

LAND USE AND URBAN

FORM

The consumption theory of land rent
GRANT IAN THRALL

GRANT IAN THRALL

LAND USE AND URBAN FORM

The consumption theory of land rent

Methuen
New York and London

First published in 1987 by
Methuen, Inc.
29 West 35th Street, New York NY 10001

Published in Great Britain by
Methuen & Co. Ltd
11 New Fetter Lane, London EC4P 4EE

© 1987 Grant Ian Thrall

Printed in Great Britain at the University Press, Cambridge

All rights reserved. No part of this book may be reprinted or reproduced or utilized in any form or by any electronic, mechanical or other means, now known or hereafter invented, including photocopying and recording, or in any information storage or retrieval system, without permission in writing from the publishers.

Library of Congress Cataloging in Publication Data

Thrall, Grant Ian.

Land use and urban form.

Bibliography: p.

Includes index.

1. Land use, Urban – Mathematical models. 2. Space in economics – Mathematical models. 3. Rent (Economic theory) I. Title.
HD108.4.T47 1987 333.77'13 87-1678

ISBN 0 416 35540 4

British Library Cataloguing in Publication Data

Thrall, Grant Ian

Land use and urban form: the Consumption theory of land rent.

1. Land use, Urban 2. Land

I. Title

333.77 HD111

ISBN 0 416 35540 4

Land Use and Urban Form

To my parents

WILLIAM HERMAN THRALL

CAROLYN MAY BROWN THRALL

*This book is a direct consequence of their
decision to migrate in 1947 from
Columbus, Ohio, to San Gabriel,
California. I could not have had a better
laboratory to learn the importance of
urban space than post World War II
Los Angeles.*

List of figures

- 2.1 The unfolding of household welfare over space
- 2.2 Spatial equilibrium welfare band
- 2.3 The budget line
- 2.4 Utility frontier
- 2.5 Diminishing marginal utility
- 2.6 Utility curves do not intersect
- 2.7 Equilibrium consumption of goods
- 2.8 CTLR solution for spatial equilibrium land rent
- 2.9 Spatial equilibrium land rent and household welfare
- 2.10 Land rent is neither constant nor increasing with increasing distance from the city center
- 2.11 Spatial equilibrium land rent decreases as distance between the city center and the land site increases
- 2.12 Spatial equilibrium land rent, land consumption, and composite good consumption for three example locations
- 2.13 Unfolding across space of spatial equilibrium welfare surface, land, and composite good consumption using the CTLR methodology
- 3.1 Derivation of urban limits for an interactive city
- 3.2 Derivation of urban limits for a radially constrained city
- 3.3 Derivation of urban limits for a solitary city
- 3.4 The population density cone
- 4.1 Median family income for black and white four-person households in the United States
- 4.2 Direct effects from a decrease in household income
- 4.3 Indirect effects in an open-interactive city from a decrease in household income
- 4.4 Derivation of the relative location of rich and poor households in an open-interactive city
- 4.5 Indirect effects in a closed-interactive city from a decrease in household income
- 4.6 Combining the production (PTLR) and consumption (CTLR) theories of land rent

- 4.7 Inner city commercial land rent changes and their effect upon the household sector
- 4.8 CTLR proof that households' welfare is greater in cities composed of households with incomes different than themselves
- 5.1 Average retail price in the United States of a gallon of regular gasoline in a full service station, 1953–81
- 5.2 Direct effects of an increase in the cost of transportation
- 5.3 Indirect effects of an increase in the cost of transportation in an open-interactive city
- 5.4 Indirect effects of an increase in the cost of transportation in a closed-interactive city
- 6.1 Proportion of median income required to purchase regular gasoline (effort) in a full service station in the United States, 1953–81
- 6.2 Direct effects of constant effort with increasing transportation cost and income
- 6.3 Indirect effects in an open-interactive city where transportation effort is constant while transportation cost and income both increase
- 6.4 Three cases for indirect effects in a closed-interactive city where transportation effort is constant while transportation cost and income both increase
- 6.5 The case of constant transportation effort and unchanging land rents in a closed-interactive city while transportation cost and income both increase
- 6.6 The case of constant transportation effort and increasing urban core land rents in a closed-interactive city while transportation cost and income both increase
- 6.7 The case of constant transportation effort and decreasing urban core land rents in a closed-interactive city while transportation cost and income both increase
- 6.8 Per capita consumption of gasoline in the United States, 1978–84
- 7.1 The direct effect of introducing a low-cost transportation network accessible by a single node
- 7.2 The indirect effect in an open-interactive city from introducing a low-cost transportation network accessible by a single node
- 7.3 The indirect effect in a closed-interactive city from introducing a low-cost transportation network accessible by a single node
- 8.1 Contour map of assessed value to market value ratios in standard deviation units for Hamilton, Ontario, Canada
- 9.1 Direct effects of an increase in mortgage interest rates
- 9.2 Indirect effects in a closed-interactive city from an increase in mortgage interest rates
- 9.3 Comparison of an increase in mortgage interest rates between settings with and without the mortgage interest deduction

