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Taxes and allowances in a dynamic equilibrium model of urban housing with a size–quality hierarchy

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Abstract

The paper investigates the effects of an income tax, a property tax, and a housing allowance in the Chicago Prototype Housing Market Model (CPHMM), a dynamic, perfect foresight simulation model of the housing market with a size–quality hierarchy and with multiple household groups. The income tax discriminates against housing conversions with large nonfinancial costs, since these are not deductible. In a perfectly competitive housing market, each housing policy in isolation is distortionary. However, the excess burden of a pair of jointly implemented policies may be less than that for one of the policies in isolation. For some realistic parameter values, a housing allowance aimed at improving the average housing quality consumed by the poor improves efficiency by offsetting part of the deadweight losses of the taxes. The allowance benefits both consumers and landlords in the targeted submarkets, but it hurts landlords on the average by inducing substitution from the non-targeted towards the targeted submarkets.

Keywords: Housing demand; Supply and markets; Computable general equilibrium; Intertemporal choice and asset pricing; Cost-benefit analysis

JEL classification: D58; D61; D92; G12; R21; R31

1. Introduction

This paper analyzes the interrelated effects of the income tax, the property tax

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and a housing allowance system in an urban housing market using the Chicago Prototype Housing Market Model (CPHMM—see Anas and Arnott (Anas and Arnott, 1991, 1993a,b,c, 1994)). The CPHMM is a simulation model which, like Sweeney's (Sweeney, 1974a,b) conceptualization, treats a competitive housing market as a quality hierarchy of submarkets, where housing units are durable and deteriorate in quality less rapidly as more is spent on maintenance. The CPHMM enriches Sweeney's model by incorporating land, a more general maintenance technology, construction and demolition and conversion of housing from one type in the hierarchy to another, idiosyncratic tastes and costs and a solution technique for stationary and nonstationary dynamics.

The central concern of the public finance literature vis-a-vis housing has been how the taxation of housing affects the allocation of capital between the housing and non-housing sectors. To analyze this, computable general equilibrium models which provide an aggregative treatment of the housing market (e.g. Fullerton and Gordon (1983); Poterba (1984); Berkovec and Fullerton (1992)) have been employed. The review article by Rosen (1985) is a good reference source for the issues analyzed and conclusions reached in this literature.

In contrast, the urban economics literature provides a disaggregated treatment of housing and employs partial equilibrium models which ignore non-housing capital. Kain et al. (1976), deLeeuw and Struyk (1977), Carlton and Ferreira (1977), Vanski and Ozanne (1978), Hanushek and Quigley (1981) have examined the effects of housing allowances in various metropolitan areas. The first four studies disaggregated the market into various housing types. In all of these studies, allowances were viewed as instruments for improving equity rather than as policy levers that can be designed to offset the distortionary effects of income and property taxation. Housing allowances were analyzed in isolation rather than focusing on how they interact with existing tax policy.

Our model is in the urban economics tradition, and contributes to that literature by analyzing housing allowances with an income tax and/or a property tax in place. We focus on the supply-side effects of policies, providing a rich treatment of supply dynamics. Our simulations uncover a number of interesting quantitative results, several of which have not, to our knowledge, been previously identified. These are:

1. *Non-neutrality of the income tax*: We impose an income tax that is neutral with respect to investment when all costs enter the tax base. In our model, however, there are both financial and non-financial costs, and only financial costs enter the tax base. According to our calibration, the nonfinancial costs associated with operating and converting housing are substantial. Correspondingly, we find the income tax to be highly distortionary, even though it is fully efficient according to the conventional wisdom which ignores nonfinancial costs. This points to the importance of recognizing nonfinancial costs in housing models.

2. *Efficiency of the housing allowance with other taxes present*: When imposed

alone, the housing allowance program we consider is quite strongly distortionary. However, the imposition of the housing allowance program with an income tax and a property tax present actually improves efficiency. This underscores the desirability of evaluating housing policies with other policies in place rather than in isolation.

3. *Effect of the housing allowance on investors*: One of the arguments advanced against housing allowance programs is that, due to the short-run supply inelasticity of housing, a large share of the benefit accrues to the *owners* of rented property. In our simulations, however, we find that our targeted housing allowance program actually hurts rental property owners in the aggregate. The reason is that the program induces demand substitution towards the targeted housing, which reduces aggregate property values. This result would be obscured in models without housing-type disaggregation.

4. *Target efficiency of the allowance*: The targeted housing allowance program we consider performs well relative to the stated objective of such programs. Its target efficiency is high—almost all the benefit accrues to the targeted income group. Other groups receive only very small benefits from the program, and investors are hurt by it on the average, though not by much. When imposed with an income tax and a property tax present, the allowance actually improves efficiency. We hope that these results will be noted by the housing policy community and stimulate renewed interest in, and more careful thinking on, targeted allowances.

5. *Efficiency of the property tax with income taxes present*: It has been argued for centuries that a land tax is non-distortionary since land is in inelastic supply. According to the classical view, the property tax is distortionary since it taxes both land and structures, and structures are supplied elastically, at least in the long run. Consequently, there are continuing calls for the replacement of the property tax with site value taxation. The principal argument against this has been that it is difficult, with durable housing, to separate land and structure values. According to our simulation results, even though conversion costs and the rate of interest are fixed, the property tax is highly efficient, which weakens the argument for site value taxation.

The next section of the paper sets the stage. Section 2.1 presents a summary description of the model, Section 2.2 briefly describes the calibration, and Section 2.3 describes how we compute welfare measures. Section 3 is the heart of the paper, presenting and discussing the results of the simulations, where the base case has no government intervention. Section 3.1 starts with a theoretical analysis of the effects of the income tax, and then draws on this analysis to explain the results of the simulations in which an income tax on housing investors and landlords is introduced in isolation. Section 3.2 and Section 3.3 perform similar exercises for the property tax in isolation and a targeted housing allowance program in isolation. Sections 3.4 and 3.5 present simulation results for pairs of policies and discuss how the policies in each pair interact. Section 3.6 treats all three policies together. In Section 4, we provide concluding comments.

2. Setting the stage

2.1. The model

We have described the CPHMM in a number of earlier articles. The model is basically an enriched version of Sweeney's model of the housing market as a quality hierarchy (Sweeney, 1974a,b). In the Sweeney model, the housing stock is described as the number of housing units at various levels of quality. There is a fixed number of heterogeneous households, all of which rent housing, and rent as a function of quality is determined in a temporary competitive equilibrium. The housing market is in a stationary state. Knowing rent as a function of quality over time, landlords determine how much to spend on maintenance over each unit's life; the more is spent on maintenance, the less rapidly the unit deteriorates. Given landlords' profit-maximizing programs, housing value as a function of quality can be determined as the present value of the future net revenue stream from the dwelling. Housing is constructed at those quality levels at which housing value equals construction cost since there is no land in the model. Finally, the equilibrium stock of housing is determined such that the market is in a stationary state.

The CPHMM extends the Sweeney model in five major respects:

a) *Land*: Not only is the incorporation of land an important step in the direction of realism, but also, as we have demonstrated elsewhere (Anas and Arnott, 1993a,c), the inclusion of land may alter the qualitative behavior of the model.

b) *Non-stationarity*: The Sweeney model solves for a stationary-state equilibrium. We solve for a stationary-state equilibrium at some period T in the future and also solve for the non-stationary equilibrium path of the market from time $t=0$ (the beginning of period one) to $t=T$ under the assumptions that housing investor-landlords have perfect foresight, and that housing values at time T and beyond equal the stationary equilibrium values. One unsatisfactory feature of our model, which we hope to address in future work, is that households' decision making is essentially static. In each period, a household simply allocates its income between housing and non-housing consumption, and neither borrows nor saves.

c) *Housing differentiation*: In the Sweeney model, housing units are differentiated on the basis of quality alone. In our model, units are differentiated on the basis of quality and the number of bedrooms. In Anas and Arnott (1993b) we have further differentiation on the basis of location and building type (single versus multiple family).

d) *Conversion technology*: In the Sweeney model, housing is doomed to deteriorate in quality, at a rate which depends on maintenance expenditure. In our model, housing may be upgraded or downgraded. Sweeney assumed that vacant houses are demolished at zero cost without creating land, whereas we model demolition as costly and land-creating and construction as costly and land-depleting.

e) *Idiosyncratic tastes and costs*: The Sweeney model is deterministic at the individual and aggregate levels. Our model is deterministic at the aggregate level but incorporates random differences at the level of the individual. Specifically, individuals' tastes are idiosyncratic, and so too are landlords' conversion costs. This randomness not only facilitates calibration and improves realism—since not all agents in a group behave in the same way—but also, by smoothing the aggregate response to price changes, speeds up computation.

The model is built around three logit equations (the demand, occupancy and conversion probabilities). These are woven into three equation systems (stock valuation, stock adjustment and market-clearing submodels) which together characterize the equilibrium. For the derivation of these equations, the reader is referred to Anas and Arnott (1991).

i) *Demand*: Our households consume all of current income each period—they neither borrow nor save. Each household decides each period what type of housing it will rent. Moving costs are zero. Where h denotes the household type, z denotes the housing submarket (a size and quality) and t the year, the demand-side choice probabilities are logit:

$$P_{hzt} = \frac{\exp(U_{hzt})}{\Sigma_a \exp(U_{hat})}; \quad \Sigma_z P_{hzt} = 1. \tag{1}$$

Where y_{ht} is income, μ_{ht} the income tax rate, R_{zt} the submarket rent, E_{hzt} non-rent housing expenditure by the tenant of type h (utilities, insurance etc.) and Y_{hzt} a subutility function which measures the utility derived from housing size (rooms), physical quality and other submarket characteristics, the utility function is specified as:[1]

$$U_{hzt} = \alpha_h[(1-\mu_{ht})y_{ht} - R_{zt} - E_{hzt}] + Y_{hzt}. \tag{2}$$

ii) *Occupancy*: The occupancy choice probabilities describe the choice of occupancy status by landlords in each time period. Depending on the realization of the idiosyncratic occupancy-vacancy costs, each landlord decides whether to rent his unit or keep it vacant. Where c_{1zt} and c_{0zt} denote the non-idiosyncratic financial

