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ABSTRACT

It is often argued that low tax rates on owner-occupied housing divert investment from equipment. This paper demonstrates that if people are heterogeneous in their propensity to save, and if there are constraints on borrowing, favorable tax treatment of owner-occupied housing up to a certain value increases equipment investment. This is because low housing taxes encourage renters to become owner-occupiers, and this leads existing owner-occupiers to shift their portfolio of other assets from rental housing to equipment.

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1 Introduction

Many economists believe that investment in equipment and research and development is less than socially optimal, either because there are positive externalities to such investment (Romer [1986] or DeLong and Summers [1989]), or because this investment is discouraged by capital income taxation (Feldstein [1987]). Many of those who feel that there is too little equipment and R&D investment oppose favorable tax treatment of owner-occupied housing because they believe that it diverts investment towards housing (Feldstein [1987], Kay and King [1990]).

In this paper we will accept for the sake of argument that increased investment in equipment and research and development is desirable. We contend, however, that low taxation of owner-occupied housing up to some threshold amount will not depress but actually raise equipment investment, if taxpayers have heterogeneous discount rates and face credit constraints. The intuition is straightforward. As is conventionally argued, lower housing taxes will cause people to move assets from equipment to housing. If people are homogeneous or if there are no binding credit constraints, the analysis stops there. However, suppose the population consists of low savers, who hold neither housing nor financial assets, and high savers, who own houses they occupy, houses they rent to low savers, and equipment. Lower taxes on owner-occupied housing will not only cause high savers to buy bigger houses, but will also encourage low savers to purchase the houses they had been renting. High savers will not want to decrease their total assets, and hence are likely to invest at least some of the proceeds from the sale of rental housing in equipment. Low taxes on housing shift saving from equipment to housing but also increase total saving.

This implies that a housing tax regime that discriminates in a particular way between types of savers will almost certainly increase non-housing investment. Suppose, for example, there is some minimal level of accommodation which all people consume. Favorable tax treatment of owner-occupied housing up to this value will encourage renters to buy without giving an incentive to existing owners to trade-up to more expensive houses. More generally, the effect of reducing taxes on housing up to a certain value depends on the relative numbers of renters who are induced to buy and high savers who are induced to buy larger houses.

It is worth noting, in fact, that the U.S. and the U.K. allow mortgage interest payments to be deducted from tax only up to a certain limit. In the U.K., interest on the first £30,000 of a mortgage is tax-deductible, and it seems likely that any further reductions in the real value of this cut-off would reduce the capital stock. The equivalent cut-off in the U.S. is $1,000,000, presumably well above the level which maximizes equipment investment.

Judd [1985] and Chamley [1986] demonstrate that the optimal long-run capital tax rate is zero in a wide variety of circumstances, including those examined in the paper. (See Aiyagari [1995] for conditions under which capital taxes are desirable). Opponents of favorable tax treatment of housing typically make the second-best argument that since equipment is taxed, housing should be equally taxed to avoid diverting investment from equipment. We agree that politically, zero capital income taxes seem unlikely, and our analysis takes the tax rate on capital income from equipment investment as given. (Low housing taxes seem politically easier than low taxes on equipment investment, perhaps because they are perceived as benefitting the middle class, rather than the rich.) However, we reject the second-best argument for equal tax treatment of owner-occupied housing.

The paper is organized as follows. Section two examines the effects of tax on the im-

puted rental income of owner-occupiers in a simple two-period model, in which borrowing is assumed to be impossible. We show that a non-linear tax on owner-occupied housing maximizes equipment investment. In section three we show that the analysis of interest tax deductibility is similar - awarding tax relief on interest paid on mortgages up to a certain limit increases non-housing investment. Section four concludes.

2 A simple model

We begin with a simple two-period model in which agents supply labor inelastically and demand goods (in both periods) and housing services (in the second period alone). In the first period people can buy owner-occupied housing, called h, which they live in, and resell, during the second period[1]. This is taxed at a rate t_h, and we assume that the tax base, the imputed rental income, is r times h, where r is the interest rate. Alternatively, people can rent housing in the second period. Their total demand for accommodation is m, so that rental demand is $m - h$.

In practice, the tenure choice is discrete - people must either rent or owner-occupy. However, in order to simplify the analysis, we assume below that an individual can own a fraction of her housing and rent the remainder. (The appendix demonstrates that allowing for discreteness at the level of an individual makes no difference to steady-state comparisons at an aggregate level. Marginal shifts in the relative shares of rented and owned accommodation for individuals in this model show up as small changes in the proportion of owner-occupiers in a model with a discrete tenure decision.)

[1] We assume asset trades are made at the end of each period. In the first period the young live with their parents.