- 9.4 Effect of the mortgage interest deduction in a nonmalleable closed-interactive city
- 10.1 Direct effects of an increase in the sales tax
- 10.2 Indirect effects in an open-interactive city from an increase in the sales tax
- 10.3 Indirect effects in a closed-interactive city from an increase in the sales tax
- 11.1 Classical aspatial economists' derivation of the burden of an increase in the property tax
- 11.2 Direct effect on annulus s_x of an increase in property tax using the explicitly spatial CTLR methodology, and indirect effects in an open-interactive city
- 11.3 Direct effects on annuli $s_1 < s_x < s_2$ from an increase in property tax using the spatial CTLR methodology, and indirect effects in an open-interactive city
- 11.4 Indirect effects from an increase in property tax in a closed-interactive city: the case where land rent decreases at the city center
- 11.5 Revealed indirect effects from an increase in property tax in a closed-interactive city: the case where land rent increases at the city center
- 12.1 Derivation of welfare effects from radially constraining a closed city
- 12.2 Radius and density effects considered from radially constraining a closed city
- 12.3 Constrained land consumption with market land rents
- 12.4 Quantity of land is zoned everywhere to be the same in the planned city, while land rents adjust in the market so that all households obtain the same welfare
- 12.5 Constrained land consumption, land rents set above market rents in the planned city
- 12.6 Constrained land consumption, land rents set below pure market rents in a planned city
- 12.7 Comparison of the pure planning scenarios
- 12.8 Comparison of the spatial welfare surfaces between the pure market solution and the case where land consumption is restricted while land rent is subsidized
- 13.1 Direct effects from the introduction of a public good, and indirect effects in an open city
- 13.2 Indirect effects from the introduction of a spatially uniform public good in a closed-interactive city
- 13.3 Indirect effects at the urban margins of a closed-interactive city from the introduction of a spatially uniform public good
- 13.4 Indirect effects at the urban core from the introduction of a negative externality in an open-interactive city
- 13.5 Indirect effects at the urban margins from the introduction of a negative externality in an open-interactive city

- 13.6 Indirect effects at the urban core from the introduction of a positive externality in a closed-interactive city
- 13.7 Indirect effects at the urban margins from the introduction of a positive externality in a closed-interactive city
- 14.1 Derivation of spatial equilibrium housing expenditures, and spatial equilibrium consumption of housing and composite good: the first branch of the utility tree
- 14.2 The four cases for the second branch of the utility tree depend upon whether the increase in transportation expenditure is offset by a decrease in composite good expenditures
- 14.3 Evaluation of case I of the second branch of the utility tree
- 14.4 Evaluation of case II of the second branch of the utility tree
- 14.5 Evaluation of case III of the second branch of the utility tree
- 15.1 Neighborhoods of Guadalajara, Mexico, by class of resident
- 15.2 Neighborhoods of Vienna, Austria, by class of resident, 1961
- 15.3 Relation between market values and population density in Hamilton, Canada
- 15.4 Location of employment in Hamilton, Canada, 1971

List of tables

- 3.1 Listing of endogenous and exogenous variables for open- and closed-interactive cities
- 4.1 Locational effects of a reduction in household income in a closed-interactive city
- 5.1 World prices for regular gasoline at a self-service station in the United States
- 5.2 Locational effects of an increase in transportation cost in a closed-interactive city
- 8.1 Percentage of total state revenue collections attributable to sales taxes, 1983
- 8.2 Effective tax rates for selected cities in the United States, 1982
- 8.3 Estimated taxes paid by a family of four, by income level for selected cities in the United States, 1982
- 8.4 Home mortgage interest rates in the United States, 1965–84
- 12.1 Vacancy rate of office buildings in the United States, 1977–84
- 12.2 Vacancy rate of rental property by selected standard metropolitan statistical area in the United States, 1980
- 13.1 Three cases for direct change in welfare as public good provision increases
- 15.1 Median sales prices and price increases of existing homes in selected metropolitan areas of the United States, 1984–5

Preface

Personal background to the book

This book presents a geometry of urban land rent and rationale for why cities acquire their particular spatial form. I call the method the Consumption Theory of Land Rent (CTLR).

