andrew Caplin's contribution surveys the theoretical efforts to integrate the nominal rigidities at the micro level into macro relationships. He provides a unified treatment of the aggregation issues within a simple framework. Taken together, these two surveys provide a strong case for the research agenda followed by the authors included in this collection. It is possible to formulate a tractable model of aggregate adjustments in which nominal and real variables interact and which is founded on plausible micro foundations. Moreover, the model has testable implications at both the micro and the macro levels.

The second part of the book treats the general problem of optimal dynamic adjustment in the presence of convex costs of adjustment. The chapter by Herbert Scarf provides the classical treatment of inventory adjustment under uncertain demand, including a proof of the optimality of *S-s* policies. The chapter by Agnès Sulem surveys the mathematical methods of impulse control. This technique provides a characterization of the optimal policy in terms of a system of inequalities and differential equations that the value function must satisfy. The necessary conditions have a direct economic interpretation. During a period of inaction the value is governed by the external forces (such as inflation), and it is maximized when an action is taken. Action is triggered if the difference between the current value and the maximal value exceeds the (lump-sum) cost of

adjustment. The analytical problem is to find the values of the state at which an action is triggered and the size of the adjustment. The chapter by Sulem contains applications to the single commodity and to the two-commodity inventory problems, in which explicit solutions are derived. The chapter by Avinash Dixit provides a more heuristic exposition of the same methods, including a diagrammatic interpretation.

The third part includes applications of the inventory models to the case of nominal price adjustment by an individual firm. The three chapters by Eytan Sheshinski and Yoram Weiss provide a general framework and yield some comparative static results. In particular, they show that an increase in the rate of inflation widens the bounds within which real prices float. Therefore, firms are pushed further from their maximal profits position. This illustrates how inflation affects the welfare (profits) of individual firms. An important methodological feature of this work is that the optimal policy is characterized in terms of a *state* variable, which is the real (relative) price of the firm at any point in time. The time pattern of price changes, rather than being prespecified, is an endogenous outcome of the model. For instance, it is shown by the authors that inflation may increase or decrease the frequency of price changes, depending on the concavity of the profit function in the log of the real price. In a later chapter they show that a monopoly that sells *two* goods will prefer to synchronize (stagger) the price changes of its products if the two prices interact positively (negatively) in the profit function.

The fourth part addresses the question of aggregation. What is the behavior of the aggregate price level and aggregate output in an economy populated by firms following an *S-s* pricing policy? Andrew Caplin and Daniel Spulber show that a nominal price rigidity at the level of the firm need not carry to the aggregate. They first argue that with a “one-sided” inflationary process, in which shocks can only be positive, the only time-invariant distribution of relative prices is the *uniform* distribution. If there is a monetary shock of size Δ , then $\Delta/(S-s)$ of the firms will be induced to raise their price by $(S-s - \Delta)$, and the remaining $(S-s - \Delta)/(S-s)$ of the firms will maintain their nominal price and suffer a real reduction of size Δ . The aggregate effect on the average *real* price is zero. This means that the aggregate price level follows the money stock and that monetary changes will have no real effects (assuming that aggregate output is fully determined by the real money stock). Ricardo Caballero and Eduardo Engel strengthen these results by showing that the price distribution *con-*

verges to the uniform distribution from any initial distribution, provided that idiosyncratic shocks are added to the common inflationary shocks. The crucial assumptions for this result are continuity and monotonicity of the inflationary process.

The neutrality of monetary policy fails if the monetary shocks can be both negative and positive, that is, if inflation is “two-sided.” In this case, the limiting distribution is triangular (or piecewise exponential) rather than uniform, since firms return to the same target both from the upper and from the lower trigger. Following a positive inflationary shock, the price increase by firms at the bottom does not offset the reduction in the real price of firms in the middle and top of the distribution. Hence the average real price declines and aggregate output rises. Thus, nominal rigidities at the level of the firm translate into aggregate rigidities. Andrew Caplin and John Leahy illustrate this principle in the context of a special case that allows them to trace the output dynamics.

The fifth part introduces active search by consumers. This option puts further constraints on the distribution of relative prices, in addition to the invariance imposed by consistent aggregation. Roland Benabou develops a general equilibrium framework in which each consumer’s search policy depends on the price variability created by the *S-s* pricing policies of firms and each firm chooses its *S-s* bounds based on the reservation strategy of searchers. He shows that a higher inflation rate, in addition to widening the *S-s* bounds, reduces the level of both *S* and *s*. This is caused by the fact that inflation increases the incentive to search and encourages competition among firms. In a subsequent chapter he shows that if one takes into account *all* the components—reduced profits, reduced prices, higher costs of nominal price changes, and higher costs of search—inflation may increase or decrease welfare. Peter Diamond, who assumes that nominal prices are “stamped” at production and can be changed only when a new product is introduced, obtains a stronger result: as inflation increases, welfare initially increases, then declines. In this model each firm sets an initial price that is equal to the consumer’s reservation price.

