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# Direct and Indirect Effects of Housing Market Policies using an Augmented DiPasquale-Wheaton framework

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## Abstract
This paper analyses a set of housing market policies in an augmented DiPasquale-Wheaton (ADPW) model where the price-rent (PR) ratio ensures housing market equilibrium across different types of tenure. The aim of the paper is educational, putting several housing market policies into a comprehensive context where the rental housing market, the housing construction industry and the market for owner-occupied housing are interrelated. Housing market dynamics takes both direct and indirect effects into account. The paper finds that introducing tax-deductible mortgage interest rates has a positive effect on house prices. This policy stimulates housing starts and pushes down rental prices. A property tax has a negative effect on house prices while lifting the rental price as the housing industry contracts. Social housing policy interventions on the supply side of the housing market partly crowd out commercial housing supply. Demand-side vouchers have stronger short-run effects as long-run effects incorporate the housing construction industry's reaction to house price signals. Finally, rental subsidies create a gap between the rent paid by a tenant and the rent received by a landlord. The aggregate effect of a rental subsidy is related to the elasticities of supply and demand, where not only renters, but also homeowners and landlords, may benefit when supply and demand are very elastic.

Keywords
Housing market policy, DiPasquale-Wheaton model, PR-ratio, crowding out

## Introduction

The housing market system includes the rental and owner-occupied housing market as well as the housing construction industry. The links between the different parts are subtle, bi-directional, and challenging to frame in, and shocks to the economy have both direct and indirect effects across the system. When analysing housing policies, both direct and indirect effects should be accounted for, especially when discussing the long-run outcomes.

Several housing market policies are fundamental to the housing market debate. Whether or not subsidised housing starts crowd out private housing supply (see e.g., Murray, 1983, 1999, or Sinai & Waldfogel, 2005), and whether tax-deductible mortgage rates favour insiders in the market for owner-occupied housing while harming outsiders (see e.g., Shao & White, 2020), are merely two examples of such discussions. The issue of housing taxation is highly debated in the public domain, although most economists consider housing to offer an efficient tax base. In Norway, the (re)introduction of a scheme in which the rental value of owner-occupied housing is included in the personal income tax base, and a reduction in the tax-deductible mortgage rates, have recently been proposed (NOU 2022: 20).

The DiPasquale-Wheaton (DPW) model (1992, 1996) constitutes a seminal pedagogical tool for analysing the links between the different parts of the real estate system. While typically used to study the commercial real estate system, the model may also be used to describe owner-occupied real estate (DiPasquale & Wheaton, 1992). Indeed, DiPasquale and Wheaton (1992) affirm that their model is valid also for owner-occupiers, and that the annual cost of home ownership is equivalent to rent. Borgersen and Emblem (2022) extends the conventional DPW framework by including a price-rent (PR) ratio, thus explicitly addressing the connection between the rental and owner-occupied housing markets in the model. Focusing on the role of the funding structure of housing purchases, their paper applies before-tax user costs when analysing the links between the housing and mortgage markets.

This paper contributes to the literature in two ways. First, it offers an extension of Borgersen and Emblem's (2022) analysis of a set of housing market policies by considering the net-of-tax rental and user cost. Second, it illustrates how different types of housing policies aimed at homeowners (e.g., subsidised mortgage payments and property taxation) indirectly spill over to the rental housing market, and how polices aimed at households in the rental housing market (e.g., rental subsidies and affordability measures) spill over to homeowners. The main aim of the paper is educational, offering a comprehensive and non-technical framework for analysing policies to include both direct and indirect effects.

In the long run, the introduction of property taxation is shown to harm not only owner-occupiers but also tenants, as the housing industry responds to the lower house prices that come about from such a tax. The introduction of tax-deductible mortgage rates may lead to lower rental prices in the long run as housing construction responds to higher house prices. Public housing crowds out part of the commercial housing supply, while housing affordability interventions increase the rent on rental housing and lifts the number of housing starts as the price of owner-occupied housing increases. The effect of rental subsidies is model-specific, as the wedge between the rental price paid by tenants and the rental price received by landlords allows for different contexts. As the supply of housing is given in the short run, a rental subsidy unambiguously lifts the rent paid by a tenant in the short run. The long-run effect of the subsidy is related to market elasticities. When the long-run supply (LRS) curve is perfectly inelastic, the subsidy also lifts the rent paid by a tenant in the long run. The rent paid by a tenant is reduced in the long run when LRS is perfectly elastic. Supply-side conditions are also important for determining the extent a tenant benefits from a rental subsidy in the long run. Indirectly, homeowners benefit from a rental subsidy as it lifts house prices and stimulates housing wealth in the long run. It is intriguing that homeowners benefit from the rental subsidy as house prices increase.

The rest of the paper is structured as follows. The next section presents our augmented DPW model, while related literature and the model set-up is discussed in section three. The fourth section briefly shows the effects of business cycles and slow regulation of land on housing markets, and the fifth section analyses a set of housing policies. The final part provides a summary of the results.

## The model

Borgersen and Emblem (2022) sets out an Augmented DiPasquale-Wheaton (ADPW) model where a PR ratio ties the model closer to residential housing markets. Analysing the links between housing and mortgage markets, the paper addresses user cost gross of taxes. Here, this model is extended to explicitly incorporate taxation aimed at the market for rental and owner-occupied housing, applying the user cost approach. The subsequent analysis abstracts from speculation in the market for housing and assumes perfect tenure flexibility. A minimalistic presentation of the model is given in the following.

The housing market consists of the market for owner-occupied housing, the market for rental housing, and the housing construction industry. The model also considers the relation between the flow and the stock of housing.

Housing services may be obtained in the rental market at a unit rental price *R*, or in the owner-occupied housing market at the prevailing user costs of homeownership. While the rental price is explicit in the market, the user cost of owner-occupied space is implicit. By assumption, households are indifferent between shelter services provided in the rental and the owner-occupied housing markets, i.e., housing is a homogenous commodity.