Another form of saving is to buy assets other than owner-occupied housing, denoted a. These could be either equipment or housing which is rented out, but income from both sources is taxed at a rate t_k. This means that if both rental housing and equipment are held in equilibrium, the pre-tax return on housing which is rented out must be the same as that on equipment, which is r. We impose this condition at the start. We also assume the purchase price of housing, whether subsequently rented out or owner-occupied, to be fixed, and normalize it at one. (In other words, housing supply is assumed fully elastic. In Appendix A we extend the model to allow for an inelastic supply of housing.) This means that the price of rented accommodation is also r. Labor income is taxed in both periods at a rate t_w. Below, w_i refers to after-tax wages in period i.

So, assuming agents won't want to throw anything away, consumption in each period is

$$\begin{aligned} c_1 &= w_1 - a - h, \quad \text{and} \\ c_2 + rm &= w_2 + Ra + R_h h, \end{aligned} \tag{1}$$

where $R_h \equiv 1 + r(1 - t_h)$ and $R \equiv 1 + r(1 - t_k)$ denote the after-tax gross rates of return on owner-occupied housing and other assets respectively. In the first period, consumption is labor income less total asset purchases. In the second period labor income is supplemented by the proceeds of asset sales, less payments of tax. These resources also go towards any rented accommodation, $m - h$. Because neither rented nor owner-occupied housing can be negative $m \geq h \geq 0$.

If there were no constraints on borrowing then an individual's decision about total saving, a plus h, would be determined at the margin by the rate of return R. In this case changes in the tax on owner-occupied housing t_h would have similar effects on everyone, influencing

only the *allocation* of saving between a and h.[2] Instead, we assume for now that there is no borrowing, so that a is constrained to be non-negative. (In section three we relax this assumption, and allow people to hold negative financial assets, but they can still only borrow up to some limit.)

In order to abstract from income effects, we assume that utility is linear in second period consumption. (More generally, restricting any tax changes to be revenue neutral has similar effects. In appendix A we derive all the relevant results for more general preferences.) In addition, utility is assumed to be logarithmic in accommodation and first period consumption, so the problem facing agents is

$$max_{a,h,m} \quad [\log(c_1) + \delta c_2 + \delta \log(m)]$$

$$\text{subject to: } a, h \geq 0 \ , \ h \leq m,$$

where $0 < \delta < 1$ is a discount factor. There is a range of discount factors across the population, but people are otherwise assumed to be identical. There is no uncertainty about future wages or rates of return. Production of goods in the second period is carried out by profit maximizing firms which use the constant returns to scale technology $f(k)$, where k is equipment per head of population, and $f(.)$ is strictly concave.

[2]This assumes that individuals could borrow at a gross interest rate R, receiving tax relief on debt interest at a rate t_k. We examine the effects of varying tax relief on debt interest more closely in Section 3.

2.1 The solution

2.1.1 Types of agent

Suppose we assume that owner-occupied housing is tax-favored to start with[3], i.e. that $t_h < t_k$, or $R_h > R$. According to their propensity to save, people will then hold different quantities of assets. People with $\frac{1}{R_h w_1} < \delta < \frac{1}{R_h(w_1 - 1/r)}$, whom we label "renters", will invest in some owner-occupied housing and rent the remainder of their housing. Renters hold no other assets. Changes in the rate of return on owner-occupied housing R_h have a first-order effect on how renters allocate their total demand for accommodation between rented and owner-occupied housing and, therefore, on their saving. High-saving "owner-occupiers", for whom $\delta > \frac{1}{R(w_1 - 1/(r(1-t_k+t_h)))}$, own all their own housing and hold other assets as well. Owner-occupiers' total saving is determined at the margin by R, the rate of return on rental housing and equipment. Changes in R_h affect only the allocation of owner-occupiers' portfolios between owner-occupied housing and other assets.[4]

The proportions of each type are denoted λ^r and λ^o. To keep the model reasonably simple we assume that the behavior of each group can be represented as that of a single representative agent. So, for example, the contribution of renters to the total demand for owner-occupied housing is calculated as λ^r times h^r, where h^r is the level demanded by the

[3]This ensures that owner-occuiped housing is demanded in equilibrium.

[4]We ignore the two other types as they do not affect how aggregate equipment responds to changes in capital income taxes. The least patient people, for whom $\delta \leq \frac{1}{R_h w_1}$, have no savings and their behavior is unresponsive to changes in rates of return. Intermediate between renters and owner-occupiers (their disount factors satisfy $\frac{1}{R_h(w_1 - 1/r)} \leq \delta \leq \frac{1}{R(w_1 - 1/(r(1-t_k+t_h)))}$) are people who neither rent any accomodation nor hold any assets other than owner-occupied housing. They can therefore have no bearing on aggregate equipment.

representative renter[5].