[1] As will be explained in the next subsection, the linear-in-rent utility function differs somewhat from the one originally estimated in Anas and Arnott (1993b), but is calibrated to have the same rent elasticities of demand and marginal rates of substitution between rooms and housing expenditure. The linearity in rent facilitates welfare analysis per Small and Rosen (1981).

costs ("maintenance" costs) of occupancy and vacancy respectively, μ_t is the landlord's income tax rate, ϕ_{zt} is the dispersion parameter of the idiosyncratic component of costs (which is inversely related to the variance) and $d_{zt} \equiv c_{1zt} - c_{0zt}$, the probability that the unit is offered for rent is:[2]

$$q_{zt} = \frac{\exp \phi_{zt}(1-\mu_t)(R_{zt} - d_{zt})}{1 + \exp \phi_{zt}(1-\mu_t)(R_{zt} - d_{zt})} \tag{3}$$

iii) *Conversion*: Conversion probabilities describe the year-end decision of an investor-landlord to convert a unit from type z to z', where $z = z' = 0$ corresponds to land so that $z = 0$, $z' > 0$ corresponds to construction and $z > 0$, $z' = 0$ to demolition. We can restrict the set of housing types to which a unit of type z can be converted, denoting it by $A(z)$. A landlord's conversion decision will depend on housing and land values $\{V_{zt}\}$, systematic financial conversion costs $\{C_{zz't}\}$, systematic nonfinancial conversion costs $\{D_{zz't}\}$, the dispersion parameter of the idiosyncratic nonfinancial conversion costs Φ_{zt}, the number of units of type-z housing needed to create one type z' unit (denoted by $m_{zz'}$), as well as the tax system. Systematic and idiosyncratic nonfinancial costs play an important role in the model's calibration.

The income tax system, as it applies to landlords, is simple. The tax base is rent net of financial maintenance costs plus capital gains net of financial conversion costs minus mortgage interest payments (no downpayment is assumed), minus property tax payments. The property tax is an ad valorem tax on property value at the rate θ_{zt}. r_t is the before-tax discount rate, and $\rho_t = (1 - \mu_t) r_t$, the after-tax discount rate.

Because time is discretized, assumptions have to be made concerning when rents are received and which costs are incurred at the beginning of each period and which at the end. We assume that rent is received at the beginning of a period and that maintenance and nonfinancial conversion costs are incurred at that time, as is the income tax on rental income net of maintenance cost. All other costs are incurred and taxes are paid at the end of the period. Asset values are measured at the beginning of each period.

Where Φ_{zt} is the dispersion parameter of conversion costs (inversely related to the standard deviation), the conversion probabilities are given by:[3]

[2]It is assumed throughout that the income tax is paid at the moment revenue is received. Thus, for example, the tax on rent is paid at the start of each period, while a tax refund is paid at the end of each period when conversion costs are incurred.

[3]Note that current (year t) property taxes are paid on z units before these units are converted. Hence, the property tax is a sunk cost in the conversion decision and does not affect the conversion probabilities. Future property taxes do affect the decision indirectly by having been capitalized into the values of z' units at time $t+1$.

$$Q_{zz't} = \frac{\exp \Phi_{zt}\{[(1-\mu_t)(V_{z't+1} - C_{zz't})/((1+\rho_t)m_{zz'})] - D_{zz't}\}}{\Sigma_{x\in A(z)} \exp \Phi_{zt}\{[(1-\mu_t)(V_{xt+1} - C_{zxt})/((1+\rho_t)m_{zx})] - D_{zxt}\}},$$

$$\Sigma_{z'} Q_{zz't} = 1. \tag{4}$$

iv) *Asset valuation*: Since investor-landlords are risk neutral and since the housing asset market is perfectly competitive, asset prices are such that the expected return to owning rental housing equals the after-tax discount rate. Since there is no aggregate uncertainty, asset prices are deterministic. Let $w_{zt}(R_{zt})$ be the expected rent from a housing unit of type z in year t, taking into account the probability that the unit may be kept vacant. Then

$$w_{zt}(R_{zt}) = (1/\phi_{zt}) \ln\{\exp[\phi_{zt}(1-\mu_t)(R_{zt} - c_{1zt})] + \exp[-\phi_{zt}(1-\mu_t)c_{0zt}]\}, \tag{5}$$

for $z>0$. For land, it is assumed that there is a net rent which is exogenously given. Asset prices are given by:

$$V_{zt} = \frac{\ln \Sigma_{z'\in A(z)} \exp \Phi_{zt}\left[w_{zt}(R_{zt}) + \dfrac{(1-\mu_t)(V_{z't+1} - C_{zz't})}{(1+\rho_t)m_{zz'}} - D_{zz't}\right]}{\Phi_{zt}(1 + r_t + \theta_{zt})(1-\mu_t)/(1+\rho_t)}. \tag{6}$$

Note that asset prices depend on this period's expected after-tax rent and next period's asset values net of financial conversion costs discounted by the after-tax interest rate and on non-financial conversion costs. Asset values also depend on the property tax rate. Given rents and asset values at terminal time, asset prices in prior periods can be solved recursively backwards.

Hereafter, the three choice probabilities in year t will be abbreviated as follows. The demand-side probabilities are written as $P_{hzt} = P_{hzt}(\boldsymbol{R}_t)$, where $\boldsymbol{R}_t$ is the vector of submarket rents in year t; the occupancy probabilities as $q_{zt} = q_{zt}(R_t)$; and the stock conversion probabilities as $Q_{zz't} = Q_{zz't}(V_{t+1})$, where V_{t+1} is the vector of submarket asset prices at the beginning of year $t+1$ (or end of year t).

v) *Stock adjustment*: Once asset prices are known for all years and submarkets, stocks, S_{zt}, are calculated from the stock adjustment equations, beginning with year one's given stocks and working recursively forward in time:

$$S_{zt+1} = \Sigma_{x\in B(z)}(1/m_{xz})S_{xt}Q_{xzt}(V_{t+1}), \tag{7}$$

where $B(z)$ is the set of housing types that can be converted to housing type z.

vi) *Rent determination*: Once stocks are calculated, rents are calculated from temporary equilibrium in the rental market:

$$\Sigma_h N_{ht}P_{hzt}(\boldsymbol{R}_t) - S_{zt}q_{zt}(R_{zt}) = 0, \tag{8}$$

for $z>0$ where N_{ht} is the exogenously given number of households of type h in year t.

The stationary equilibrium for time T and beyond is calculated by solving (6), (7) and (8) simultaneously for $\mathbf{V}_T$, $\mathbf{S}_T$ and $\mathbf{R}_T$ after imposing stationarity which is done by rewriting (6) and (7) for the Tth period and then setting $\mathbf{V}_{T+1}=\mathbf{V}_T$ and $\mathbf{S}_{T+1}=\mathbf{S}_T$. The solution algorithm for the dynamic phase of the model (from $t=0$ to $t=T$) starts with a guess of the matrix of rents for all periods and the stationary state equilibrium solution of rents and asset values for year T. Then, asset values are determined for all periods from (6); stocks are then calculated for all periods from (7); and a new matrix of rents is determined from (8). A new guess is found for the matrix of rents by calculating a weighted average of the rents used in the previous iteration and those obtained from (8), and new asset values are recalculated from (6) and so on, with the iterative procedure repeated until convergence is obtained. Fig. 1 shows the block-recursive manner in which Eqs. (6)–(8) are linked to each other in the iterative algorithm.[4]

Simulations were performed on a 486/33MhZ personal computer. Two tolerance criteria were imposed simultaneously for convergence to have occurred: (1) the maximum absolute value change in rent (over all housing types and periods) must be less than $1.00; and (2) "the square root of the mean of the sum of excess demands squared" (over all housing types and periods) must be less than 0.00004.

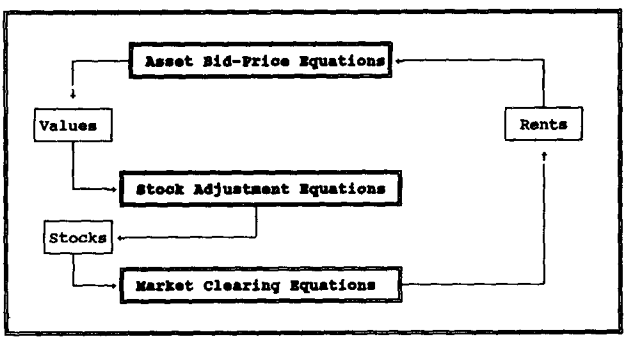

Fig. 1. Graphical representation of solution procedure.

[4]In Anas and Arnott (1993a) we proved the existence of a unique equilibrium (which is also a welfare maximum) for a version of the above model without taxes, a single demand group and a single housing type and land. Although that version can be generalized to deal with multiple demand groups and a size-quality hierarchy of housing types, we have not developed that proof. In numerical simulations, we have always succeeded in finding an equilibrium regardless of the size and complexity of the model or the presence of taxes.

The first criterion alone is not enough to confirm equilibrium because it can be satisfied when the excess demand equations are very flat in terms of rent. For most simulation runs, convergence was achieved in about 15 minutes.

2.2. Calibration

The version of the CPHMM used in this article is an aggregation of the more disaggregated version described in Anas and Arnott (1993b). The tenure choice decision was present in that more detailed model, but the current simulation model assumes that all households rent. In calibrating the model we treated owner-occupiers as renters who pay a rent equal to their owner-occupancy user cost, as explained in Anas and Arnott (1993b). The calibration data came from the 1970 and 1980 Public Use Microdata Samples of the U.S. Census for the Chicago MSA.

Housing units, in the current version, are aggregated into just twelve submarkets comprising a size–quality hierarchy. Size is defined by the number of bedrooms in the housing unit, grouped into four categories (0–1, 2, 3 and 4+) and by three physical quality levels for each size based on an index of bathrooms, heating, air conditioning, kitchen and plumbing facilities and other housing characteristics.[5] During the decade, the aggregate housing stock increased by 14.3%, households increased by 11.9% and population (number of persons) by 1.8%.