Inflation has two opposing effects on the reservation price and, therefore, on welfare. On the one hand, it raises the variance of relative prices, which increases the reservation price. On the other hand, it reduces profits and causes firms to exit. This implies a longer waiting period until a purchase occurs, which reduces the reservation price. The first factor dominates at low levels of inflation and the second dominates at higher rates.

The sixth and last part of the book is devoted to empirical analysis of nominal price rigidities. Alan Blinder summarizes the results of interviews in which companies report the frequency of price changes and the causes for price rigidity. The chapter by Stephen Cecchetti analyzes the nominal price adjustments of newspapers in the United States. Saul Lach and Daniel Tsiddon analyze the price adjustments of a group of products during two inflationary episodes in Israel. Mariano Tommasi provides a similar analysis for Argentina. All these studies find a substantial amount of nominal rigidities and systematic effects of inflation on the frequency and size of price adjustments.

Our objective in gathering all these works within a single volume is twofold. First, we wish to give a sense of the scope of recent efforts to explicitly incorporate *frictions* in economic models. Second, by providing easy access to some of the main works, we hope to promote further research on an elusive but important question: What are the real effects of inflation?

Acknowledgments

Some of the chapters in this volume have previously appeared elsewhere, and are reprinted here with permission. In Part II, Chapter 3, "The Optimality of (S, s) Policies in the Dynamic Inventory Problem," was published in K. Arrow, S. Karlin, P. Suppes, eds., *Mathematical Methods in Social Sciences*, Stanford University Press, 1959: 196–202. Chapter 5, "A Simplified Treatment of the Theory of Optimal Regulation of Brownian Motion," appeared in *Journal of Economic Dynamics and Control*, 1991, vol. 15, 657–673.

In Part III, the following articles have been reprinted from the *Review of Economic Studies*: Chapter 6, "Inflation and Costs of Price Adjustment," 1977, vol. 44, 287–303; Chapter 7, "Optimum Pricing Policy Under Stochastic Inflation," 1983, vol. 50, 513–529; and Chapter 8, "Staggered and Synchronized Price Policies Under Inflation: The Multi-product Monopoly Case," 1992, vol. 59, 331–359.

In Part IV, Chapter 9, "Menu Costs and the Neutrality of Money," was previously published in *Quarterly Journal of Economics*, 1987, vol. 102, 703–726. Chapter 10, "Dynamic $(S-s)$ Economies," appeared in *Econometrica*, 1991, vol. 59, 1659–86, and is used here with the permission of The Econometric Society. Chapter 11, "State Dependent Pricing and the

Dynamics of Money and Output,” appeared in *Quarterly Journal of Economics*, 1991, vol. 106, 683–708.

Part V consists of articles that previously appeared in *Review of Economic Studies*: Chapter 12, “Search, Price Setting and Inflation,” 1988, vol. 55, 353–373; Chapter 13, “Inflation and Efficiency in Search Markets,” 1992, vol. 59, 299–329; Chapter 14, “Search, Sticky Prices and Inflation,” 1993, vol. 60, 53–68.

In Part VI, Chapter 15, “Why Are Price Sticky? Preliminary Results from an Interview Study,” appeared in *American Economic Review*, 1991, vol. 81, 89–96. Chapter 16, “The Frequency of Price Adjustment,” was published in *Journal of Econometrics*, 1986, vol. 31, 255–274. Chapter 17, “The Behavior of Prices and Inflation: An Empirical Analysis of Disaggregated Price Data,” appeared in the *Journal of Political Economy*, University of Chicago Press, 1992, vol. 100, 349–389.

Contributors

Roland Jean-Marc Benabou
Department of Economics
MIT
Cambridge, MA

Alan S. Blinder
Department of Economics
Princeton University
Princeton, NJ

Ricardo J. Caballero
Department of Economics
MIT
Cambridge, MA

Andrew Caplin
Department of Economics
Columbia University
New York, NY

Stephen G. Cecchetti
Department of Economics
Ohio State University
Columbus, OH

Peter A. Diamond
Department of Economics
MIT
Cambridge, MA

Avinash Dixit
Department of Economics
Princeton University
Princeton, NJ

Eduardo M.R.A. Engel
Department of Economics
MIT
Cambridge, MA

Saul Lach
Department of Economics
The Hebrew University of
Jerusalem
Jerusalem, Israel

John Leahy
Department of Economics
Harvard
Cambridge, MA

Herbert E. Scarf
Cowles Foundation
and Department of Economics
Yale University
New Haven, CT