2.1.2 Market clearing

In the second period the total demand for rented accommodation must equal supply:

$$m - h = a - k. \tag{2}$$

Total rental demand is $m - h$, where h is aggregate owner-occupied housing. The supply of rented housing is that part of all assets not accounted for by owner-occupied housing or by equipment, k. This condition pins down the supply of equipment, which in equilibrium equals demand, so that

$$r = f'(k). \tag{3}$$

2.2 A reduction in housing tax

To illustrate the basic principle at work, suppose that the marginal rate of tax on owner-occupiers is cut slightly, with the revenue being made up by an increase in the wage tax. The first thing to notice is that neither the non-savers nor the intermediates contribute to a change in aggregate equipment. Non-savers' demand for rented accommodation is unchanged and intermediate savers neither rent nor hold any non-housing assets[6]. From

[5]This should be understood as a proxy for the general case which involves some continuous distribution over preference parameters. Note that with a continuous distribution there is no first-order effect of small tax (price) changes on the relative numbers of types of savers, so we are justified in treating these proportions as fixed.

[6]This ignores any second order effects of changes in factor prices, dr and dw. When production is CRS and labor supply is inelastic these effects depend solely on the reaction of equipment capital, so they effect only the scale, not the sign of dk/dt_h.(See below for details.)

equation (2), the change in equilibrium equipment will depend on the responses of renters' rental demand and owner-occupiers' saving:

$$dk = \lambda^o da^o - \lambda^r (dm^r - dh^r). \tag{4}$$

Take the renters first. They will buy just enough owner-occupied housing to make them indifferent between first and second period consumption, and rent sufficient accommodation to make up their total demand for housing services:

$$w_1^r - h^r = 1/(\delta^r R_h), \tag{5}$$

$$m^r = 1/r. \tag{6}$$

Renters' demand for rented accommodation therefore responds to a small change in the tax on owner-occupied housing as follows:

$$\begin{aligned} d(m^r - h^r) &= -c_1^r \frac{dR_h}{R_h} - m^r \frac{dr}{r} \\ &= \frac{r c_1^r}{R_h} dt_h - (m^r + (R_h - 1)c_1^r/R_h)\frac{dr}{r}. \end{aligned} \tag{7}$$

A lower tax on owner-occupation causes renters to save more, and substitute away from rented accommodation for their housing needs. At the same time, owner-occupiers reallocate their assets:

$$da^o = \frac{r m^o}{r'} dt_h + (m^o + (R - 1)c_1^o/R)\frac{dr}{r}. \tag{8}$$

Although reducing taxes on owner-occupied housing does not affect owner-occupiers' incentives for aggregate savings, it does encourage them to substitute towards housing and away from other assets. This represents the conventional wisdom about the effects of such a tax change on equipment investment.

However, the effect of this intra-temporal substitution on equipment investment must be weighed against the effect of higher saving by renters. The net effect of small changes in the tax on owner-occupied housing on equipment is:

$$(1 - \phi f''(k)).\frac{dk}{dt_h} = -\lambda^r \frac{rc_1^r}{R_h} + \lambda^o \frac{rm^o}{r}, \tag{9}$$

where ϕ is positive. (We have substituted for the effect on interest rates from equation (3). Changes in wages, whether they reflect changes in the pre-tax wage or revenue-compensating adjustments in the tax on wages, make no difference to equipment with quasi-linear utility because they are absorbed by second-period consumption.) Equation (9) says that with sufficient numbers of renters relative to owner-occupiers, reducing the tax on owner-occupied housing will increase investment in equipment. In fact, if we start from a position where all forms of capital are taxed at the same rate[7], reducing the tax on owner-occupied housing will increase equipment investment whenever

$$\frac{\lambda^r}{\lambda^o} > \delta^r \left(\frac{R}{r}\right)^2. \tag{10}$$

This condition is simple partly because we have abstracted from risk, so that renters hold no non-housing assets as long as they yield a lower mean rate of return than owner-occupied housing. If renters are risk-averse and the returns on housing and non-housing assets are random and differently correlated with labor income, renters might include equipment even if its mean rate of return, $E[R]$ is less than the mean rate of return on owner-occupied housing, $E[R_h]$. In that case, renters might finance any purchase of owner-occupied housing

[7]We solved the model for the case where $t_h < t_k$, but equation (7) is still valid at $t_h = t_k$, for reductions in t_h at least: equipment is a kinked but continuous function of $t_k - t_h$ at that point. Small increases in t_h have no effect on equipment when $t_h \geq t_k$ as there is no owner-occupied housing in this range.

by selling equipment as well as reducing consumption in the first period. This would weaken our effect but not eliminate it.