The model is illustrated by means of four quadrants. The first quadrant of the model determines the price of rental housing. The model assumes a given level of housing stock, $S_0$. Let $H$ denote the number of households in the economy. We assume a conventional downward sloping demand curve $D$ related to household income $\beta_0$ and the rental price $R$, expressed as $D = H(\beta_0 - \beta_1 R)$. We introduce two social housing policy parameters in the rental housing market: a rental subsidy $t_s$ and an affordability subsidy $t_a$, making rental demand equal to $D = H(\beta_0(1 + t_a) - \beta_1 R(1 - t_s))$. It follows that rental demand is increasing in $t_a$ and $t_s$. While the former enhances household income, often targeting low-income households, the latter is a direct subsidy of the cost of renting.

The rental market equilibrium is ensured by the intersection of the supply of housing $S_0$ and the demand for rental housing. The rental market equilibrium is given by a rental price:

$$R_0 = \frac{\beta_0(1+t_a)-(S_0/H)}{\beta_1(1-t_s)}. \tag{1}$$

The aggregate housing stock is allocated between the two forms of tenure $S_0 = S^{rental} - S^{own}$, where the rental housing stock $S^{rental}$ is determined together with the stock of owner-occupied housing $S^{own}$ in equilibrium, making $S^{rental} = S_0 - S^{own}$. To enhance reader-friendliness the model considers the role of the aggregate housing stock instead of the allocation of the housing stock between the two forms of tenure at the cost of a scaling effect on prices. In Appendix 1 we neutralise the scaling effect when the equilibrium allocation of the housing stock between rental and owner-occupied housing is determined.

The user costs of owner-occupied housing services, *U*, is dependent not only on the market price of the housing unit but also on the financing structure of the housing purchase, among which is the loan-to-value (LTV) ratio, the mortgage interest rate, and costs associated with the house itself (e.g., maintenance costs). Along the lines of Himmelberg et al., (2005) we consider the following cost of owner-occupied housing:

$$U = (1-\theta)r^{RF}P + \gamma P + \delta P + \theta r^{M}P(1-t_m) - gP + t_p P. \tag{2}$$

where $P$ denotes the market value of owner-occupied housing. The parameter $\theta$ represents the loan-to-value (LTV) ratio, the risk-free interest rate is given by $r^{RF}$, and $r^M$ is the mortgage rate while $g$ equals the house price growth rate and gives us the capital gain of ownership. The rate of depreciation is given by $\delta$ and $\gamma$ is the risk premium of owner-occupied housing over renting. The two tax parameters represent the tax-deductibility of mortgage rates: $t_m$ and the property tax: $t_p$. While the former reduces the user cost, the latter has the opposite effect. We ignore transaction costs and inflation.

The expression for annual user costs in equation 2 can be rewritten as $U = uP$ where $u$ is the user cost per euro of housing service value and given by:

$$u = (1-\theta)r^{RF} + \gamma + \delta + \theta r^{M}(1-t_m) - g + t_p. \tag{3}$$

Since, by assumption, households are indifferent between owning and renting (i.e., the two are perfect substitutes), then in a housing market equilibrium, the user cost of owner-occupied housing should equal the rent on rental housing:

$$uP = R. \tag{4}$$

This amounts to the owning-renting no-arbitrage condition and may be expressed as a conventional PR ratio:

$$\frac{P}{R} = \frac{1}{u}. \tag{5}$$

This PR ratio links the rental housing market equilibrium explicitly to the inverse of the user cost of owner housing.[1]

Figure 1 illustrates the ADPW model. The north-east quadrant of the model determines the equilibrium rental price of housing at a given level of housing stock $S_0$. The no-arbitrage condition ensures that in equilibrium, this rental price $R_0$ equals user cost of owner-occupied housing. At the prevailing user cost per euro of housing service value ($u_0$), the price of owner-occupied housing $P_0$ is determined in the north-west quadrant. The ray emanating from the origin is related to the inverse of the user cost per euro of housing value: *1/u*.

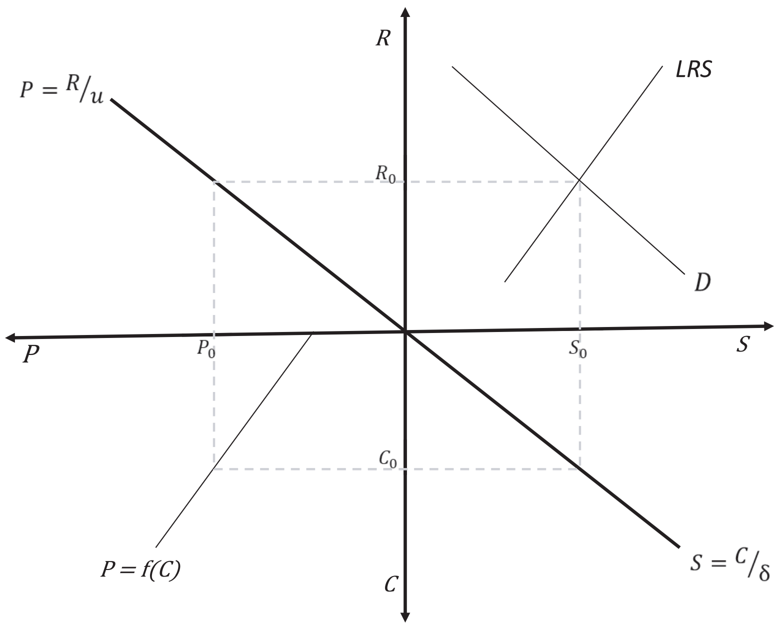


**Figure 1.** The Augmented DiPasquale-Wheaton model.

1 Appendix 1 relates the user cost to the tenure distribution in the housing market. A higher user cost goes together with a more rental-intensive (and less owner-occupied) housing market equilibrium structure.