Households are aggregated into ten types according to race of household head (white and non-white) and five income intervals roughly corresponding to income quintiles in 1980. The quintile income-boundaries are deflated to 1970 by using the Consumer Price Index change for the decade. During the decade, average household income increased by 84% in nominal terms, while housing units gained 150% in value on the average and 102% in rent (or estimated rental value for owner-occupied units).

i) *Demand*: As explained in Anas and Arnott (1993b), the logit model (1), with a utility function $U_{hzt} = \alpha_h \ln [(1-\mu_{ht})y_{ht} - R_{zt} - E_{hzt}] + Y_{hzt}$, was first estimated separately for white and non-white households using 1980 Census data but no significant difference was found in the coefficient estimates by race of head.[6] The households were pooled by race of head and the model was reestimated. From this reestimated model we calculated the own-price elasticity of housing demand and the marginal rate of substitution between rooms and housing expenditure for each

[5] The physical housing quality index is described in detail in Anas and Arnott (1993b).

[6] The estimated utility function was linear in the log of the household's disposable income after rent and other housing expenditure, whereas (2) is linear in rent plus other housing expenditure. The linearity in rent facilitates welfare analysis (the calculation of consumer surplus a la Small and Rosen (1981)), which is the central focus of this paper. The subutility function Y was specified to depend on the average number of rooms in the submarket, the average physical quality in the submarket and the proportion of single-family dwellings in the submarket.

Table 1
Rent Elasticities and MRS's ($/room) of Estimated Demand Model. 1980 Chicago MSA

	Income Group	Rent El.	MRS
White Households			
1	$0–$10,128	−1.675	−431
2	$10,128–$19,623	−0.839	−1020
3	$19,623–$27,430	−0.366	−1871
4	$27,430–$37,347	−0.219	−2314
5	>$37,437	−0.180	−3225
		−0.516	−1953
Non-White Households			
1	$0–$10,128	−1.376	−741
2	$10,128–$19,623	−0.685	−1589
3	$19,623–$27,430	−0.264	−3292
4	$27,430–$37,347	−0.225	−3605
5	>$37,437	−0.152	−3761
		−0.683	−2145
Overall means		−0.554	−1996

Note: Elasticities and MRSs are mean values over the sample or subsample. See Anas and Arnott (1993b).

household type. These elasticities and MRSs from the pooled model are reported by race of head and income interval in Table 1.

The price elasticity measures the percentage increase in the probability that a household will choose its current submarket when the submarket rent drops by one percent, keeping the rent of all other submarkets constant.[7] This was calculated for each household in the estimation sample and then averaged over all households. From Table 1, the weighted average price elasticity (over whites and non-whites) in 1980 is −0.554. This value agrees with consensus estimates from the literature [see, for example, Mayo (1981)].[8] The overall average MRS in 1980 is $1,996 per year or $166 per room per month. The utility function is specified in such a way that the MRS increases with income, the age of the household head and the number of persons in the family. Details are given in Anas and Arnott (1993b).

Because, as noted earlier, the estimated utility function and that used in this article are not of the same functional form, the coefficients of "rooms" and of "total housing expenditure" in the utility function (2) were calculated such that

[7]It is important to note that the notion of an elasticity calculated from discrete choice models differs from the notion of housing price elasticity in a neoclassical model. In the neoclassical model, if the price of housing falls (i.e. the prices of all houses fall) all households will buy more housing. In the discrete choice context, if the price of housing in one submarket falls (keeping the prices in all other submarkets constant) then some households will want to switch from their current submarket.

[8]Although most of the studies surveyed by Mayo conform to the neoclassical model, there are several studies of discrete choice which produce similar elasticities. See, for example, Lerman (1977) and Anas and Chu (1984).

the price elasticities and MRSs calculated from (1) and (2) replicated the average elasticity and MRS by income group and race of head from the originally estimated model.

ii) *Occupancy*: As explained in Anas and Arnott (1993b), the binary logit occupancy model (3) was estimated by maximum likelihood using aggregate data on the one hundred housing submarkets of a less aggregated version of the model. For each submarket, we calculated the observed left side of (3) as the proportion of rental units of that type which were occupied. The value of μ_t, the investors' marginal tax rate, was estimated by the corporate tax rate. We set it equal to its actual value for each year which varied from 0.492 in 1970 to 0.460 in 1980.

In the calibration, which is explained in Anas and Arnott (1993b), we assumed that $\phi_{zt} = \phi_t$ for each housing type z and set the time trend of ϕ_t's such that the nonfinancial idiosyncratic costs, ϕ_t, grew over time according to the producer price index. The value of the estimated cost dispersion parameter ϕ_t in the occupancy model was such that, keeping the stock of units constant on average, a one percent increase in the rent of a submarket resulted in a 0.1 percent increase in the number of the occupied units in that submarket. This reflects, as is realistic, an inelastic short run supply curve for housing.

iii) *Stock conversion*: Calibration of our stock adjustment model was more ad hoc because there are no data on housing conversions or conversion costs. In Anas and Arnott (1993b) we have described the assumptions whereby we make conversion costs functions of housing quality differences. The dispersion coefficients of the idiosyncratic nonfinancial costs, Φ_{zt}, were set to reflect the assumption that idiosyncratic nonfinancial costs grow over time according to the producer price index. We also limited conversions in each housing submarket as shown in Fig. 2. For each bedroom size, construction can occur at quality levels two and three only and demolition at quality level one only. Units can remain at the same quality level or deteriorate one quality level per year, but can be upgraded to any higher quality level in one year. Housing cannot be converted directly from one bedroom size to another. Such conversions can be achieved by

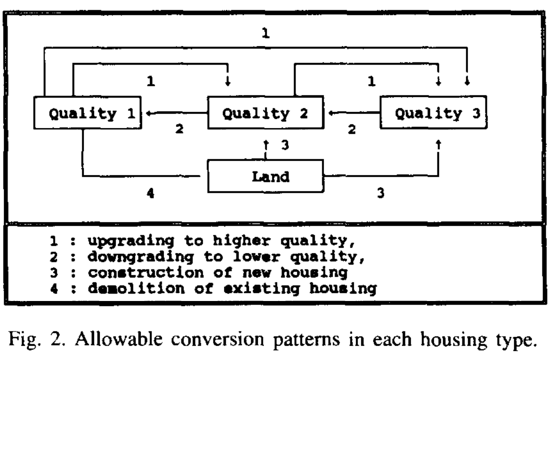

Fig. 2. Allowable conversion patterns in each housing type.

demolishing the units of the old bedroom size and then constructing units of the new bedroom size.

Using the above framework, the stock adjustment probabilities given by (4) are calibrated by setting the cost dispersion parameters Φ_{zt} such that reasonable responses of construction and demolition are obtained with respect to the year-ahead rent, holding rent in the subsequent years fixed. Based on our reading of the literature, which is sparse on this topic, we selected the rent elasticities of both the construction rate and the demolition rate to be +0.3.[9]

The calibrated conversion probabilities and the associated nonfinancial costs are shown in Table 2 and Table 3 for the initial year. Rows correspond to "before conversion" and columns to "after conversion". Note first, from Table 2, that the conversion probability matrix is highly diagonal. Depending on the submarket, from 80% to 99% of the stock remains at the same quality, only about 2% to 3% is demolished and the remainder is converted up or down in quality. From Table 3, these conversion probabilities are sustained by means of substantial dollar-valued nonfinancial costs. For example, demolition typically entails a high nonfinancial benefit and downward and upward conversions in quality typically carry high nonfinancial costs.[10]

2.3. Welfare measures

We shall want to compute the discounted dollar welfare gain or loss due to various tax and housing allowance policies. Our model has three sectors: households (consumers), investors and government. Hence, there will be three present-valued components of welfare (discounted to $t=0$) which will be summed together. Let us call these CW, IW and GW respectively. Government welfare will be calculated as the present value of gross tax revenue change less the present value of expenditures required for a policy (e.g. a housing allowance program). Therefore, net-present-value benefits (NPVB) due to a policy or tax change will be calculated as:

$$NPVB = \Delta CW + \Delta IW + \Delta GW \tag{9}$$

where quantities preceded by Δ are the changes in each welfare measure (possibly negative) caused by the policy or tax change.

In calculating consumer welfare in dollar terms, we first recall our assumption that consumers neither borrow nor rent. Then, with the logit specification of choice

[9] This value is in the lower range of the estimates reported by Smith (1976) who estimates long run new construction elasticities for Houston. Because our model is an annual dynamic adjustment model rather than a long run equilibrium model we prefer to assume relatively inelastic stock adjustments.

[10] Investors' discount rates were assumed to equal the average yield on newly issued 6-month treasury bills in each year. The 1970 yield was 6.56% which fluctuated with an upward trend reaching 11.37% in 1980. It was assumed to stay there subsequently. Hence, investors are assumed not to have anticipated the gradual drop in interest rates which began in 1983.

Table 2
Calibrated Conversion Probability Matrix (1970) with income and property taxes in place

BDRM	QUAL	0–1			2			3			4+			LAND
		1	2	3	1	2	3	1	2	3	1	2	3	
	1	0.9664	0.0018	0.0001										0.0318
0–1	2	0.0536	0.9460	0.0004										
	3		0.1975	0.8025										
	1				0.9734	0.0020	0.0007							0.0240
2	2				0.0488	0.9481	0.0032							
	3					0.0299	0.9701							
	1							0.9709	0.0042	0.0021				0.0228
3	2							0.0235	0.9717	0.0048				
	3								0.0204	0.9796				
	1										0.9609	0.0060	0.0056	0.0274
4+	2										0.0163	0.9745	0.0092	
	3											0.0108	0.9892	
LAND			0.0006	0.0000		0.0009	0.0003		0.0020	0.0010		0.0024	0.0022	0.9907

(Probability of a blank cell is zero)

Table 3
Calibrated Systematic Nonfinancial Costs (1970 $) with income and property taxes in place

BDRM	QUAL	0–1			2			3			4+			LAND
		1	2	3	1	2	3	1	2	3	1	2	3	
	1	0	2374	2493										−5014
0–1	2	−2761	0	81										
	3		−263	0										
	1				0	9023	12105							−2946
2	2				3379	0	9255							
	3					3349	0							
	1							0	6041	7787				−3506
3	2							6717	0	7939				
	3								5266	0				
	1										0	11149	14469	1183
4+	2										13710	0	15700	
	3											9819	0	
LAND			310598	100717		138650	118730		15744	1000		−14564	−14174	0

(Value of nonfinancial cost in a blank cell is infinity. A minus sign indicates a nonfinancial benefit).