I first started working on the foundations of the geometric method presented in this book while I was a graduate student at Ohio State University, and continued to work on it, off and on, for more than a decade. As a student I made what I then thought to be a minor move following completion of my MA degree from the Department of Economics and relocated across the corridor of Hagerty Hall to complete a Ph.D. from the Department of Geography. Indeed, it was my intrigue with space that drew me, and has kept me, within the discipline of geography. This is important to the reader, in that the CTLR analysis is differentiated from microeconomic consumer behavior theory by way of the geographers' emphasis upon space; the central theme of this book and the CTLR methodology is upon how certain things determine land use and affect the spatial form of the city.

Between 1975 and 1978 I presented a series of lectures on mathematical land rent theory in the Departments of Geography and Economics at McMaster University in Canada. At that time I presented the CTLR alongside the contemporary calculus-based mathematical land rent literature, first demonstrating the CTLR solution followed by the solution in calculus. I presented a course based exclusively on the CTLR paradigm between 1978 and 1983 in the Departments of Geography and Economics, where I then had a joint appointment, at the State University of New York at Buffalo, and beginning in 1984 at the University of Florida.

In 1980, under the prompting of one of my mentors from my years as a graduate student, Reginald Golledge, I rather belatedly published the foundations of the CTLR in the first volume of his journal, *Urban Geography*; without his encouragement that article and consequently this book would not have been written. Subsequent to that first article in *Urban Geography*, I published a succession of CTLR formulations with the dual

purpose of demonstrating the power of the paradigm, and also to provide solutions that had not yet been done in the general mathematical land rent theory. Many of the chapters in this book are based upon those articles – Chapters 2, 3, 4, 5, and 6: *Urban Geography* (1980, 1982); Chapters 9, 10, and 11: *Professional Geographer* (1981); Chapter 13: *Papers of the Regional Science Association* (1982); Chapter 9 and part of Chapter 14: *Canadian Geographer* (1982); and Chapter 12: *Political Geography Quarterly* (1983). The analysis of Chapter 8 is based upon my work in *Professional Geographer* (1979, 1981).

At the same time, this book is more than an essay about journal articles I have written. Though the analysis dates to lectures I gave at SUNY-Buffalo, no part of Chapter 7 has been published elsewhere, and much of Chapters 4 and 14 are being published for the first time; space restrictions in the case of journal articles are typically more severe than in books thereby requiring cuts, usually at the expense of explanation. A not insignificant benefit of the CTLR presented here for the first time in book form is that while the articles were written to stand independent of one another, the paradigm of the CTLR can be seen holistically from the sum of its constituent parts. Moreover, the CTLR is presented, again for the first time, in a new format.

The presentation is divided into both *direct* and *indirect* effects. Direct effects include the impact upon the system resulting from the change in some external component of the model while holding land rent constant; indirect effects isolate the subsequent effect that adjustments in land rent have upon the system. The direct effects are first derived which explains the behavior of the system down to a small last step, where the results of the open, closed, and planned cities can be derived. The benefit of the direct and indirect vehicle is that instead of open, closed, and planned cities appearing as entities independent from one another, they are clearly seen as slight though important variations of one another.

I have found the CTLR geometry to have four general advantages over the calculus formulations. First, the CTLR is a paradigm whose use presents a firm explanation of the underlying forces for the behavior of the system. In contrast, the calculus often reduces the problem to one of statement of the problem followed by solution; the mechanics of calculus as typically deployed by all the mathematical land rent literature is with a lack of explanation as to why the solution is as it is.

Second, many problems that have been stated in the calculus-based mathematical land rent theories become, due to their complexity, intractable and often unsolvable without alluding to numerical methods of solution (Thrall, 1979a); though not entirely without rewards, such approaches lack both generality and again forsake explanation as to why the system behaves as it does. Regardless of its simplicity, the CTLR is here demonstrated to be able to solve and explain many problems that are finally intractable using alternative approaches.

Third, the CTLR is accessible. The major theorems of mathematical land rent theory, heretofore only understandable by those with advanced training in mathematics and microeconomics, can be understood by means of the CTLR by persons whose analytic training has not extended beyond what would be expected of an entering college student. This has been accomplished without loss of rigor of the logic.