The housing construction industry is depicted in the south-west quadrant. The level of construction is given by $C = c_0 + c_1P$, relating the activity in the housing construction industry to the house price level. The housing construction industry is characterised by decreasing returns to scale and, as competition eliminates all excess return, the market adaption resembles a Tobin's Q condition where the level of construction is determined by equality between the house price and the cost of construction. The recursive model structure implies that the equilibrium house price level $P$ is determined in the north-west quadrant. The equilibrium flow of housing $C_0$ is then equal to:

$$C_0 = c_0 + c_1P_0. \tag{6}$$

The housing stock is determined in the south-east quadrant. The housing supply is related to the rate of physical depreciation $\delta$ and the level of housing construction by $\Delta S = C - \delta S$. By assumption, the rate of depreciation is identical for owner-occupied and rental housing.[2] If the level of depreciation of housing stock $\delta S$ is equal to the number of housing-starts $C$, then $\Delta S = 0$ and the equilibrium level of housing stock is equal to:

$$S_0 = \frac{C_0}{\delta}. \tag{7}$$

The long-run supply curve (LRS) as derived by Colwell (2002) is found by using the conditions $\Delta S = 0$ and $\Delta S = C - \delta S$. The LRS expression is derived by inserting for housing starts $C = c_0 + c_1P$ and rearranging, hence: $S = \frac{c_0}{\delta} + \frac{c_1P}{\delta}$. Finally, inserting for house prices from the non-arbitrage condition $P = \frac{R}{u}$, the LRS curve is given by:

$$S = \frac{c_0}{\delta} + \frac{c_1}{\delta} * \frac{R}{u} \tag{8}$$

It follows that the position of the LRS curve is affected by the price of rentals, the user cost of housing and the construction industry's cost components. The LRS curve gives the model an integrated short- and long-run equilibrium at the intersection of the LRS curve, the demand for rental housing and the vertical short-run supply curve.

The long-run equilibrium determines rent, house prices, housing construction and the housing stock ($R_0$, $P_0$, $C_0$, $S_0$). Our ADPW model hence relates the market for rental housing to the markets for owner-occupied housing and housing construction. As the different parts of the housing market system are interrelated, the model provides a comprehensive framework for housing market analysis and sheds light on both direct and indirect effects of shocks.

2 The user-cost expression for owner-occupied housing includes depreciation quite conventionally. Differences in rate of depreciation between rental and owner-occupied housing might impact the housing market equilibrium, as expressed by the PR ratio. A higher rate of depreciation of rental housing will influence the rental price set by a landlord and, hence, a household's choice of tenure. As the PR ratio is based on a demand-side approach equating the cost of different forms of tenure, the higher depreciation cost associated with rental housing would be reflected in the rental price paid by a tenant in a competitive market. While depreciation of owner-occupied housing is explicit in the user cost, the depreciation of rental housing is implicitly included in the rental price paid by a tenant, allowing differences in depreciation rate across form of tenure to impact the housing market equilibrium. To simplify, we assume the rate of depreciation to be equal across forms of tenure.

## Discussion of the model set-up

The DPW model analyses the links between the different parts of the real estate system. The model is illustrated by means of four quadrants, each describing a long-run equilibrium situation. While typically used to study commercial real estate, the model may also describe the market system for owner-occupied real estate (DiPasquale & Wheaton, 1992). Different aspects of the DPW model are analysed by Aschour-Fischer (1999), Colwell (2002), de Salvo (2017) and Lisi (2015, 2020). Leung and Wang (2007) analyse developments in the Chinese housing market in a DPW framework, tracing the impact of different policies. In these contexts, housing is typically implicitly treated as an investment object. Owner-occupied housing serves however multiple purposes: e.g., a consumption good offering housing services, an investment object, serving as a collateral for mortgages (Sommervoll et al., 2010), and the role of housing consumption may be argued particularly important for understanding housing demand.

In the following, our ADPW model is discussed.

The *first* important link for the model's housing market dynamics is that of rental and owner-occupied housing. The market for rental housing is linked to the market for owner-occupied housing by a price-rent (PR) ratio equating the cost of housing services across different forms of tenure, i.e., renting or owning. This no-arbitrage condition ensures that households are indifferent between the two types of tenure.

The PR ratio is a well-established condition for housing market equilibrium (see e.g., Ayuso & Restoy, 2006; Gallin, 2008; Kishor & Morley, 2015; Hill & Syed, 2015). As the DPW model relates housing rent and housing price, extending the model to integrate the PR ratio seems logical. To the best of our knowledge, Borgersen and Emblem (2022) is the first to link rental and owner-occupied housing by means of a PR ratio in the DPW model. This paper augments Borgersen and Emblem (2022) by considering the after-tax user cost and extending the model framework to allow for assessment of a wide set of housing policies.

The no-arbitrage condition is in many ways strict, as owner-occupied housing may indeed offer additional non-monetary benefits (emotional, social standing, etc.) than rental housing does. Moreover, focusing on monetary aspects of tenure decision, in real housing markets transaction costs impact the choice of changing housing (Corradin et al., 2014), uncertainty matters for housing demand (Han, 2010), and when including the investment aspect of housing: portfolio considerations might matter for the choice of tenure (Poterba, 1984; Berkovec & Fullerton, 1992). Indeed, the long-run nature of housing investments may give sub-optimal portfolio shares for housing during periods of house price growth, and liquidity constraints might impact tenure choices (Yao & Zhang, 2005).[3] Since the model is a long-run equilibrium model, issues of transaction costs, portfolio considerations and low liquidity are toned down.