probabilities and with the linear-in-rent utility function, an exact dollar-valued measure of consumer surplus for a household of type h, in year t (at the beginning of the year), is calculated using the well-known result in Small and Rosen (1981)):[11]

$$CS_{ht} = (1/\alpha_h) \ln \Sigma_z \exp\{\alpha_h[(1-\mu_{ht})y_{ht} - R_{zt} - E_{hzt}] + Y_{hzt}\} \quad (10)$$

Then the total consumer surplus in year t is $CS_t = \Sigma_h N_h CS_{ht}$. In computing CW, we take the gross-of-tax interest rate as the social rate of discount for consumer welfare. Accordingly, the discount factors are $F_1 = 1$ and $F_t = 1/(\Pi_{s=1,t-1}\ (1+r_s))$ for $t=2,\ldots\ \infty$. Hence, the present-valued consumer welfare is $CW = \Sigma_{t=1,\infty} CS_t F_t$.[12]

We compute investors' present value of utility as the market value of their assets at $t=0$, and hence ΔIW is the capital gain or loss in aggregate land plus housing value induced by the (unanticipated) policy under consideration.[13]

Government welfare in year t is calculated as tax revenue from all sources less disbursements including the cost of a policy (PC_t) such as a housing allowance.

$$\begin{aligned} GW_t = {} & \Sigma_h \mu_{ht} y_{ht} + \Sigma_z \mu_t S_{zt}\{q_{z1t}(R_{zt} - c_{z1t}) - q_{z0t}c_{z0t}\} \\ & + \Sigma_z S_{zt} \Sigma_{x \in A(z)} [Q_{zxt}/(1+r_t)]\{[(V_{xt+1} - C_{zxt})/m_{zx} - (1 + r_t + \theta_{zt})V_{zt}]\mu_t \\ & + \theta_{zt}V_{zt}\} - (PC)_t. \end{aligned} \quad (11)$$

We assume that the government's discount rate is the gross-of-tax interest rate, the same as the rate used to discount consumer utility. Our justification for this is that the government distributes net tax revenue to households in lump-sum fashion, which does not alter their choices among submarkets since the utility function is linear in income.

In discussing the benefits of housing allowance programs, we will also make reference to a (net) benefit-cost ratio, B/C, which is calculated as the NPVB given by (9) divided by $\Sigma_t(PC)_t F_t$, the present value of the expenditure on the housing

[11]Note that μ_{ht} is the average income tax rate (on gross income) of a household of type h. This does not appear earlier in the article because it is constant across housing choices and, hence, has no effect on choice probabilities as long as utility is linear in income.

[12]An alternative assumption would be that consumers use their own rates of time preference in computing their own present value benefits. However, since our consumers have static expectations, such a calculation is not meaningful except only as a static measure of consumer welfare as anticipated by the consumers, not as the discounted value of their *actual* welfare.

[13]If the model was fully general equilibrium, households would own shares in housing and the distinction between households and investors would disappear. Our treatment can be interpreted as assuming that investors adjust their consumption in the first period by the full amount of the capital gain or loss induced by the policy.
Our treatment also assumes that the government does not tax windfall gains nor allows the deduction of windfall losses in computing the income tax. The assumption is immaterial to the computation of total welfare since the dollar gain to the government in the first period from taxing windfall gains is precisely offset by the dollar loss to investors.

allowance. The government expenditure program is desirable according to conventional cost-benefit criteria if its benefit-cost ratio, so defined, is positive.

3. Policy analysis

In all of our policy analyses, we compare the results of a base run with the results of a policy run. We assume that all policies are imposed at the beginning of 1970 and last forever. To truncate the model, we assume that values reach their stationary state levels at the beginning of 1980 and we report the discounted values (of consumer welfare, for example) for the stationary phase (years eleven to infinity).[14]

3.1. Income tax

We start out with a theoretical discussion of the effects of the income tax, and then we proceed to the policy simulation.

3.1.1. Theory

The centerpiece of the analysis of the income tax is a well-known result, due to Samuelson (1964), that an income tax on the stream of returns from an asset does not affect the asset's value if: i) true economic depreciation is deductible in the income tax, and ii) interest income is included in the income tax base so that the investor's discount rate is $r_t(1-\mu_t)$, the after-tax rate.

Under this income tax system, the income tax is said to be *neutral* with respect to investment. The proof of this is sketched in part I of the Appendix to Anas and Arnott (1995). In our model, this form of the income tax would be neutral with respect to investment if all costs, including idiosyncratic and systematic nonfinancial costs, were deductible in computing the income tax.[15] The income tax we treat—and the actual income tax—differ from the ideal type, however, in that nonfinancial costs are not deductible in computing the income tax. This causes the

[14]To permit replicability of our results we can provide authors with a full listing of our parameter values and data, upon request.

[15]There is another qualification: all transactions within a period (rent collections, tax payments etc.) should be made at the same point in time. The proof is available from the authors upon request. We assume, in contrast to the second qualification, that some transactions are made at the end of a period and others at the beginning. The non-neutrality this causes is of a trivial importance and is ignored in the subsequent discussion.

income tax to be non-neutral, and, as we shall see, the effect is quantitatively important.

Housing investment is a complex enterprise involving many non-financial costs. These include such things as dealing with tenants, housing contractors, real estate agents and lawyers, monitoring the condition of units and taking various risks which are not present in more liquid investments. The calibration experience of our model shows that the inclusion of nonfinancial costs plays an important role in generating conversion probabilities which are reasonable.

Table 2 shows the calibrated conversion probabilities for 1970, and Table 3 the associated calibrated systematic non-financial costs. Because for each bedroom size, one nonfinancial cost is arbitrary, the matrix of nonfinancial costs has been normalized so that the diagonal elements are zero and $D_{zz't} - D_{zzt}$, for z' different from z, are shown in the off-diagonal positions. Inspecting this matrix reveals the following pattern of systematic nonfinancial costs. For units with 0–1 bedrooms, upgrading entails moderate nonfinancial costs and downgrading small nonfinancial benefits (i.e. negative costs). For other types of units, both upgrading and downgrading involve moderate nonfinancial costs. Demolition of large (4+ bedrooms) housing units entails small non-financial costs, and of other units moderate nonfinancial benefits. Construction of smaller housing units entails large nonfinancial costs, of 3-bedroom units moderate nonfinancial costs, and of 4-bedroom units small nonfinancial benefits.

3.1.2. Simulation

The results of the simulation run for the income tax, compared to the base run which has no taxes, are given in the left-most columns of Tables 4–8. Consider first Table 4. We know that the changes relative to the base run derive from the non-deductibility of nonfinancial costs in computing the income tax. On this basis, we can tell a story that is broadly consistent with the results.

Let us turn first to the stationary state (years 11+ in Table 4). We know that the non-deductibility of positive nonfinancial costs reduces the value-to-rent ratio. That the value-to-rent ratio in years 11+ (from Table 4) is, on average, almost double that of the base run implies that activities with negative non-financial costs dominate in the housing market. From Table 3, we know that nonfinancial benefits come mainly from the construction of 4+ bedrooms and the demolition of smaller low-quality units. That the government does not tax the nonfinancial benefits, though it taxes income, encourages investors to switch from other assets to housing, which raises values. The extent to which the increase in the value-to-rent ratio is due to an increase in value, rather than a fall in rent, can be understood by examining the extreme cases. Suppose that values rise only a little and rents fall a lot. This implies a large increase in the supply of housing (which causes a large

Table 4
Percentage Changes in Housing Values, Stocks and Rents Relative to Base

BASE		NO TAXES												PROPERTY TAX ONLY			INCOME+PROPERTY TAX		
BD	YR	Income Tax Only			Property Tax Only			Income+Property Tax			Allowance (Medium)			Allowance (Medium)			Allowance (Medium)		
		Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3
VALUE																			
0–1	1	−4.45	10.25	5.33	−6.55	−5.26	−5.27	−10.47	4.29	−0.01	−5.41	3.58	−2.32	−5.18	4.17	−1.91	−3.33	5.47	0.40
2	1	31.35	27.55	27.24	−11.32	−10.16	−8.99	18.32	15.87	16.50	−1.84	3.11	−0.88	−1.79	3.89	−0.62	−0.87	4.32	0.52
3	1	19.27	12.05	10.96	−13.76	−13.44	−12.48	3.40	−3.30	−3.31	−0.26	−0.22	−0.16	−0.29	−0.24	−0.16	−1.30	−1.34	−1.18
4+	1	5.84	−3.25	2.08	−16.82	−16.67	−14.75	−10.15	−18.79	−11.89	−1.24	−1.19	−0.96	−0.71	−0.69	−0.49	−0.98	−0.93	−0.58
STOCK																			
0–1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4+	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RENT																			
0–1	1	145.39	88.17	83.42	0.00	0.00	0.00	145.40	88.18	83.43	−19.13	49.30	−6.11	−19.12	49.31	−6.10	−10.96	27.68	−4.77
2	1	110.50	84.80	70.86	0.00	0.00	0.00	110.51	84.81	70.86	−11.07	45.82	−2.70	−11.06	45.82	−2.70	−7.43	25.23	−2.46
3	1	78.53	58.44	60.5	90.00	0.00	0.00	78.53	58.45	60.59	−6.11	−3.31	−2.20	−6.10	−3.31	−2.19	−4.71	−2.93	−2.13
4+	1	53.99	40.64	44.22	0.00	0.00	0.00	53.99	40.65	44.22	−3.82	−2.21	−0.56	−3.81	−2.21	−0.56	−3.18	−2.09	−0.81
VALUE																			
0–1	5	−0.10	13.48	15.43	−2.96	−2.47	−2.19	−2.65	11.11	13.37	−3.24	−0.04	−0.85	−3.30	0.04	−0.85	−1.27	0.82	0.06
2	5	20.47	19.73	24.52	−6.66	−5.90	−4.86	13.54	13.68	19.35	−1.39	−0.86	−0.90	−1.50	−0.86	−0.93	−0.26	0.54	0.17
3	5	12.44	11.59	14.58	−9.72	−8.93	−7.91	1.90	1.90	5.94	−0.53	−0.49	−0.43	−0.71	−0.64	−0.56	−0.78	−0.71	−0.60
4+	5	−2.71	−1.89	6.32	−12.22	−11.14	−9.46	−14.06	−12.31	−2.62	−0.85	−0.78	−0.66	−0.65	−0.59	−0.49	−0.54	−0.43	−0.30