Eytan Sheshinski
Department of Economics
The Hebrew University of
Jerusalem
Jerusalem, Israel

Daniel F. Spulber
Department of Economics
Northwestern University
Evanston, IL

Agnès Sulem
I.N.R.I.A.
Cedex, France

Mariano Tommasi
Department of Economics
UCLA
Los Angeles, CA

Daniel Tsiddon
Department of Economics
The Hebrew University of
Jerusalem
Jerusalem, Israel

Yoram Weiss
Department of Economics
Tel Aviv University
Tel Aviv, Israel

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I NOMINAL RIGIDITIES: MICROECONOMIC EVIDENCE AND MACROECONOMIC IMPLICATIONS

1 Inflation and Price Adjustment: A Survey of Findings from Micro-Data

Yoram Weiss

Introduction

The purpose of this survey is to summarize the empirical findings that are in the background of the theoretical chapters in this volume. To capture the complex interactions between theory and evidence, I provide an almost historical account of recent developments in this area. First came the realization of a potentially important empirical regularity, namely, nominal price changes occur in discrete jumps. Since firms can change the size and frequency of price changes, old issues such as whether prices are “administrated,” “rigid,” or “flexible” can be put in a *dynamic* context where rigidities are matter of degree and are in principle measurable. By definition, nominal rigidities affect real variables. The question is whether these effects are in any way systematic. The second discovery was that inflation, combined with nominal rigidities at the level of the firm, indeed affects the *distribution* of relative prices in a clear way. As inflation rises, the variance of relative prices across products and sellers increases.

Based on these regularities, it appears that a question that has eluded economists for many years—What are the welfare costs of inflation?—can perhaps be resolved. The missing step to be filled in is an economic model that would explain the nominal rigidities, link the pricing policies of different firms in a consistent way, and identify the interactions between consumers’ and firms’ behavior. The chapters in this volume are only a small, nonrepresentative selection of this research effort.

The theoretical challenge is substantial. In particular, economists versed with the importance of real variables are puzzled by the absence of indexation. Although the role of prices is to provide information on opportunity costs in terms of other goods (rather than money), indexation makes sense only if many firms adopt it. The “public good” aspect of pricing rules suggests that if firms act independently, there will be multiple equilibria, some with and some without indexation (see Ball and Romer [1991]). A shift between such equilibria requires *coordination*. Indeed, collective bargaining often leads to explicit wage indexation. In some markets, indexation is achieved in a nonorganized fashion. For instance, since the sharp inflation in 1983–1984, real estate transactions in Israel are denominated in U.S. dollars, although only Israeli shekels change hands.

However, for most goods, sellers and customers are only casually related and, therefore, have to rely on standard modes of transaction.

A model that yields, as an equilibrium outcome, a standard pricing mode in which firms post *nominal* prices and *maintain* them sufficiently long to allow consumers to make comparisons has not yet been constructed. Instead, there are various models that use shortcuts consistent with nominal rigidities but do not fully explain them. For example, the introduction of cost of price adjustment is an attempt to capture, at the level of the firm, the informational costs imposed on consumers by too frequent price changes. The general approach is to focus on relatively simple pricing rules and to examine their sensitivity to market structure and macro changes. These simple models generated testable implications and spawned new empirical work. One can discern the development of two distinct but complementary lines of research. The first is the formulation of models with testable implications at the level of the pricing unit (a firm or a store). The second is the formulation of models with testable implications at the level of the industry or the economy at large.

Following these developments, I first survey evidence on individual price paths, inflation, and price variability. I then describe some tests concerning time-dependent and state-dependent pricing policies of individual firms and conclude with a description of findings related to aggregate behavior. The focus of this survey is exclusively on micro data. For related surveys, dealing with the macro evidence, the reader is referred to Gordon [1990] and Ball, Mankiw, and Romer [1988]. The survey is further tilted toward relatively recent studies. The reader would perhaps not be surprised to learn that the empirical regularities of relative price dispersion and inflation (or deflation) have been known for many years (see, in particular, Mills [1927] and Lange [1932]). A comprehensive discussion of this earlier literature would be useful and relevant, but is outside the scope of this survey.