The *second* link important for the model's housing market dynamics is supply-side elasticity. In analyses of the supply side of housing markets, the inelasticity of the supply side is often in focus (see e.g., Ball, 2012 or Caldera & Johansson, 2013). There are nuances to the supply-side elasticity argument. Pirounakis (2013) argues that the elasticity of housing supply increases with the share of capital costs in total development costs, the elasticity of substitution between land and non-land inputs and the supply elasticity of developable land. The elasticity decreases if the share of land costs in total cost rise, an argument which implicitly distinguishes between supply-side elasticities in different markets segments, i.e.,

3 Homeownership is also hump-shaped across the lifecycle (Chambers et al., 2009), allowing for demographic nuances in terms of tenure.

between segments for detached housing and apartment buildings. Analysing US metropolitan areas, Aastveit et al. (2019) find declining supply elasticities over the period 1996–2004, and the largest decline is in areas where land-use regulations have tightened the most. Likewise, Herkenhoff et al. (2018) find large changes in land-use regulations in most US states over time, with the largest declines in supply elasticity being in states where regulations have tightened the most. Differences in supply elasticities are identified as a driver of cross-sectional variation in US house prices (Huang & Tang, 2012; Glaeser et al., 2008).

The distinction between market segments is also relevant for the *third* important link in the model: the link between the flow of housing (i.e., construction) and the stock of housing, as derived from the relation between the rate of depreciation and the volume of new construction. The model is stylised and assumes the same rate of depreciation across the system. Empirically, the depreciation of rental housing is found to exceed the rate of depreciation of owner-occupied housing (Getzlaff et al., 1988; Harding et al., 2000, 2007). As the PR ratio equates the cost of different forms of tenure in equilibrium, a higher depreciation cost associated with rental housing is reflected in the rental price paid by a tenant in a competitive market and will thus influence the choice of tenure. The model does not address the issue of housing units differing with respect to quality and type (e.g., apartments and detached housing), and correspondingly does not address variations in the provision of housing services. Such a heterogeneous housing market structure could invalidate the assumption where new construction is a perfect substitute for depreciation of existing housing, which prevails in our homogenous housing market structure model.

Variations in either of the three links between the four quadrants in the model may produce different market dynamics than predicted by our benchmark market outcome, either in rental prices, house prices, construction, the housing stock, or a combination of these.

The model application is on housing policy, and housing market policies are analysed in a number of papers (e.g., Apgar, 1990; Agnello & Schuknecht, 2011). After the US subprime mortgage crisis, several papers highlight the importance of housing markets for macroeconomic development, focusing on policy interventions to avoid financial crisis and housing market busts (see e.g., Aherne et al., 2005; Goodhart & Hoffman, 2008; Duca et al., 2010). Others such as Himmelberg et al. (2005) or Maclennan (2012) focus more on the housing market itself. This paper relates to the latter of these papers, analysing a set of housing market policies and taking into account the links between different parts of the housing market system, in particular: the link between the different markets for tenure. A significant volume of literature analyses households' choice of tenure. Implicitly, there is an argument across this reasoning in favour of policy interventions supporting home ownership if the aim is to sustain owner-occupation over renting. The question of affordability is discussed in several papers, see e.g., Meen and Whitehead (2020) or Galster and Lee (2021) and the literature therein. While owner-occupied housing is the dominant form of tenure across the western hemisphere, some question whether this will still be the case following recent changes in labour markets (Arundel & Doling, 2017; Haffner et al., 2017).

The focus in this paper is on long-run implications of housing market policies, in particular policies affecting affordability and user costs. Analysing affordability in the short and long run, Haffner and Heylen (2011) link long-run affordability to user costs. Related to this is the connection between user cost and homeownership as discussed by Diaz and Luengo-Prado (2008), who find a bias in terms of cheaper housing services for homeowners than renters, such as mortgage interest payments being deductible. A tax-deductible mortgage rate reduces the user cost of owner-occupied housing and favours owner-occupied housing over rental directly. A tax-deductible mortgage rate is a type of policy analysed by many papers (Poterba & Sinai, 2008; Bourassa et al., 2013; Hanson, 2012; Hanson & Martin, 2014; Splinter, 2019; Karlman et al., 2021). Likewise, property tax, or tax on housing equity (gains), affect homeownership by increasing the user cost of owner-occupied housing, impacting house price growth and divergence of asset accumulation across groups of households with different forms of tenure (Weiss, 1978; Bai et al., 2014; Bhutta & Keys, 2016). The direct effects of policies addressing insiders in the market for owner-occupied housing are analysed by e.g., Englund (2003) and Poterba and Sinai (2008), but to the best of our knowledge few, if any, analyse explicitly the indirect effect on renters and rental markets.[4] While papers focusing on the PR ratio analyse the interrelation between different forms of tenure, others focus on rental housing separately. The seminal Smith (1974) and Rosen and Smith (1983) papers analyse partial price adjustment in rental markets.

Generally, the social housing policy discussion is focused on whether governments should intervene on the supply or on the demand side of housing markets, and whether to support renting or owning. Analysing policy interventions on the supply side of housing markets, the crowding-out debate dominates (Sinai & Waldfogel, 2005; Nordvik, 2006; Eriksen & Rosenthal, 2010). Housing subsidies is the focus of Yates (2012), while Malpezzi and Vanell (2002) consider the effect of a low-income tax credit on the supply of housing. Highlighting the demand side of the housing market, some focus on whether to support renting or owning (see for instance Galster, 1997). In this paper, we focus on the interrelations between direct and indirect effects across the housing market system, both when analysing supply-side interventions and potential crowding out, and when analysing social housing policies on the demand side, i.e., rental or affordability subsidies.

A seminal approach to housing market policies is given by e.g., Poterba et al. (1991), Poterba (1992), or Bruckner (1997). Sommer and Sullivan (2018) is a later contribution that considers tax policy implications for US housing markets in an equilibrium housing market analysing rent, house prices and homeownership. Allowing for links between different parts of the housing market system, this approach is related to this paper highlighting indirect effects of different types of housing policy.