STOCK																			
0–1	5	−4.88	−18.68	−19.28	−0.02	−4.89	−7.28	−4.43	−21.38	−25.13	−6.47	18.73	−4.00	−6.48	18.99	−3.63	−7.42	21.09	−3.10
2	5	6.98	−3.55	−9.25	1.07	−0.48	−4.14	6.84	−4.97	−15.13	−5.22	8.78	−2.69	−5.23	8.86	−2.61	−5.58	10.74	−2.78
3	5	27.96	7.44	3.49	−0.33	−0.80	−1.40	27.89	6.90	1.49	−2.52	−1.50	−1.18	−2.32	−1.32	−0.99	−2.08	−0.86	−0.37
4+	5	37.48	13.25	8.06	1.01	0.15	−0.79	37.27	12.11	4.56	−0.35	−0.18	0.14	−0.81	−0.51	−0.09	−1.56	−0.87	−0.21
RENT																			
0–1	5	38.05	66.62	75.25	17.08	23.88	27.36	62.02	95.87	112.77	−6.76	0.86	−2.83	−6.05	0.75	−2.54	−0.95	2.65	0.33
2	5	9.33	25.12	44.42	10.54	12.76	17.00	26.46	44.47	71.43	−1.06	1.38	−0.38	−1.13	1.65	−0.24	0.78	3.70	1.75
3	5	−22.15	−6.48	1.43	8.17	9.42	10.96	−12.07	4.78	15.56	0.00	0.00	0.00	−0.27	−0.26	−0.24	−1.49	−1.22	−1.16
4+	5	−28.43	−13.82	−9.79	3.95	5.14	7.63	−21.74	−5.49	3.64	−1.55	−1.49	−1.53	−0.88	−0.84	−0.84	−0.93	−0.61	−0.52
VALUE																			
0–1	10	12.29	14.14	25.63	−0.89	−0.97	−0.67	10.60	12.69	24.40	−1.01	−0.08	−0.36	−1.00	−0.05	−0.34	−0.63	0.20	−0.05
2	10	18.02	16.90	25.56	−3.16	−2.74	−2.07	14.11	13.52	22.85	−0.55	−0.39	−0.34	−0.57	−0.41	−0.34	−0.27	0.06	−0.06
3	10	12.50	16.60	22.79	−6.33	−5.23	−4.28	5.40	10.70	17.90	−0.27	−0.22	−0.18	−0.30	−0.24	−0.20	−0.21	−0.16	−0.12
4+	10	−0.04	9.65	19.43	−8.17	−6.36	−5.02	−8.61	2.86	13.97	−0.26	−0.20	−0.16	−0.22	−0.17	−0.13	−0.18	−0.12	−0.08
STOCK																			
0–1	10	−7.04	−33.31	−23.30	0.32	0.72	−7.20	−6.48	−35.20	−32.25	−8.14	15.46	−6.24	−8.21	15.06	−5.86	−9.19	24.81	−3.79
2	10	20.09	3.05	−3.97	1.60	−0.58	−4.82	20.04	0.66	−13.17	−5.43	9.91	−2.37	−5.45	9.93	−2.00	−6.72	15.20	−2.55
3	10	58.35	16.68	−0.62	1.62	−0.85	−2.71	62.27	15.01	−4.97	−2.43	−1.40	−1.48	−2.33	−1.22	−1.19	−2.61	−1.10	−0.46
4+	10	113.52	43.01	17.82	3.37	0.51	−1.43	122.74	41.03	12.05	−0.25	−0.15	−0.12	−0.68	−0.44	−0.34	−2.16	−1.13	−0.42
RENT																			
0–1	10	−60.97	−47.73	−39.28	11.97	12.18	15.37	−51.36	−36.03	−22.42	−4.59	−0.85	−2.58	−4.07	−0.61	−2.06	−2.81	1.78	0.08
2	10	−61.40	−53.21	−42.36	9.53	10.23	12.18	−53.09	−43.91	−29.52	−2.97	−2.85	−2.81	−2.72	−2.66	−2.50	−1.80	0.32	−0.60
3	10	−63.78	−54.18	−43.13	7.06	8.70	10.53	−58.25	−46.55	−32.87	−1.63	−1.59	−1.61	−1.59	−1.52	−1.52	−3.25	−2.31	−1.79
4+	10	−66.72	−56.28	−48.65	3.50	5.49	7.97	−63.56	−50.78	−39.69	−1.38	−1.36	−1.47	−1.05	−1.03	−1.08	−2.08	−1.34	−1.08

VALUE																			
0–1	11+	24.26	22.06	33.47	−1.53	−1.32	−0.95	22.67	20.68	32.39	−0.32	0.04	−0.10	−0.33	0.04	−0.09	−0.46	0.09	−0.06
2	11+	26.76	24.02	31.72	−3.61	−3.05	−2.22	22.98	20.82	29.31	−0.09	0.02	−0.02	−0.10	0.02	−0.02	−0.17	0.06	−0.03
3	11+	20.79	23.60	28.15	−6.80	−5.38	−4.25	13.70	17.98	23.71	−0.01	0.00	0.00	−0.01	0.00	0.00	−0.03	−0.02	−0.01
4+	11+	8.40	17.34	24.99	−8.52	−6.23	−4.74	−0.44	10.85	20.04	−0.01	0.00	0.00	−0.01	0.00	0.00	−0.04	−0.03	−0.02
STOCK																			
0–1	11+	−23.59	−26.49	−18.41	0.83	−1.92	−8.17	−22.71	−27.23	−28.63	−11.79	25.60	−4.96	−11.75	26.11	−4.21	−9.76	30.21	−2.44
2	11+	17.51	7.78	5.93	1.47	−1.04	−5.39	17.92	5.28	−6.83	−6.14	9.79	−2.89	−6.16	9.82	−2.45	−7.08	17.01	−2.53
3	11+	49.95	19.05	12.42	2.84	−0.46	−2.39	55.50	16.88	5.63	−2.11	−0.98	−0.67	−2.20	−0.93	−0.56	−4.94	−2.23	−1.21
4+	11+	76.45	34.26	26.86	2.78	−0.79	−2.72	88.83	30.88	17.34	−0.61	−0.31	−0.14	−0.65	−0.28	−0.10	−3.46	−1.56	−0.63
RENT																			
0–1	11+	−37.47	−28.90	−21.11	11.96	12.11	15.65	−19.97	−12.05	3.17	−0.35	0.05	−0.15	−0.35	0.05	−0.14	−1.03	0.24	−0.23
2	11+	−46.84	−39.96	−31.66	8.38	9.14	11.34	−33.86	−26.57	−13.62	−0.08	0.02	−0.03	−0.09	0.02	−0.02	−0.38	0.14	−0.07
3	11+	−52.29	−44.35	−37.97	5.12	7.21	8.73	−44.21	−33.58	−24.51	−0.01	0.00	0.00	−0.01	0.00	0.00	−0.05	−0.04	−0.02
4+	11+	−54.01	−45.88	−44.81	3.30	6.01	8.35	−49.59	−37.40	−32.15	0.00	0.00	0.00	0.00	0.00	0.00	−0.08	−0.05	−0.04

BD: bedroom size; YR: year; Q1, Q2, Q3: quality levels (low, medium, high).

Table 5
Percentage Changes in Average Annual Conversion Rates (1970–1980)

BASE	NO TAXES									PROPERTY TAX ONLY		INCOME+PROPERTY TAX	
		Income Tax Only		Property Tax Only		Income+Property Tax		Allowance (Med)		Allowance (Med)		Allowance (Med)	
BDRM	BASE # (%)	AFTER	%CHNG	AFTER	%CHNG	AFTER	%CHNG	AFTER	%CHNG	AFTER	%CHNG	AFTER	%CHNG
UPGRADE													
0-1	0.13	0.29	121.1	0.12	−8.3	0.26	95.5	0.48	260.2	0.47	286.9	0.61	133.8
2	0.69	0.23	−66.3	0.62	−10.3	0.20	−71.7	0.88	27.9	0.81	30.6	0.27	39.5
3	12.41	0.19	−98.5	12.36	−0.4	0.16	−98.7	12.39	−0.2	12.34	−0.2	0.16	0.6
4+	4.17	0.37	−91.2	4.13	−0.9	0.30	−92.8	4.17	0.0	4.12	−0.4	0.32	8.0
DOWNGRADE													
0-1	0.19	0.29	48.4	0.21	7.8	0.30	55.2	0.06	−70.3	0.06	−69.6	0.24	−20.8
2	0.19	1.08	464.4	0.21	8.9	1.13	491.1	0.19	−3.1	0.20	−5.8	0.87	−22.6
3	10.69	1.22	−88.6	10.75	0.5	1.34	−87.4	10.75	0.6	10.80	0.5	1.34	−0.6
4+	2.11	0.55	−74.1	2.14	1.3	0.64	−69.5	2.11	0.0	2.14	0.0	0.62	−4.5
DEMOLITION													
0-1	0.00	0.27	*	0.00	*	0.28	*	0.00	*	0.00	*	0.42	49.5
2	0.00	0.03	*	0.00	*	0.08	*	0.00	*	0.00	*	0.09	17.7
3	0.63	0.01	−98.6	0.70	11.5	0.01	−98.1	0.77	22.4	0.82	17.6	0.08	591.7
4+	0.00	0.01	*	0.01	*	0.01	*	0.00	*	0.04	333.3	0.02	38.5
CONSTRUCTION													
0-1	2.29	0.81	−64.7	2.33	1.6	0.75	−67.1	2.47	7.6	2.49	6.8	1.12	47.9
2	0.01	1.27	15750.0	0.01	0.0	1.15	14262.5	0.01	−25.0	0.01	−25.0	1.20	4.0
3	0.01	1.33	11963.6	0.01	9.1	1.24	11209.1	0.01	−9.1	0.01	−8.3	1.19	−4.5
4+	0.12	3.37	2804.3	0.10	−12.1	3.18	2644.0	0.10	−11.2	0.10	−6.9	3.10	−2.6

*Large percentage changes.
#Average annual conversion rate in BASE run.