2.3 A non-linear tax schedule - targeting renters

Suppose that we again begin from a position in which capital tax rates are identical and that we can selectively alter the tax on the imputed rental income from owner-occupied housing for one group of savers but not the other. If in particular the marginal tax rate could be reduced for renters without changing the tax rate faced by owner-occupiers then investment in equipment would unambiguously increase. Renters would buy more owner-occupied housing but there would be no switch of existing high savers' assets away from equipment.

Under some circumstances this could be achieved simply by levying the tax at a lower rate on housing valued below some threshold level. Suppose, for example, that people required some strictly positive minimum level of accommodation, $\overline{m} > 0$. A reduction in the tax on owner-occupied housing below $\overline{m}$ would always increase equipment, since only renters would be encouraged to buy houses. In the simple model we examine here, for example, no-one has accommodation worth less $\overline{m} = 1/r$. Eliminating the tax on owner-occupied housing worth less than this amount would therefore lead to higher equipment investment.

Even if there is no minimum level of accommodation, cutting housing taxes below some common threshold increases savings for all renters, without causing owner-occupiers to shift assets into larger houses, as long as all renters live in less valuable houses than all existing owner-occupiers. In practice, this extreme condition is unlikely to be met - some rented accommodation is worth more than some owner-occupied housing. A simple dollar cut-off

will therefore be an imprecise instrument for inducing renters to become owner-occupiers without at the same time causing some owner-occupiers to buy bigger houses.

Nonetheless, as long as there is a sufficiently high ratio of renters to owners at a particular value of accommodation, favorable tax-treatment of owner-occupied housing of that value will increase equipment investment. The housing tax regime which maximizes equipment investment, taking as given the tax on equipment income, is therefore likely to involve an increasing marginal tax rate on owner-occupied housing. Suppose that of the people owning some level of housing h, a proportion $\lambda^r(h)$ also rent some accommodation[8] and a proportion $\lambda^o(h)$ also own other assets. The equipment-maximizing schedule for $t_h(h)$ will be non-decreasing as long as $\lambda^o(h)/\lambda^r(h)$ is also. (The fewer the renters living in accommodation worth h the less will favorable tax-treatment of owner-occupied housing increase equipment investment reward substitution into owner-occupied housing at that point.) Casual empiricism suggests that the greater the value of a house the more likely it is to be owner-occupied rather than rented.

It might be possible to target more accurately low taxes on owner-occupied housing at people who would otherwise rent by using a rule that made the cut-off for a lower tax rate dependent on labor income of taxpayers as well as the value of housing they own. An example would be a rule that exempts from tax imputed rental income on owner-occupied housing up to some proportion, say 5%, of annual income. This rule would presumably

[8]In practice it is not possible for someone to rent only a fraction of her housing, but recall that the aggregate implications of discrete and continuous tenure decisions at the individual level are the same (see Appendix B). The proportion $\lambda^r(h)$ should be thought of as those for whom the discreteness constraint binds - i.e. occupants of rented (owner-occupied) housing worth h who would choose to buy (rent) some of h if they could.

encourage renters to buy without encouraging owner-occupiers to buy larger houses since most existing owner-occupiers would already have an imputed rental income worth more than 5% of their annual income.

More generally, any characteristic influencing the proportion of renters and owner-occupiers, such as age, marital status, or number of dependents would be used to target tax reductions at people who would otherwise rent. For example, people under 40 may be more likely to rent, so providing favorable tax treatment of housing to this group specifically could increase equipment investment. (We are not recommending such a policy, since we think tax policy should serve goals besides maximizing equipment investment.)

3 Tax relief on home loans

The simple model we have used so far illustrates the basic principle at work, but attention has been restricted to a tax on imputed rental income. In practice, much of the criticism of the overall tax treatment of owner-occupation is directed specifically at tax relief given to mortgage interest. In this section we allow for home loans, and we show, perhaps counter-intuitively, that the same basic principle applies in this case as well: an increase in the rate of tax relief on interest payments may increase rather than reduce non-housing investment.

We denote mortgage borrowing by b, and the rate of tax relief on the interest by τ, so that the gross after-tax rate of interest is $R_b \equiv 1 + r(1 - \tau)$. The loan is negotiated in the first period and repaid, with interest, in the second period, and consumption in each period is now given by:

$$c_1 = w_1 - a - h + b,$$

$$c_2 + rm = w_2 + Ra + R_h h - R_b b. \tag{11}$$

We continue to assume that borrowing is constrained - specifically, each agent's mortgage debt is limited by the value of owner-occupied housing in her possession, so that $qh \geq b \geq 0$ where q lies between zero and one. The coefficient q represents the proportion of the value of owned housing against which agents can borrow, so $(1-q)h$ is the down-payment required to buy a house worth h. We treat q as exogenous.[9]

The equilibrium equipment stock now depends on net (rather than gross) financial assets, and equation (2) becomes:

$$m - h = a - b - k. \tag{12}$$

In other words, saving in any non-housing assets must now be enough to cover not only shares in equipment but also mortgage debt.