## Housing market analysis: the effects of business cycles and land regulation

Short-run analysis of housing markets often highlights the effect of business cycles (see e.g., Davis & Heathcote, 2005; Leamer, 2007) and the inelastic housing supply curve often related to the slow regulation of land for housing construction by local governments (see e.g., Ihlanfeldt, 2007; Paciorek, 2013) on house prices. In this section, we track the long-run effects of (*i*) a business cycle expansion and (*ii*) slow regulation of land. We derive model predictions in terms of how the market for rental housing, the market for owner-occupied housing, and the housing construction industry respond to each of these two types of shocks.

4 For an interesting overview of housing taxation in Europe, see Barrios et al. (2019). The paper analyses tax incentives favouring homeownership, thus creating distortions for households and markets, and sets out a database for housing taxation in 28 European countries. Housing tax incentives may have significant costs through reduced tax revenues and affect agents' decisions adversely related to labour market decisions and investment choices, while having positive effects on wealth accumulation, children's school performance, neighbourhood stability and improved maintenance.

We start by considering how the business cycle affects the long-run market equilibrium. The initial market equilibrium is given by ($R_0$, $P_0$, $C_0$, $S_0$) as illustrated in Figure 2. A positive shock to output stimulating employment and household income is illustrated by a positive shift in the demand for rental housing in the north-east quadrant. As shown in Figure 2, the new housing market equilibrium is given by ($R_1$, $P_1$, $C_1$, $S_1$).

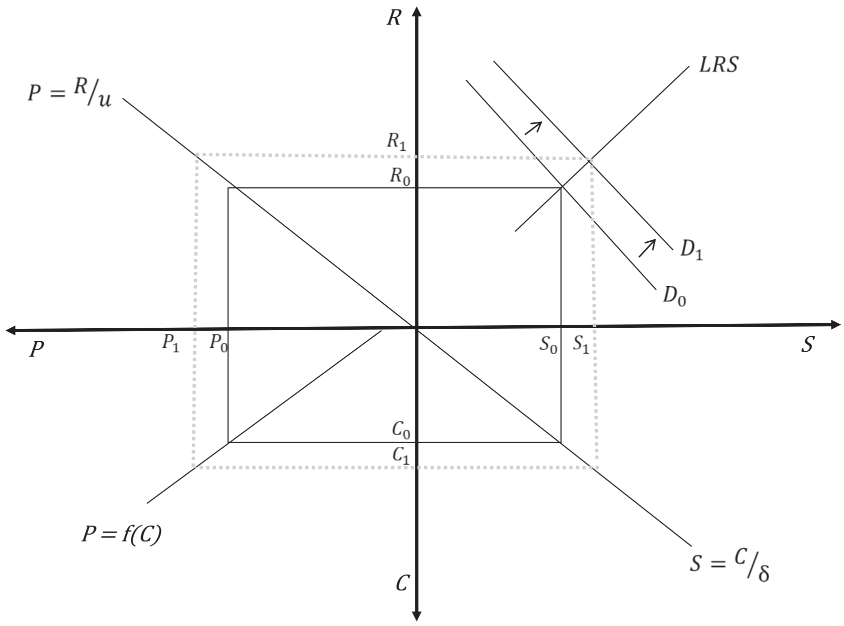


**Figure 2.** The business cycle effect on the housing market.

Compared to the initial equilibrium, the positive business cycle shock has increased rent $R_0 \rightarrow R_1$, house prices $P_0 \rightarrow P_1$, activity in the construction industry: $C_0 \rightarrow C_1$ and the housing stock $S_0 \rightarrow S_1$. Naturally, the size of changes depends on the elasticities of the different functions (illustrated by the slopes of the different curves). In Figure 2 we only sketched the two equilibrium situations, as given by ($P_0$, $P_1$) for house prices, ($R_0$, $R_1$) for rental prices and ($C_0$, $C_1$) for housing construction.

The DPW model is basically a static model and as such does not address the short-run market dynamics. Even in this paper the long-run outcomes are in focus. One could, along the lines of Colwell (2002), describe the adjustment process from one equilibrium to another. However, the adjustment process is lengthy and may not be smooth, and the short-run market dynamics and the process to the new equilibrium may resemble a cobweb. Indeed, the short-run market dynamics may be convergent or divergent.[5]

Turning to the supply side and the rather inelastic supply curve characterising several housing markets, we relate supply inelasticity to slow (and strict) public regulation of land available for housing construction. Slow regulation limiting the availability of land for residential building, imposes higher costs on the construction industry. Here we

5 In our model, we assume a convergent cobweb structure. In the case of a relatively flat demand curve, the adjustment process may not be described by a lengthy adjustment processing (cobweb structure), but indeed by a one-period adjustment. So, while we implicitly assume a convergent cobweb structure with some overshooting, the case of a no-dynamic cobweb is in conformity with the arguments in section 5. If overshooting is absent, the housing market system moves directly from one equilibrium to another. In this paper, we do not focus on the adjustment process as such, but rather on the long-run outcomes.

assume this cost effect to increase the industry's fixed costs $c_0$, which shifts the cost curve leftwards in the south-west quadrant as illustrated in Figure 3. As the activity in the housing industry is reduced and the number of housing starts falls $C_0 \rightarrow C_1$, the housing stock decreases $S_0 \rightarrow S_1$. From equation 8 we see that the LRS curve will shift leftwards as illustrated in the north-east quadrant. Regulation of land thus has an impact on the market for both types of tenure. In fact, in the housing literature it is a conventional argument that when regulation of land tightens, house prices increase. A less-argued effect is how the reduction in the number of housing starts affects the rental housing market. As shown in Figure 3, a reduction in the level of construction reduces the stock of housing, which increase rent $R_0 \rightarrow R_1$ and makes house prices increase $P_0 \rightarrow P_1$. Thus, tighter regulation of land harms both forms of tenure as both $R$ and $P$ increases. The new market equilibrium is given by $(R_1, P_1, C_1, S_1)$.