Table 6
Aggregated Policy Benefits (MIL. 1970 $)

BASE	NO TAXES				PROPERTY TAX ONLY	INCOME+PROPERTY TAX
POLICY	Income Tax Only	Property Tax Only	Income+Property Tax	Allowance (Med)	Allowance (Med)	Allowance (Med)
CONSUMERS[1]	−153616.3	−9105.5	−166213.7	1956.3	1876.7	1756.4
INVESTORS[2]	−5746.1	−13672.7	−19246.0	−269.8	−144.4	−133.7
GOVERNMENT[3]	147811.8	22741.5	174797.4	−2092.4	−2102.2	−1540.2
NPVB[4]	−11550.6	−36.8	−10662.3	−405.9	−370.0	82.5
POL.BUDGET[5]	-	-	-	2092.4	2092.4	2092.4

[1] Present value of annual changes in aggregate consumer surplus.
[2] Aggregate change in initial asset values of housing and land.
[3] Present value of annual changes in government revenues.
[4] Net present value benefit: sum of consumer, investor and government benefits.
[5] Government expenditure on housing allowances.

Table 7
Aggregated Policy Benefits (MIL. 1970 $)

BASE	NO TAXES						INCOME+PROPERTY TAX					
POLICY	Allowance (low)		Allowance (med.)		Allowance (high)		Allowance (low)		Allowance (med.)		Allowance (high)	
	BENEFIT	B/C[6]	BENEFIT	B/C[6]	BENEFIT	B/C[6]	BENEFIT	B/C[6]	BENEFIT	B/C[6]	BENEFIT	B/C[6]
CONSUMERS[1]	1129.1	1.08	1956.3	0.94	2665.6	0.85	1005.1	0.96	1756.4	0.84	2414.0	0.77
INVESTORS[2]	−217.4	−0.21	−269.8	−0.13	−262.6	−0.08	−111.2	−0.11	−133.7	−0.06	−126.1	−0.04
GOVERNMENT[3]	−1046.2	−1.00	−2092.4	−1.00	−3138.6	−1.00	−731.5	−0.70	−1540.2	−0.74	−2382.6	−0.76
NPVB[4]	−134.5	−0.13	−405.9	−0.19	−735.6	−0.23	162.4	0.16	82.5	0.04	−94.7	−0.03
POL.BUDGET[5]	1046.2		2092.4		3138.6		1046.2		2092.4		3138.6	

[1] Present value of annual changes in aggregate consumer surplus.
[2] Aggregate change in initial asset values of housing and land.
[3] Present value of annual changes in government revenues.
[4] Net present value benefit: sum of consumer, investor and government benefits.
[5] Government expenditure on housing allowances.
[6] B/C is the benefit cost ratio defined as NPVB/POL.BUDGET.

Table 8
Consumer Surplus Changes per Household by Income Group ($)

BASE		NO TAXES									PROPERTY TAX ONLY		INCOME+PROPERTY TAX	
POLICY		BASE*	Income Tax Only		Property Tax Only		Income+Property Tax		Allowance (Med.)		Allowance (Med.)		Allowance (Med.)	
YR	IG		CHANGE	%CHANGE	CHANGE	%CHANGE	CHANGE	%CHANGE	CHANGE	%CHANGE	CHANGE	%CHANGE	CHANGE	%CHANGE
1	1	21420.2	−1209.5	−5.65	0.0	0.00	−1209.6	−5.65	231.2	1.10	231.1	1.08	257.3	1.31
1	2	50564.6	−2159.1	−4.27	0.0	0.00	−2159.2	−4.27	−28.3	−0.10	−28.3	−0.06	−5.1	−0.01
1	3	129069.4	−3269.6	−2.53	0.0	0.00	−3269.6	−2.53	−37.5	−0.01	−37.6	−0.03	−19.1	−0.00
1	4	216300.3	−4622.2	−2.14	0.0	0.00	−4622.3	−2.14	−34.5	−0.01	−34.6	−0.02	−18.1	−0.01
1	5	314079.9	−10138.2	−3.23	0.0	0.00	−10138.3	−3.23	−18.9	−0.00	−19.0	−0.01	−3.2	−0.01
5	1	21262.0	−797.9	−3.75	−202.1	−0.95	−1080.1	−5.08	305.0	1.40	305.0	1.45	252.9	1.32
5	2	52412.1	−2307.0	−4.40	−211.4	−0.40	−2602.1	−4.96	20.0	0.01	21.3	0.04	−7.5	−0.01
5	3	132715.2	−3810.9	−2.87	−227.7	−0.17	−4126.0	−3.11	11.9	0.01	12.9	0.01	−1.9	−0.01
5	4	223554.0	−5682.6	−2.54	−242.3	−0.11	−6017.7	−2.69	11.4	0.01	11.1	0.01	6.0	0.01
5	5	325953.8	−13852.5	−4.25	−254.2	−0.08	−14215.2	−4.36	18.8	0.00	14.7	0.00	13.4	0.01
10	1	18292.4	2408.2	13.17	−578.0	−3.16	1911.1	10.45	461.8	2.50	460.1	2.60	321.2	1.60
10	2	52891.5	470.7	0.89	−594.8	−1.12	−55.4	−0.10	147.9	0.31	147.0	0.28	46.4	0.11
10	3	136215.6	−2348.3	−1.72	−624.6	−0.46	−2913.8	−2.14	143.1	0.10	142.5	0.11	56.4	0.01
10	4	232337.7	−6338.0	−2.73	−653.5	−0.28	−6944.6	−2.99	139.4	0.11	137.5	0.06	65.5	0.01
10	5	342147.6	−20168.8	−5.89	−687.6	−0.20	−20836.2	−6.09	138.4	0.00	131.3	0.04	70.2	0.01
11+	1	19934.0	876.5	4.40	−392.2	−1.97	288.3	1.45	304.8	1.50	303.5	1.55	289.5	1.42
11+	2	55328.3	−1133.6	−2.05	−416.3	−0.75	−1762.2	−3.19	3.1	0.01	3.6	0.00	6.3	0.01
11+	3	139350.4	−4103.7	−2.94	−453.5	−0.33	−4791.1	−3.44	1.6	0.01	1.8	0.00	3.8	0.01
11+	4	236627.3	−10119.8	−4.28	−495.4	−0.21	−10871.2	−4.59	0.9	0.01	1.1	0.00	2.80	0.01
11+	5	348148.9	−25106.8	−7.21	−562.2	−0.16	−25959.3	−7.46	0.6	0.01	0.6	0.00	2.4	0.01

* BASE consumer surplus level.

fall in rents). The elasticity of supply is, in turn, larger the lower the variability of idiosyncratic costs.[16]

Let us now turn to the instantaneous effect of the income tax in year one (see Table 4). The tax increases housing values, on average, but increases rent proportionally considerably more. The reason why rents increase so sharply can be seen from (3). The imposition of the income tax significantly increases the incentive to hold housing off the market—we shall explain why shortly—which, with the low estimated short-run supply elasticity, implies a substantial increase in rent to reequilibrate the market. Since, in our model, there are no systematic nonfinancial costs associated with occupancy or vacancy, the incentive to hold housing off the market comes from idiosyncratic nonfinancial costs. In the base, no-tax equilibrium, far more than half of the landlords rent out their units. This means that the landlord who is indifferent between renting and holding his unit vacant incurs a substantial idiosyncratic cost associated with renting. After the imposition of the income tax, the landlord who was previously marginal has an incentive to hold his unit off the market. Note also that housing values in year one change by smaller percentages than do rents. This is because values reflect not only current but also future rent changes, and future rent increases are smaller than initial ones and rent changes eventually become negative.

The transition path from the temporary equilibrium immediately after the income tax is imposed up to period 11, when housing assets reach their new stationary state values, unfolds as follows. The initial rise in rents is largest in smaller and lower-quality units. In year one, this causes households to want to shift towards larger and higher-quality units. The stock expands accordingly. Table 5 shows the changes in the rates of conversions induced by the income tax. These rate changes support the accumulation of lower quality but larger housing units. For 0–1 bedroom units, the income tax speeds up demolition and slows down construction. For 3-bedroom units, construction is speeded up significantly relative to demolition. The tax also speeds up upgrading of 0–1 bedrooms but slows down downgrading of 3 and 4 bedrooms and speeds up downgrading of 0–2 bedrooms.

By year 11+, the stock configuration has changed in favor of larger and lower-quality units. The stock of 1-bedrooms has decreased drastically to make room for increased construction of larger units. The largest percentage drops in rent occur for these larger and lower-quality units.

It is worth repeating and emphasizing the central point. All the action generated by the income tax derives from nonfinancial costs. That the income tax has a strong effect implies that the nonfinancial costs obtained through calibration of the

[16]To seek further confirmation of the effect of nonfinancial costs we also simulated the model assuming that systematic nonfinancial benefits are taxed and systematic nonfinancial costs are tax deducted. Although the conversion probabilities became highly unrealistic, the year 11+ value-to-rent ratio was only a few percentage points different from the corresponding value-to-rent ratio for the no-tax base case.

model are substantial, which is supported by Table 3. This suggests one of two hypotheses. The first is that nonfinancial costs really are significant in housing. If true, this implies that analysis of the impact of taxation on housing which ignores nonfinancial costs may be seriously misleading. The second alternative is that our model is misspecified. Recall that we estimated the nonfinancial costs so as to get a reasonable conversion matrix. Without these costs, the conversion probabilities turn out to be substantially higher than the probabilities of keeping housing unchanged in quality. Then it is possible that nonfinancial costs may be capturing omissions in our model specification.

Tables 6–8 summarize the results of the welfare analysis. The tax decreases total consumer surplus by about 153 billion dollars in 1970 present value terms and decreases initial asset prices by 5.7 billion. However, government revenues increase by 148 billion and the net deadweight loss is 11.5 billion. From Table 8, consumer surplus changes are negative for each income group in years one and five but are positive for the poorest income group in years 10 and 11+. The reason for the negative change in consumer surplus in the face of ubiquitously lower rents in years 10 and 11+ is that the income tax paid by the consumer more than offsets the effect of the lower rents. Only income group one has a significant positive consumer surplus in years 10 and 11+, which reflects the fact that this group, which has the lowest average tax rate, benefits more from the lowered rents than it loses from the introduction of the tax.