3.1 An increase in tax relief

What happens when home-owners borrow depends on the terms they face, and in particular the scale of interest tax relief relative to the two rates of capital taxation. To begin with, for there to be any borrowing at all, $R_b < R_h$ ($t_h < \tau$) otherwise it would always make sense for anybody with a mortgage loan to repay it by selling some housing[10]. So, to generate a role for debt, we will assume at least that the rate of mortgage interest tax relief exceeds the tax on owner-occupied housing. This condition is easily satisfied in most countries since there is typically no tax on imputed rental income for owner-occupiers.

[9]It is possible that mortgage tax deductability reduces the required down-payment, which would tend to reduce aggregate saving.

[10]Some non-savers might want to borrow at $R_b \geq R_h$, but they are constrained by lack of collateral.

We will go further and assume that $R_b \leq R$ ($t_k \leq \tau$), so that interest tax relief is high enough to mean that the net costs of borrowing for owner-occupied housing are also no higher than the return on other assets. (We consider this the more realistic case.) Under these circumstances, it is easy to see that every agent that owns assets will take out the biggest mortgage allowable, $b = qh$. This follows because it makes sense for all types to borrow an extra dollar, where possible, and invest it in whichever asset is sensitive to aggregate saving at the margin - owner-occupied housing for renters and intermediate savers, other assets for existing owner-occupiers. The fact that all agents are constrained in their borrowing also makes their response to small changes in the tax relief on borrowing easy to determine. If we define "net" housing investment $\bar{h} \equiv h(1-q)$, and its return $\bar{R}_h \equiv (R_h - qR_b)/(1-q)$, then consumption becomes

$$\begin{aligned} c_1 &= w_1 - a - \bar{h}, \\ c_2 + rm &= w_2 + Ra + \bar{R}_h \bar{h}. \end{aligned} \tag{13}$$

and the condition for clearing the rental market can be written:

$$m - \bar{h} = a - k. \tag{12}$$

Agents choose assets $a \geq 0$ and $\overline{h} \geq 0$ and accommodation m subject to the constraint $m(1-q) \geq \overline{h}$. Rewriting the problem in this way reveals two important features of the model with non-zero debt. First, when all agents are constrained, changes in the rate of mortgage interest tax relief τ and the tax on owner-occupation t_h only matter inasmuch as they affect the effective return $\overline{R}_h$. Thus a small increase in tax relief $d\tau$ has the same effect as a cut in the tax on owner-occupied housing, $dt_h = -qd\tau$. Increasing tax relief makes housing services become more attractive to owner-occupiers, who therefore substitute out of

non-housing assets. At the same time, renters' net assets go up. Borrowing is made cheaper, and renters will want to take out more debt, but being credit constrained they must also buy more owner-occupied housing. Because $q < 1$, this extra saving in housing must exceed the increase in debt.

Second, if borrowing is possible, renters react relatively more strongly to changes in the tax on imputed rental income from owner–occupied housing or to the rate of mortgage interest relief. Introducing debt allows agents to alter, potentially, the trade-off between first and second-period consumption. Foregoing one unit of consumption in the first period, for example, allows renters to buy $1/(1-q)$ units of owner-occupied housing. Reducing the tax on owner-occupiers by $-dt_h < 0$ therefore increases renters' second period consumption by $rdt_h/(1-q)$ for each unit of earlier consumption foregone. For owner-occupiers, however, this intertemporal decision is still governed by $R = 1 + r(1 - t_k)$, which is unaffected by the presence of debt or its interest cost. Changes in t_h still affect the relative price of accommodation to consumption in the second period, and so high savers' allocation of assets. But the magnitude of this effect - the same change of $-dt_h < 0$ makes accommodation cheaper by rdt_h - is unaltered by debt. For a given distribution of types, a universal cut in the tax on owner-occupied housing (or an increase in the rate of interest tax relief) will increase equipment investment if[11]:

$$\frac{\lambda^r}{\lambda^o} > \delta^r(1-q)\left(\frac{R}{r}\right)^2. \tag{14}$$

Note that this condition is less stringent than condition (10), which holds if borrowing is impossible. At the same time, an economy with gearing $q > 0$ will have relatively fewer

[11] As before, this calculation assumes that immediately before the cut the tax rates were equal, $t_k = t_h = \tau$. Notice that setting $q = 0$ takes us back to the zero-debt case (condition (10)).

renters and more owner-occupiers than an economy with no borrowing ($q = 0$). It is not clear whether, for a given distribution of discount rates, a universal cut in the tax on owner-occupation is more or less likely to increase equipment investment when borrowing is easier.

However, in just the same as in the case in which borrowing was impossible, interest tax relief for renters alone encourages higher aggregate saving without prompting owner-occupiers to switch assets away from equipment and towards housing.