Nominal Prices Change in Discrete Jumps

Individual firms do not change prices continuously. *Nominal* prices of narrowly defined goods are held constant during time intervals that are sufficiently long to contain observable changes in circumstances or “fundamentals.” The frequency of price changes is highly sensitive to macroeconomic variables, in particular to the rate of inflation. Generally, a higher

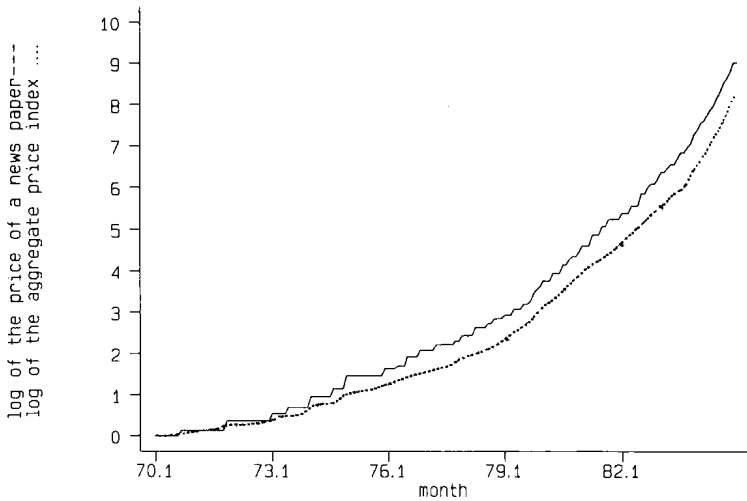


Figure 1.1

Nominal price of a daily newspaper and the aggregate price level: Israel, 1970–1984

rate of inflation leads to more frequent price changes. Yet nominal price rigidities are observed even under sharp inflation, causing substantial erosion of real prices. Figures 1.1 and 1.2 illustrate these general points. They record the price path of a single product, a daily newspaper in Israel, in comparison with the aggregate price path. Observations were taken monthly. As the inflation rate rises from 1 percent to 10 percent a month, the duration of the fixed price intervals is reduced from eight months to one month (or less). Figure 1.3 records the prices of two daily newspapers in Germany during the hyperinflation of 1921–1923. Except for some isolated cases, where the two firms raised their price on the same day, we can note lack of synchronization. The (relative) size of price changes differs, too. Consequently, during any short interval, such as a week, the rates of price change differ. Similar patterns have been recorded in many studies (Sheshinski, Tishler, and Weiss [1981]; Cecchetti [1985], [1986]; Kashyap [1991]; Lach and Tsiddon [1991]; Hanoch and Galyam [1984]; and Tommasi [1991]). They all point to the same empirical regularity.

An immediate implication of nominal rigidity is that the price of any given product, relative to the aggregate of all other products, varies over time. Even if fully predictable, these changes may cause welfare costs as

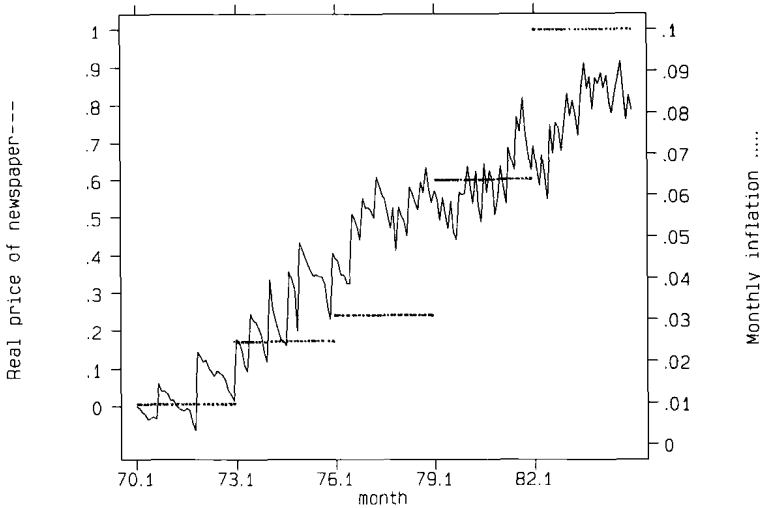


Figure 1.2
Real price of a daily newspaper (logs) and monthly inflation (three years averages)

they force each firm to diverge from the optimal real price at any given moment. A question of interest is whether a higher inflation rate increases or decreases this variation over time. This depends on the adjustments in the two main aspects of the pricing policy: frequency and size of price changes. Lach and Tsiddon [1991] compare two inflationary episodes in Israel. They find that in the period with higher inflation, there was higher frequency and a wider variation in real prices between nominal price changes. Real prices eroded by about 10 percent prior to a nominal price increase. Kashyap [1991] performed a similar experiment, using U.S. data, and found no systematic effect of inflation on the size of price changes. Note that the two studies differ substantially in the inflation rates within their sample periods (2.5–7.5 percent annual rates in the United States vs. 4–9 *monthly* rate in Israel).

Inflation and Relative Price Dispersion

Among the important observable consequences of nominal price rigidities are the effects on relative price variability. That is, different sellers vary in the timing and size of nominal price changes. Consequently, there is vari-