Fourth, while all the before-mentioned advantages may be value laden, this last point most certainly rests upon one's own aesthetics of research. While I recognize that not all problems in mathematical land rent theory can be solved using the CTLR, I find that when the CTLR can be used it gives me more pleasure than an equivalent solution using the calculus. My reasons are simple. Given that a problem can be stated and solved under two paradigmatic approaches, one mathematically complex versus one elegantly simple, and given that the solutions of both are compatible, I prefer the elegantly simple approach. For those problems that can be solved using the CTLR, I can make an even stronger and more utilitarian point that the paradigm of the CTLR should be used instead of the calculus solution because of its elegant simplicity. Our various disciplines cannot survive by limiting the important contributions to be understood only by extreme specialists in the literature. Rather, for these endeavors to continue to receive the resources from universities, and respect from the professional environments, then the accomplishments must be made accessible (including to undergraduates). The CTLR is then demonstrated here to be both an effective research and pedagogical vehicle.

Content of the book

Following a brief introduction in Chapter 1, the foundations of the CTLR model are presented in Chapters 2 and 3. This includes an elementary overview of microeconomic consumer behavior theory, the notion of spatial equilibrium in the context of the CTLR, determination of urban radius, definition of open and closed cities, and the interaction of production and consumption sectors.

The idea of direct and indirect effects in the comparative static analysis of changing household income is introduced in Chapter 4, which includes an analysis of the conditions that will lead to dominance of the inner core of cities by the wealthy or by the poor, the contribution of rising incomes to suburbanization, and the importance of income differentials and mix to migration.

Chapters 5–7 are devoted to an examination of transportation: the effect upon urban spatial structure from changing cost of transportation holding all other parameters constant, then allowing both income and transportation cost to change. These analyses assume an isotropic transportation surface;

however, in Chapter 7 this assumption is relaxed to include a limited access network analogous to a light rail rapid transit system or limited access highway.

Chapters 8–11 collectively look at the role and subsequent impact of government taxation upon the geography of the city. Specifically, the effects upon urban space from sales, property, and income taxes are derived. This analysis is followed in Chapters 12 and 13 by the derivation of the linkage between urban space and government activities.

The government provides constraints in the form of planning, analysed in Chapter 12, and in the form of the provision of goods, analysed in Chapter 13. The public goods can either be uniformly distributed or conform to positive or negative externalities. These chapters are two of the more complex and possibly more important analyses of the book. Many phenomena can be reduced to arguments conforming to externalities, including some of the components of the spatial effect of racial prejudice.

Chapter 14 demonstrates how a housing rent function can be derived, where housing is composed of a combination of capital and land. This is done for completeness. In the last chapter, the Postscript, I discuss the utility and application of the CTLR, and argue for what I believe should be an appropriate balance of research (and when I have used this material in the classroom the students have been requested to read the Postscript immediately after the Preface). It is my goal that the CTLR be available at one's fingertips, like the supply and demand curve, so that one can quickly and accurately analyze problems demonstrated in this book and that may be encountered in the future.

I would like to express my gratitude to Tammy Virana, who was responsible for quickly transforming my squiggles into publication-quality figures. The diplomacy of Mary Ann Kernan, my editor at Methuen, in London, was exactly the right balance of necessary patience and pressure throughout the lengthy period of writing this book. But most important to the completion of the volume is my wife, Susan Elshaw Thrall, of the Computer Science Program of the Department of Business, Lake City College; she has been my most constructive critic, and exercised a wonderful patience in reading and commenting on the entire manuscript.

References

Thrall (1979a, 1979b, 1979c, 1979d, 1980a, 1980b, 1981a, 1981b, 1982a, 1982b, 1982c, 1983a, 1983b).

Contents

<i>List of figures</i>	viii
<i>List of tables</i>	xii
<i>Preface</i>	xiii
PART I: FOUNDATIONS OF THE CONSUMPTION THEORY OF LAND RENT (CTLR)	1
1 Introduction	3
2 Foundations	10
3 Further specification of the CTLR model	27
4 Income	37
PART II: TRANSPORTATION SYSTEMS	61
5 Transportation cost	63
6 Transportation effort	74
7 Transportation nodes	87
PART III: GOVERNMENT REVENUE	101
8 Tax expenditure overview	103
9 Income tax, interest rates, and mortgage interest deductions	116
10 Sales tax	130
11 Property tax	136
PART IV: GOVERNMENT SERVICES	151
12 Planning	153
13 Public goods and externalities	174
PART V: MULTILEVEL DECISION-MAKING	197
14 Housing	199
15 Postscript	211
<i>Glossary</i>	224
<i>Bibliography</i>	233
<i>Index</i>	237

PART I

Foundations of the Consumption
Theory of Land Rent (CTLR)