4 Conclusion

Far from deterring investment in equipment, lower taxes on owner-occupiers who would otherwise be renting housing encourage aggregate saving and therefore tend to increase equipment in general equilibrium. This implies that favorable tax treatment of owner-occupied housing may be desirable if other capital taxes are constrained to be positive and equipment investment lies below the socially optimal level. If taxes were reduced for all owner-occupiers there would also be some people who reallocate existing assets towards housing and away from equipment. However, a suitably targeted tax schedule can encourage additional saving by low savers while avoiding the intratemporal substitution effects on high savers. An exactly equivalent result for the rate of tax relief on mortgage interest applies when borrowing is advantageous for all agents.

These results depend centrally on both the heterogeneity of discount rates in the population and the presence of binding borrowing constraints, both of which we think plausible features of the model.

The standard argument for taxation of housing is a second-best argument: given that

taxes on equipment investment lead to sub-optimal levels of equipment, low housing taxes may be harmful because they divert investment away from equipment. We have argued that in a second-best setting in which taxes on equipment investment are constrained to be positive, low taxes on owner-occupied housing up to a certain value may nonetheless be desirable. However, it is also worth noting that models which suggest that zero taxation of equipment income is first-best also typically imply that imputed rental income from housing and mortgage interest income should not be taxed (Chamley [1986], Judd [1985]).

Finally, this paper has pointed out that heterogeneity in the population could be exploited to some advantage in the tax code. In this particular case we have shown that a rationale for some existing treatments of owner-occupied housing is that they direct lower taxes on owner-occupiers mainly at those who are likely to respond by saving more. But the principle of targeting tax cuts to take advantage of population heterogeneity has wider applicability. Kremer [1997], for example, explores the possibility of conditioning payroll taxes on age.

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A General Preferences and Production

This appendix examines the effects of lower owner-occupation taxes on agents with generalized preferences $U(c_1, c_2, l, m)$, where l is leisure. We continue to assume that utility is time-separable and that no good is inferior. Except for the usual concavity assumption $U(.)$ is otherwise unrestricted. We also extend the model to allow for different production technologies for housing and the consumption goods, and therefore a non-trivial purchase price of housing, p_m. Production of consumption goods in the second period relies on a CRS production function using equipment and labor as inputs. Individuals are endowed with L units of leisure. The supply of housing is unrestricted - we simply assume that higher aggregate demand for housing raises its price. Because of arbitrage, which ensures that the rates of return on rented housing and equipment are the same, any rise in the purchase price of housing is matched by proportionate rise in the rental price. The constraints facing agents become:

$$\begin{aligned} c_1 &= w_1 - a - p_m h, \quad \text{and} \\ c_2 + r p_m m + w_2 l &= w_2 L + Ra + R_h p_m h, \end{aligned} \tag{A1}$$

and market clearing for rented accommodation implies, in aggregate

$$p_m(m - h) = a - k. \tag{A2}$$

The contribution of each agent i to aggregate capital is therefore

$$k^i = w_1^i - (c_1^i + p_m m^i) \tag{A3}$$

The key effect in the paper rests on the response of renters dk^r to a cut in the tax on owner-occupation, $dt_h < 0$, and a compensating increase in the wage tax, $dt_w > 0$. The scale of dt_w

relative to dt_l is determined by the constancy of aggregate government revenue. We assume that the necessary increase in the wage tax rate is given by $dt_w = \gamma. - rpdt_h/w_{2g} > 0$, $(\gamma > 0)$.

For renters, these changes correspond to a higher price of first-period consumption and a lower price of leisure. For owner-occupiers, a cut in t_h represents a fall in the price of accommodation. (Note, however, that if the tax change is well targeted at renters, owner-occupiers experience no price changes.) We ignore mortgage debt here. Recall that in a model with mortgage debt, a compensated increase in mortgage tax relief τ has exactly the same effects as a cut in the tax on owner-occupation t_h (as long as $\tau \geq t_k$ to begin with)

We begin by examining the substitution and income effects of the tax changes, taking as given the price of housing, p_m. We establish sufficient conditions for a compensated and targeted reduction in the tax on owner-occupied housing to increase equipment. We then isolate the effects of an increase in p_m.

It will be convenient to define key preference parameters. We use α_{my} as the spending on accommodation as a share of lifetime resources, *including the endowment of leisure*, and ε_{xy} as the income elasticity of demand for good x. We also define ε_{xz} as the compensated elasticity of substitution of the demand for x with respect to the price for z. Finally, y is used for total lifetime income (for agent i, $y^i = R^i w_1^i + Lw_2$) and $\sigma = (a + ph)/y$ for savings as a proportion of income.