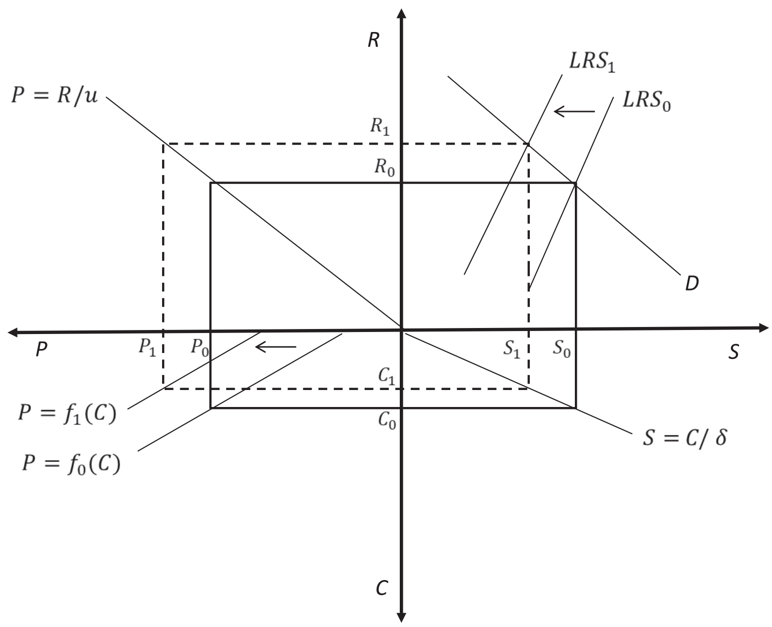


**Figure 3.** The effect of strict supply-side regulation of residential land.

The long-run effects of the two types of shocks to the housing market are summarised in Table 1. Arrows in red indicates the outset of the shocks (i.e., short-run effect).

**Table 1**. Long-run equilibrium effects of a positive business cycle and strict land regulation in an augmented DiPasquale-Wheaton framework

| | Rent | House prices | Housing starts | Housing stock |
|---|---|---|---|---|
| Positive business cycle | ↑↑ | ↑ | ↑ | ↑ |
| Land regulation | ↑ | ↑ | ↓↓ | ↓ |

## Housing market policies

In our analysis of housing market policies, several topics are debated. In the following we discuss the implications of different policies aimed either at the owner or the rental housing market. Since we are using the no-arbitrage model, such policies may in the short run disturb, or even cut, the links between the market for owner occupied housing and that of rental housing. Our discussions will thus focus mainly on the long-run implications, taking both direct and indirect effects of different policies into account. Moreover, without loss of generality, we simplify the graphic illustration by abstracting away from changing slopes of the LRS curve and only illustrate parallel shifts.[6]

We will subsequently consider the effect of introducing permanent taxes and subsidies. As taxes and subsidies are permanent, their effect on the housing market system is fundamental. Naturally, as the ADPW model shows aggregate effects, our policy analysis is also stylised with respect to magnitude. For instance, when analysing affordability, we implicitly assume that all households benefit from affordability interventions. Likewise, when analysing tax-deductible mortgage rates, we treat all housing investments to be partially mortgage-financed. In real housing markets, the effects of such measures are more nuanced, depending on how tenure is divided between owner-occupied housing and rental housing, the number of households that would qualify for affordability subsidies and real housing market funding structures, i.e., the extent of equity and mortgage financed housing investments.

### Tax-deductible mortgage interest payments

A policy where owner-occupiers benefit from tax deductions $t_m > 0$ on their mortgage interest payments implies a reduction in the user cost of owner-occupied housing.[7] It follows that the higher the LTV ratio $\theta$, the larger the reduction in user costs, *cet. par*. Homeowners with heavy leverage hence benefit more from such a policy than do owners with lower leverage. Tax deductions of mortgage interest payments lower the cost of owner tenure relative to rental tenure and as such, may lead to overconsumption of owner tenure (see e.g., Berkovec & Fullerton, 1992, or Skinner, 1996).

Assuming an initial equilibrium illustrated by $(R_0, P_0, C_0, S_0)$ in Figure 4 – an equilibrium where mortgage rates are not tax-deductible, then introducing tax-deductible mortgage interest payments, implies a reduction in the user costs of owner-occupied housing, and hence a change in the equilibrium PR ratio, ref. equation 5. This is illustrated in Figure 4 by a downward rotation in the line in the north-west quadrant. A lower user cost lifts house prices $P_0 \rightarrow P_1$, which stimulates the number of housing starts $C_0 \rightarrow C_1$, increases the stock of housing $S_0 \rightarrow S_1$ and, as more space is made available in the market; subsequently brings down the rent $R_0 \rightarrow R_1$. The LRS curve will shift rightwards as illustrated in the north-east quadrant. The new long-run housing market equilibrium is thus given by $(R_1, P_1, C_1, S_1)$. While tax deductibility for mortgage interest payments increases house prices, we also see how renters benefit from lower rents as the housing industry responds to new price signals and increased profitability.

6 Referring to equation 8, the LRS curve equals $S = \frac{c_0}{\delta} + \frac{c_1}{\delta}\frac{R}{u}$, and when rearranged in terms of rent, $R = -\frac{c_0 u}{c_1} + \frac{\delta u}{c_1} S$. The relation between rent and housing supply equals $\frac{\partial R}{\partial S} = \frac{\delta u}{c_1} > 0$, where $u$ is net of tax user cost and $c_1$ is the responsiveness of construction to changes in house prices. It follows that the LRS curve has a positive slope. Moreover, the user cost impacts both the slope and the intersection of the LRS curve. Tax policies affecting the user cost will thus impact both the slope as well as the position of the LRS curve. This applies both for tax-deductible mortgage rates and property taxation. When we expand the model to allow for rental subsidies $t_S$, the rental price paid by a tenant equals $R^{tenant} = R(1 - t_S)$, making the LRS curve equal to $R = -\frac{c_0 u}{c_1(1 - t_S)} + \frac{\delta u}{c_1(1 - t_S)} S$. From this it follows that also the rental subsidy affects both the slope and the position of the LRS curve. Without loss of generality, we abstract away from changing slopes and illustrate policy shocks as parallel shifts in our graphical analysis.