3.2. Property tax

In this subsection, we consider the effects of the property tax relative to a base case with no taxes in place.

3.2.1. Theory

In Anas and Arnott (1993a), we presented a stripped-down version of our model, with only rental housing that is fully occupied, only one housing type and only one household group, and we investigated analytically some of the comparative static properties of its stationary state. Our focus in that paper was on the effects of changes in construction and demolition costs on the market equilibrium. In part II of the Appendix to Anas and Arnott (1995), we undertook a comparative static analysis of the stripped-down model with respect to the property tax rate.

Applied to the property tax, the stripped-down model predicts that a rise in the property tax rate reduces land and housing value, speeds up demolition and slows down construction, which together reduce the stock of housing, causing rents to rise. The intuition is as follows. Property value is the expected discounted sum of net (of costs) rent. Thus, rent received this period is taxed only this period, whereas rent received next period is taxed both this period and next since it contributes to values in both periods. Hence, the tax is reduced by front-loading net rents, which is achieved by spending less on maintenance. We should therefore expect the property tax to speed up downgrading and demolition and to slow down upgrading. And since the property tax lowers values, it should discourage construction. The increase in demolition, combined with the decrease in construction, reduces the stock of housing, which induces an increase in rent. While the effects of the property tax are considerably more complicated when there are multiple housing types, the same broad intuition applies.

3.2.2. Simulation

The results of the simulation are shown in the second column of Tables 4–8. The level of the property tax in the Chicago MSA in 1980 was approximately 1.5% of values and this ratio varied very slightly among the twelve submarkets represented in our model and in the period 1970–1980. The results are consistent with the stripped-down model, with only minor qualifications. Turn first to the terminal period (years 11+ in Table 4). The property tax causes the value of all types of housing to fall and all rents to rise. It also causes the aggregate stock of housing to fall. The property tax also affects the quality composition of the housing stock. This was not captured by our theoretical discussion which was based on the stripped-down version and considered only one quality type. The major effect comes through the demand side; the general increase in rent causes a substitution towards larger and lower-quality housing. The net effect of the aggregate and compositional changes is that the stock of low quality housing increases while that of middle and high-quality housing decreases and the stock of larger, lower-quality housing increases the most.

Turn now to the instantaneous effect of the property tax (year 1, Table 4). It does not affect the instantaneous stock, the demand function, or the form of the occupancy probability function, nor therefore, the instantaneous rent. It does, however, reduce housing values instantaneously, and the reduction is proportionally larger for larger and lower-quality housing. In response to the fall in housing values, the quality-adjusted stock of housing gradually falls, with the result that rents rise and the proportional fall in values is reduced over time.

Table 5 contains few surprises. The property tax discourages "maintenance" and causes a demand shift towards lower-quality housing. As a result, the proportion of housing units that are upgraded falls, and that are downgraded or demolished rises. The effect on average construction is ambiguous because of two offsetting effects. On the one hand, the property tax slows down the rate at which vacant land is built on; on the other hand, the stock of vacant land rises. Construction flow, which is the product of the stock of vacant land and the rate at which it is built on, may therefore rise or fall. There is, as well, a compositional effect. On balance, the construction rate for the lower-quality housing rises, while that for the top-quality housing falls.

Table 6 indicates that the property tax hurts both consumers and investors and, of course, generates revenue. The extent to which the tax is shifted from investors to consumers depends on the elasticities of the demand for housing and the supply of housing. The most striking feature of the table is that the proportional deadweight loss due to the property tax, the ratio of the fall in aggregate benefits to the tax revenue raised is only about 0.16%.

To put this into perspective, consider the simple partial equilibrium diagrammatic analysis of the deadweight loss due to a tax on rent, when both the housing demand and supply curves are linear. Let θ' denote the effective tax rate on rent implied by the property tax on values. Then:

$$\frac{\text{Deadweight Loss}}{\text{Tax Revenue}} = (1/2)\theta' \left(\frac{1}{|\epsilon_D|} + \frac{1}{|\epsilon_S|} \right)^{-1}.$$

In our model, the average rent-to-value ratio is about 0.08 in 1970 and falls to about 0.065 by 1980 due to the rise in values relative to rents during the decade. Since the tax rate on housing value is about 0.015, the implied tax rate on rent is about 0.21. From Table 1, we know that our demand elasticity is on average about −0.55. It is hard, in our model, to identify what corresponds to a conventional supply elasticity. But to obtain a proportional deadweight loss of 0.16% would require a supply elasticity of 0.0156, which seems much too low in light of the substantial stock adjustments observed in the simulations. This suggests that tax analysis which provides an aggregative treatment of the housing market may be quite misleading, and that simulation models are justified to account for the compositional complexity of the housing market.[17]

Finally, the percentage fall in consumer surplus due to the property tax is largest for low income households and decreases with income because, first, the percentage rent increase is largest for smaller units which are occupied disproportionately by the poor, and second the poor spend a larger proportion of their income on rent than do the rich.

By and large then, the effects of the property tax produced by our simulation model are readily explainable.

3.3. Housing allowances

In this subsection, we consider the effects of housing allowances relative to a base case with no taxes. To our knowledge, there is no analysis in the literature of the effects of housing allowances in models of the housing market with land, with the exception of applications of the NBER and the Urban Institute models cited in the literature. As explained earlier, these models focused on the distributional

[17] We also calculated the deadweight loss of the property tax by assuming a hypothetical property tax rate of 2.4% of value (one percentage point higher than the observed level). In this case, government revenue from the tax falls to 12.7 billion and the present value deadweight loss rises to 58.9 million. The ratio of the deadweight loss to tax revenue rises from 0.0016 (when the tax rate is 1.4%) to 0.0046 when the tax rate is 2.4%.

effects of the allowances but not on their potential effects in improving efficiency when other taxes were present.

Sweeney-like models without land developed by Ohls (1975), Braid (1986) have been used to analyze the effects of income subsidies (although Ohls focuses mostly on construction subsidies). In Braid (1986), the effect of an income subsidy (as opposed to a targeted allowance) to low income consumers is treated within a two-income-group, Sweeney-like theoretical model without any other taxes. Braid's model does not incorporate land but allows construction to occur at endogenously determined quality levels. His model bears some similarity to ours, because in our model construction can occur at any quality level. Braid shows that the income subsidy to low-income renters has an ambiguous effect on the richer group's welfare.

3.3.1. Theory

As shown in part III of the Appendix to Anas and Arnott (1995), the stripped-down model of Anas and Arnott (1993a) obtains the following results from a housing allowance. The housing allowance increases the profitability of renting housing, which causes land and housing values to increase. As well, the subsidy stimulates construction and discourages demolition, with the result that the stock of housing rises and the stock of vacant land falls. The increase in the stock of housing causes the consumer rent on housing to fall, but the producer rent on housing rises. In the simulation model, we should expect to see a mix of these effects with those that derive from substitution towards those types of housing for which allowances are available.

3.3.2. Simulation

We consider a housing allowance program designed to assist low income households by helping them improve their housing consumption. More specifically, an exogenous budget is specified with the funds being divided equally among those households in the lowest income group which, in the post-subsidy equilibrium, reside in housing of quality two in the 0–1 and 2-bedroom size categories. Since most of these targeted households reside in 0–1 bedrooms and quality-one units in the pre-tax equilibrium, the subsidy is designed to improve the housing consumption of low-income households by increasing the proportion of their members who move up in quality and/or bedrooms. The aggregate allowance budget is deducted from government revenues. The allowance is assumed to be non-taxable to the recipients.

We treated three budget levels for the allowance: 0.5% (low), 1.0% (medium) and 1.5% (high) of the aggregate income of the richest group in each year. The 1.0% (medium) case results are included in Tables 4–8.

Broadly speaking, the simulation results are consistent with the comparative–static properties of the stripped-down model. In particular, values, stocks and rents of the targeted housing move in the direction predicted by the theory. For most non-targeted housing types, however, the substitution effect towards targeted housing is sufficiently strong that their values, stocks and rents tend to fall.

Consider first the terminal period. What is particularly remarkable in Table 4 is that the allowance program has a substantial effect on the targeted housing stock but relatively little effect on housing rents and values. Since there is land in the model, this is not due to a very elastic long-run supply of housing—a feature of non-spatial models. The explanation is that the stimulative effect of the housing allowance program on values and rents is largely neutralized by substitution away from non-targeted housing. The channels through which the substitution towards targeted housing occurs are suggested by Table 5. Low-quality, 1- and 2-bedroom housing units are upgraded at a considerably faster rate. Also, the rate at which 3-bedroom units are demolished increases, and the construction rate of 1-bedroom units increases while that of other-sized units decreases.[18]

Consider next the immediate impact (in year one) of the housing allowance program from Table 4. Since there is no stock adjustment in period one, the change in rents reflects purely demand effects, and the effects are substantial. The change in values are more modest since they capture future supply adjustment.

The characteristics of the path of adjustment merit comment. First, the stock adjustment is rapid—about two-thirds of the total stock adjustment occurs within five years. Second, the results for year ten are puzzling since both rents and values for targeted housing have fallen relative to the base run. Perhaps this is evidence of overshooting; perhaps it is an artificial phenomenon created by the truncation procedure which forces convergence to stationarity in period 11.

Turn now to Table 6. As expected, the allowance program helps consumers in the aggregate, but contrary to conventional wisdom hurts investors in the aggregate. The conventional wisdom is that, because of the inelasticity of housing supply, a substantial part of the benefits from a housing allowance accrues to investors. The effect is present in the targeted submarkets. However, the conventional wisdom fails to take into account the substitution effects induced by a targeted housing allowance program. In the simulations, as a result of the substitution effects, the increase in the aggregate value of the targeted housing is less in absolute value than the fall in the value of non-targeted housing.[19]

[18]The fall in the construction rate of two-bedroom units is unexpected. Recall that both one- and two-bedroom units are subsidized. Presumably, the substitution towards the construction of one-bedroom units dominates the substitution towards the construction of two-bedroom units. The opposite might have been observed if, say, the second-lowest income group was subsidized. That group would have higher demand for two- rather than for one-bedroom units while the lowest-income group has a higher demand for one-bedroom units.