A.1 Substitution effects

A.1.1 Renters

Suppose first that the purchase price of housing is fixed, $p_m \equiv 1$. After simplifying, the *substitution* effects of the tax change on renters' contribution to equipment can be written

$$dk_s^r = -\sigma\varepsilon_{ss}(y/R + \gamma\varepsilon_{ly})(r - R\alpha_{my}\varepsilon_{my}) + \gamma\varepsilon_{lm} \tag{A4}$$

Sufficient conditions for these substitution effects to be positive are

(S1) leisure and accommodation should not be complements ($\varepsilon_{lm} \geq 0$), and

(S2) $r/R > \alpha_{my}\varepsilon_{my}$.

The intuition for (S1) is that a compensated increase in the tax on wages will reduce renters' demand for accommodation if leisure and accommodation are substitutes. Other things equal, lower accommodation demand leads to higher aggregate equipment in equilibrium. In the main text (S1) was satisfied because labor supply was taken to be inelastic. In (S2), $\alpha_{my}\varepsilon_{my}$ is the amount renters spend on accommodation from an extra dollar of income. To understand this condition, consider a compensated cut in the tax on owner-occupation (increase in the after-tax rate of return). This must increase renters' saving and their available resources in the second period. But if renters allocate too much of this increase to accommodation, their demand for rented housing could actually rise, which would lower aggregate equipment. When preferences are quasilinear in second-period goods consumption, as assumed in the main part of the paper, $\varepsilon_{my} = 0$, so that (S2) always holds true.

It is not obvious whether (S1) holds a priori, and there are arguments in favor of both

substitutability and complementarity between accommodation and leisure. It seems likely, however, that these effects are not strong in either direction. In that case, the necessary condition for substitution effects on renters to increase equipment, that $dk_s^r > 0$ in equation (A4), will be satisfied as long as (S2) is satisfied with some room to spare.

To judge whether (S2) is likely to be satisfied in general, we have to form a judgement about likely values of the coefficients. On an annual basis a reasonable estimate of the (risk-free) interest rate is around 3 per cent. But in this two-period model one period represents at least twenty-five years, in which case $r > 2$ and $r/R > 2/3$. As for the right-hand side, U.S. National Accounts for 1996 give a figure for the whole economy of $\alpha_{my} \approx 1/6$. Using these numbers, a sufficient condition for a selective, compensated tax change to increase equipment investment is $\varepsilon_{my} < 4$, which must surely be true.

A.1.2 Other agents

In general, equipment investment depends also on the behavior of *owner-occupiers* and of *non-savers* (those who are too impatient to own any assets at all). A universal cut in t_h and rise in t_w present owner-occupiers with a lower cost of housing and both groups with a lower cost of leisure. If the tax change is perfectly targeted, so that the reduction in t_h is selectively aimed at renters, the only price change facing other agents comes from the increase in the wage tax. The substitution effects from a higher wage tax on non-savers and owner-occupiers are respectively

$$dk_s^n = \gamma\varepsilon_{lm} \tag{A5}$$

$$dk_s^{ow} = \gamma\varepsilon_{lm} + \gamma\sigma\varepsilon_{ss}\varepsilon_{ly}(r - R\alpha_{my}\varepsilon_{my}) \tag{A6}$$

Thus the wage tax increase has for everyone a positive substitution effects on equipment as long as (S1) and (S2) are satisfied. A universal, non-targeted cut in t_h encourages owner-occupiers to switch assets away from equipment and towards housing. Substitution effects of a universal tax change on owner-occupiers' contribution to equipment come to

$$dk_s^o = \varepsilon_{mm} - \sigma m \varepsilon_{ss} \varepsilon_{my} + dk_s^{ow} \tag{A7}$$

If income effects on, and substitution effects between, leisure and accommodation are unimportant ($\varepsilon_{my} \approx \varepsilon_{ly} \approx \varepsilon_{lm} \approx 0$), then dk_s^o is dominated by ε_{mm}, which is negative. The effect is weakened if income effects on leisure and accommodation are strong and the conditions (S1) and (S2) are met.

A.2 Income effects

The income effects of the tax change depend on the change in an agent's total tax payments, at existing levels of spending. Because these are paid during the second period, higher tax payments will encourage higher saving in the first period. Thus, income effects on an individual's contribution to equipment investment are positive if tax changes mean she pays more tax when her behavior is unchanged:

$$dk_I^i = (m^i \varepsilon_{my}^i + c_1^i \varepsilon_{c_1 y}^i)(\gamma - h^i) \equiv \mu^i (\gamma - h^i), \quad \mu^i \geq 0, \quad i = n, r, o. \tag{A8}$$

Non-savers don't own any housing, so tax changes make them worse off, and they reduce their demand for rented property as a result ($h^n = 0$ so $dk_I^n > 0$). Because owner-occupiers are likely to own more housing than renters, tax changes are likely to make them better off and they will save less. The effect on renters is ambiguous. Aggregate income effects are