7 We find the effect of tax-deductible mortgage rates on the user cost from equation (3) as $\frac{\partial u}{\partial t_m} = -\theta r_t^M < 0$.

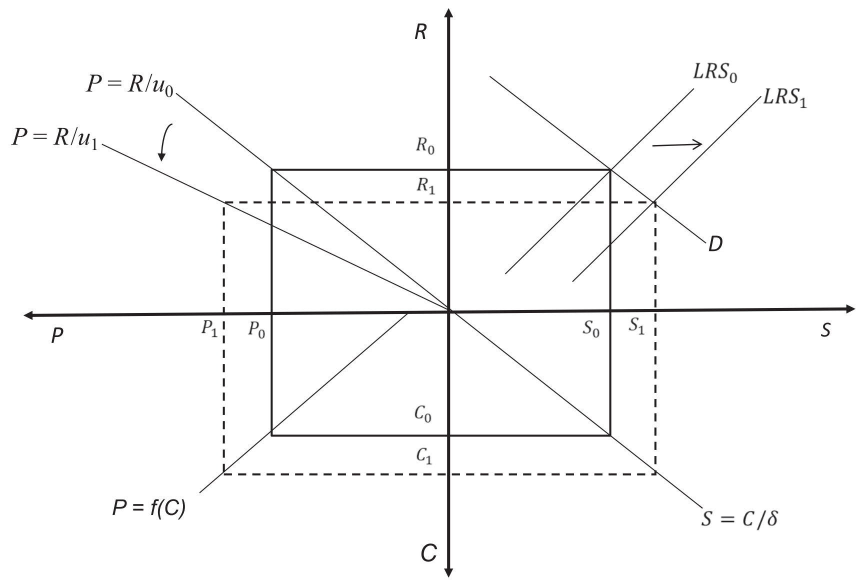


**Figure 4.** The effect of tax-deductible mortgage rates.

## Residential property taxation

Housing is the biggest investment for a household during its lifespan, and housing represents the ballpark of a household portfolio. Still, property taxation is somewhat politically controversial. A tax on housing may target housing wealth, or housing equity (gains), where the latter may be the most uncommon (e.g., among the European Union countries only Sweden and Cyprus issue capital gain tax on residential property, Barrios et al., (2019)).

Representing a substantial tax base and an efficient way to redistribute wealth, the lack of property taxation is provoking to many researchers. In the following we consider the effects of a property tax on the housing market system. Assume the initial long-run equilibrium situation ($R_0$, $P_0$, $C_0$, $S_0$) as illustrated in Figure 5. A property tax, $t_p > 0$, will increase the user cost of home ownership. This is illustrated in the north-west quadrant by an upward

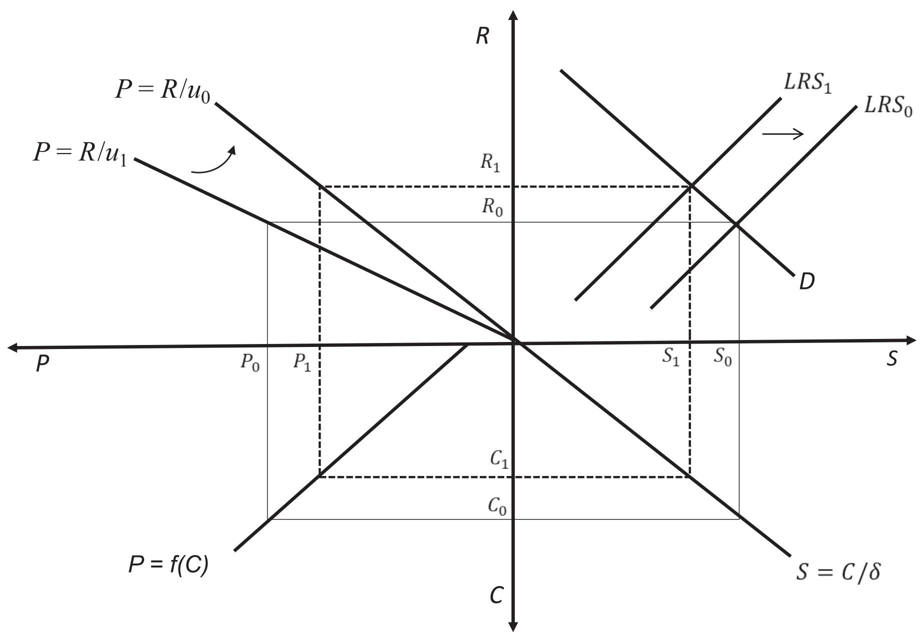


**Figure 5.** The effect of a property tax.

rotation in the curve equating the cost of different forms of tenure.[8] Higher user costs implies that prices fall $P_0 \rightarrow P_1$ which have a negative impact on the activity in the housing industry $C_0 \rightarrow C_1$ hence reducing the housing stock $S_0 \rightarrow S_1$. A lower stock increases the rent: $R_0 \rightarrow R_1$. The new long-run housing market equilibrium is given by ($R_1$, $P_1$, $C_1$, $S_1$). Thus, in the long run, although the property tax is issued on owner-occupiers, it imposes an economic burden also on households in the rental market through its indirect effect on the equilibrium level of rent.

## Social housing policy

Social housing policy might take the form of stimulating demand or supply. Here, we consider three social housing policy measures: two stimulating housing demand (rental subsidies and income affordability) while the third resides on the supply side of housing markets (public housing).