[19]The conventional wisdom is supported in the various applications of the NBER and the Urban Institute models to the analysis of the effects of allowances. See, for example, Kain et al. (1976), deLeeuw and Struyk (1977), Carlton and Ferreira (1977), Vanski and Ozanne (1978). However, in Anas and Arnott (1994) we reported simulations for Chicago, Houston, Pittsburgh and San Diego showing that housing allowances can hurt investors on the aggregate and can have efficiency improving effects when other taxes are present.

The allowance program is quite inefficient. Compare the allowance program with the property tax (different columns in Table 6). Even though the absolute size of the government budget is only about one-tenth as high with the allowance program as with the property tax, the deadweight loss is about eleven times larger.

Table 8 indicates that, even though the housing allowance program scores poorly on efficiency grounds, it is well-targeted. The lion's share of the benefits go to income group 1, the targeted group, and other income groups' welfare is little affected by the program.

3.4. Income tax and property tax

This subsection and the next two consider combined policies. Recall that the effects of the income tax depend on the structure of systematic and idiosyncratic nonfinancial costs, and that the effects of the property tax, as predicted by the stripped-down theoretical model, are to reduce land and housing values and the stock of housing and to raise rents. It is then a priori unclear whether the property tax will augment or mitigate the distortions introduced by the income tax. Table 4 shows that the effects of the two taxes on housing values, rents and stock appear, on average, to be partially offsetting. This is supported by Table 6, which shows that, with the income tax in place, introduction of the property tax reduces overall deadweight loss. We have already cautioned against attaching too much empirical significance to the structure of nonfinancial costs produced by our calibration. Accordingly, we caution against interpreting the simulation results as demonstrating that the property tax is welfare-improving when an income tax is present. The runs do, however, indicate that this is a possibility. And that possibility illustrates an important general principle—that policies should be analyzed with other policies in place rather than in isolation. This principle is widely recognized in tax policy analysis but tends to be overlooked in housing policy analysis.

3.5. Property tax and housing allowances

This pairing of policies is of special interest since the stripped-down theoretical model predicts that the two policies have offsetting effects on housing values, consumer rents, and stocks. The simulation model is considerably more complex, incorporating substitution effects between different types of housing. Are the predictions of the theoretical model borne out in the simulation model? We should not expect the housing allowance introduced in the simulation model to be as offsetting to the property tax as the allowance in the stripped-down theoretical model would be, because in that case the allowance is across-the-board whereas in the simulation model it is targeted to a specific income group and specific submarkets.

The tables include a column in which the housing allowance is introduced when the property tax is the only tax present and changes are calculated relative to that base. Consider first the terminal period from Table 4. The most striking feature of the comparison is the similarity of the proportional effects of the housing allowance program on housing values, stocks and rents when the property tax is in place and when it is not.

An interesting feature of this case is the change in aggregate policy benefits shown in Table 6. The deadweight loss with both policies in place is less than the sum of the deadweight losses from each policy in isolation; that is the deadweight losses are subadditive.

3.6. Income tax, property tax and housing allowance

Finally, we report on the effects of introducing a housing allowance program when both the income tax and the property tax are present. The qualitative effects of the housing allowance are the same as when only the property tax or neither tax is present, and the quantitative effects are similar. The most interesting effect is that when the subsidy rates are set at a low or medium level, the housing allowance program reduces the overall deadweight loss, as seen from Table 7. This result is particularly striking since the housing allowance on its own was quite distortionary. The results of Section 3.3 indicated that, when introduced alone, the housing allowance program scores well on target efficiency and equity grounds but not on general efficiency grounds. But with the income and property taxes present, the housing allowance program scores well in all these respects. Thus, a policy evaluation of the housing allowance program would judge it considerably more favorably when account is taken of the presence of income and property taxation. This underscores the potential importance of analyzing housing programs with the existing tax system and other housing programs in place rather than in isolation.

4. Concluding remarks

Simulation models are subject to several pitfalls. They are potentially a lazy substitute for theory; they can give an illusion of precision and their output can be incomprehensible. But good simulation models which are solidly grounded in theory, go beyond the limits of analytical tractability, and are carefully estimated, are potentially of considerable value. They allow for policy analysis that is as sophisticated as possible, given the current state of theory. Also, the output of a good simulation should uncover effects which have not previously been identified and which prompt further theoretical investigation. As well, simulation modeling uncovers areas of received theory which are in need of further refinement. We believe that this paper has illustrated these benefits of simulation modeling.

In this paper, we applied our dynamic simulation model of the Chicago housing market to examine the effects of an income tax, a property tax, and a targeted housing allowance program. The model is internally consistent and solidly grounded in conventional microeconomic theory and provides a sophisticated treatment of supply-side dynamics. As well, by incorporating idiosyncratic demand and idiosyncratic supply, the model accommodates the range of behavior one observes among economic agents who are descriptively identical.

On the one hand, we should not make exaggerated claims for the accuracy of our forecasts. Our treatment of the household sector ignores intertemporal aspects of households' budget allocations, moving costs and tenure choices. On the other hand, we should not be excessively apologetic. Policy analysis should be based on forecasts, even though they are imperfect. And given the current state of housing economic theory, our forecasts are probably as accurate as those of any other single policy evaluation model. Thus, the numbers generated in the simulations should be taken seriously, but also with a healthy dose of scepticism.

In future work, we hope to enrich the model to include life-cycle consumption decisions, realistic demography, moving costs, imperfect competition, alternative expectational hypotheses, imperfect capital (including mortgage) markets with endogenous default and a richer spatial structure with neighborhood effects. We also hope to obtain data which will permit more persuasive calibration of the housing conversion technology, and to develop an improved truncation procedure, based on Mercenier and Michel (1994). These extensions will no doubt uncover new effects and cause a reevaluation of the effects of tax policy and housing programs on the housing market.

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References

Anas, A. and R.J. Arnott, 1991, Dynamic Housing Market Equilibrium with Taste Heterogeneity, Idiosyncratic Perfect Foresight and Stock Conversions, Journal of Housing Economics 1, 2–32.

Anas, A. and R.J. Arnott, 1993a, Technological Progress in a Model of the Housing-Land Cycle, Journal of Urban Economics 34, 186–206.

Anas, A. and R.J. Arnott, 1993b, Development and Testing of the Chicago Prototype Housing Market Model, Journal of Housing Research 4, 73–130.

Anas, A. and R.J. Arnott, 1993c, A Fall in Construction Costs Can Raise Housing Rents, Economics Letters 41, 221–224.

Anas, A. and R.J. Arnott, 1994, The Chicago Prototype Housing Market Model with Tenure Choice and Its Policy Applications, Journal of Housing Research 5, 23–90.

Anas, A. and R.J. Arnott, 1995, Taxes and Allowances in a Dynamic Equilibrium Model of Urban Housing with a Size–Quality Hierarchy, Working Paper, Department of Economics, Boston College.

Anas, A. and C. Chu, 1984, Discrete Choice Models and the Housing Price and Travel to Work Elasticities of Location Demand, Journal of Urban Economics 15, 107–123.

Berkovec, J. and D. Fullerton, 1992, A General Equilibrium Model of Housing, Taxes and Portfolio Choices, Journal of Political Economy 100, 390–429.

Braid, R., 1986, The Comparative Statics of a Filtering Model of Housing with Two Income Groups, Regional Science and Urban Economics 16, 437–448.

Carlton, D. and J. Ferreira, 1977, Selecting Subsidy Strategies for Housing Allowance Programs, Journal of Urban Economics 4, 221–247.

deLeeuw, F. and R.J. Struyk, 1977, Analyzing Housing Policies with the Urban Institute Housing Market Model, in: G.K. Ingram, ed., Residential Location and Urban Housing Markets (National Bureau of Economic Research, Cambridge MA) Chapter 7.

Fullerton, D. and R. Gordon, 1983, A Reexamination of Tax Distortions in General Equilibrium Models, in: M. Feldstein, ed., Behavioral Simulation Models in Tax Policy Analysis (University of Chicago Press, Chicago).

Hanushek, E. and J.M. Quigley, 1981, Consumption Aspects, in: K.L. Bradbury and A. Downs, eds., Do Housing Allowances Work? (Brookings Institution, Washington DC) 185–240.

Kain, J.F., W.C. Apgar Jr. and J.R. Ginn, 1976, Simulation of the Market Effects of Housing Allowances, Vol. I, Description of the NBER Urban Simulation Model (Harvard University, Cambridge, MA).

Lerman, S.R., 1977, Location, Housing and Automobile Ownership and Mode to Work: A Joint Choice Model, Transporation Research Record, 610.

Mayo, S.K., 1981, Theory and Estimation in the Economics of Housing Demand, Journal of Urban Economics 10, 95–116.

Mercenier, J. and P. Michel, 1994, Discrete-Time Finite Horizon Approximation of Infinite Horizon Optimization Problems with Steady-State Invariance, Econometrica 62, 635–656.

Ohls, J.C., 1975, Public Policy Toward Low-Income Housing and Filtering in Housing Markets, Journal of Urban Economics 2, 144–171.

Poterba, J., 1984, Tax Subsidies to Owner-Occupied Housing: An Asset–Market Approach, Quarterly Journal of Economics 98, 729–752.

Rosen, H.S., 1985, Housing Subsidies: Effects on Housing Decisions, Efficiency and Equity, in: A. Auerbach and M. Feldstein, eds., Handbook of Public Economics, Vol. 1 (North-Holland Amsterdam).

Samuelson, P., 1964, Tax Deductibility of Economic Depreciation and Invariant Valuation, Journal of Political Economy 72, 604–606.

Small, K.A. and H.S. Rosen, 1981, Applied Welfare Economics with Discrete Choice Models, Econometrica 49, 105–130.

Smith, B.A., 1976, The Supply of Urban Housing, Quarterly Journal of Economics 90, 389–405.

Sweeney, J.L., 1974a, Quality, Commodity Hierarchies and Housing Markets, Econometrica 49, 147–167.

Sweeney, J.L., 1974b, A Commodity Hierarchy Model of the Rental Housing Market, Journal of Urban Economics 1, 288–323.

Vanski, J. and L. Ozanne, 1978, Simulating the Housing Allowance Program in Green Bay and South Bend: A Comparison of the Urban Institute Housing Model and the Supply Experiment (The Urban Institute, Washington DC).