Also, a rise in p_m affects consumption in the first period. To the extent that accommodation and first-period consumption are substitutes, higher house prices will reduce saving. Finally, however, individuals are worse-off in the second period (an income effect) and this acts to increase saving and equipment. Overall, a small increase in house prices $dp_m > 0$ on its own produces a reaction in aggregate equipment of

$$dk_P = rc_{1y} + \varepsilon_{my}(\alpha_{my} + s\varepsilon_{ss}(r/R - \alpha_{my}\varepsilon_{my})) - (1 + \varepsilon_{mm}) \tag{A10}$$

The sign of dk_p is ambiguous, but if the (absolute) elasticity of demand for accommodation is high enough, higher house prices will increase equipment. By contrast Engelhardt (1994), simulating a model close to ours, claims that higher house prices will tend to reduce saving. In his model house buyers need to save for a down payment that is increasing in the purchase price. Higher house prices deter potential buyers and reduce saving for the down payment. A similar effect would operate in our model by reducing the increasing the number of renters relative to owner-occupiers. But this is only a second order effect, and in any case it only arises when the purchase price of housing alone increases. The number of renters rises only if, as Engelhardt assumes, the rental price of housing remains fixed, in which case renting is cheaper relative to buying. In general equilibrium the purchase and rental prices of housing move together.

Empirical evidence on the sign of dk_P is also inconclusive. Using the 1994 cross-section of the PSID, Sheiner (1989) finds that renters save more when house prices rise. Engelhardt (1994) uses Canadian data to show that people living in regions with higher house prices save less. However, as this paper makes clear, the overall effect on equipment investment depends also on how the aggregate demand for rented housing responds to p_m. If this

falls by more than any reduction in renters' financial assets, their contribution to aggregate equipment goes up.

A.4 Overlapping generations

The models in this paper are restricted to two periods. However, the implications of embedding the model in an OLG setting are not much different. In particular, the steady-state substitution effects are identical, since the representative generation in the steady state looks just like an agent in our two-period models. House price and income effects are, if anything diluted in an OLG setting. Note that in the period in which tax changes are announced higher house prices will yield capital gains for existing owner-occupiers and landlords. If bequests are active, or if the fiscal authority can tax pure capital gains and redistribute the gains intertemporally, these gains will offset to some degree the effects of higher house prices on future generations. Similarly, the intertemporoal income effects highlighted above will be mitigated if bequests are active in the OLG setting.

B Tenure choice

The analysis in the text allowed people to own any fraction of their housing and rent the rest. In practice this choice is necessarily discrete - accommodation must be either wholly rented or wholly owned. Suppose people differ only in their patience δ and continue to assume for the moment that the tenure decision is continuous. Suppose the marginal agent who holds no other assets than owner-occupied housing and is just content to rent zero accommodation has patience $\overline{\delta}(t_h)$. This agent lies on the boundary between renters and intermediate savers. Similarly, the agent with patience $\underline{\delta}(t_h)$ is just satisfied with owning no

assets, and so lies on the boundary between non-savers and renters. These limits describe the range within which agents are renters, so that if the distribution of patience in the population is F then $\lambda^r = F(\overline{\delta}) - F(\underline{\delta})$. With a continuous tenure choice the response of renters' aggregate contribution to equipment to a change in the tax on owner-occupation is

$$\frac{dk^r_{cont}}{dt_h} = \int_{\underline{\delta}}^{\overline{\delta}} \frac{dh(\delta)}{dt_h} dF(\delta). \tag{B1}$$

Introduce a discrete tenure choice, and call the degree of patience above which agents prefer to buy their own house $\delta^*(t_h)$ and the amount of housing bought by the marginal agent m^* (note that this will not depend on t_h because non-savers are unresponsive to the owner-occupation tax rate and by continuity of F). If F is continuous then $\underline{\delta} < \delta^* < \overline{\delta}$. Clearly, $\frac{d\delta^*}{dt_h} > 0$ - a lower rate of return on owner-occupied housing means a higher marginal degree of patience is needed to owner-occupy. The equivalent response of the contribution to equipment with a discrete tenure choice is

$$\frac{dk^l_{disc}}{dt_h} = -m^* f(\delta^*) \frac{d\delta^*}{dt_h}. \tag{B2}$$

This is strictly negative, so our previous results go through. In fact, if we suppose that agents have the simple preferences described in the model, then it is easy to work out that when F is uniform, the responses are identical:

$$\frac{dk^l_{cont}}{dt_h} = \frac{dk^l_{disc}}{dt_h} = -\frac{r}{\delta^* R_h^2} log\left(\frac{\overline{\delta}}{\underline{\delta}}\right). \tag{B3}$$