### Rental subsidies

Rental subsidies are commonly analysed in a static supply and demand context where the rental subsidy produces a gap between the rent received by the landlord and the rent paid by the tenant. A subsidy produces a deadweight loss as it introduces a wedge between the marginal cost of providing rental space and the marginal willingness to pay for space. By means of our ADPW model, we will show how the subsidy is passed through the housing market. As the model allows for different long-run outcomes, we start out with some short-run assessments.

Let the initial housing market equilibrium be given by ($R_0$, $P_0$, $C_0$, $S_0$) and introduce a (permanent) rental subsidy: $t_s > 0$. The subsidy will induce demand for rental space, illustrated in Figure 6 by a rightward shift in the demand curve. In the short run, since the stock of space is fixed, the subsidy does not alter the rental price paid by tenants ($R^{tenant}$), while the rental price received by landlords ($R^{landlord}$) increases by the full amount of the subsidy: $R^{landlord} = R^{tenant} + t_s$, ref. Figure 6.

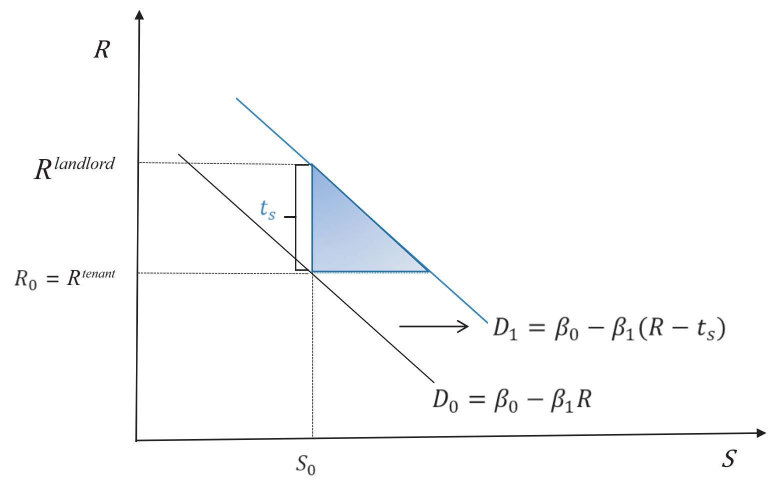


**Figure 6.** The short-run effect of a rental subsidy.

8 Comparative statics on the user cost (equation 3) of a tax on housing equity finds $\frac{\partial u}{\partial t_p} = 1 > 0$.

From the point of view of landlords, higher rental earnings make investments in real estate assets more profitable, *cet. par.* This will put an upward pressure on prices which will prompt the housing industry to increase construction. Hence, in the intermediate and long run, the supply of space will increase and dampen the initial effect on landowners' rent over time. The blue triangle in Figure 6 identifies the range within which the market rent for tenants may be a new long-run equilibrium. Let $0 \leq \omega \leq 1$ denote the fraction of the subsidy benefitting the tenants. Tenants may benefit from the subsidy in full (i.e., $\omega = 1$), or not benefit from the subsidy at all (i.e., $\omega = 0$). From the tenants' point of view, the subsidised rent makes rental housing relatively cheaper than owner-occupied housing: $R(1 - t_s) < uP$. Hence, the no-arbitrage condition between the two types of tenures is distorted and the housing market is not in equilibrium as the subsidy will induce a downward pressure on prices in the market for owner-occupied housing, *cet. par.*

In the long run, the net effect of a rental subsidy on the housing market equilibrium depends on the elasticity of demand for space and the elasticity of long-run supply. The benefit from a rental subsidy is mainly shifted towards landlords in situations in which the LRS is quite inelastic, while the subsidy is shifted towards tenants when LRS is elastic. Moreover, the less elastic the demand for rental housing, *cet. par.*, the larger the share of the subsidy accrues to tenants, and relatively less to landlords.[9]

In the following, we will briefly discuss these two extreme situations, i.e., $\omega = 1$ and $\omega = 0$, and the implications for the overall housing market outcome. We start out, however, with a short description of an intermediate situation in which the LRS is elastic.

In figure 7, we illustrate a situation in which both the LRS and the demand for rental space is assumed to be price-elastic. The subsidy will induce demand for rental housing and subsequently putting an upward pressure on rent ($R$). This is illustrated by a rightward shift in the demand curve in the north-east quadrant. Moreover, the PR ratio will change as illustrated by a downward rotation in the line in the north-west quadrant. Assuming that the demand-side effect of the subsidy dominates, then in the new long-run equilibrium, the market rent, housing prices, level of construction and stock of space will be higher compared to an equilibrium situation without a rental subsidy: $R_1 > R_0$, $P_1 > P_0$, $C_1 > C_0$ and $S_1 > S_0$.[10]

It is noteworthy that the rental subsidy has led to both higher rental prices and higher prices on owner-occupied housing. The rental subsidy's effect on the LRS curve dampens the increase in rental prices. As illustrated, the rental subsidy also benefits

9 The slope of the demand curve is given by $\frac{dR}{dS} = \frac{-1}{\beta_1(1-t_S)}$ from which it follows that the higher the price sensitivity (i.e., the higher the responsiveness ($\beta_1$) to changes in R), the flatter the curve.

10 A rental subsidy will impact both the LRS curve and the demand for rental housing. While the shift in rental demand pushes for higher rental prices, the effect of the shift in the LRS curve pushes in the opposite direction. As we consider parallel shifts, the condition for the demand-side effect to dominate and the subsidy thus leading to a higher long-run rental price ($R_1 > R_0$), (as illustrated in Figure 7) may be expressed in terms of a critical price responsiveness of rental demand: $\beta_1 < \beta_1^{critical} = \frac{\beta_0(1+t_a)c_1}{c_0 u}$. This condition is highly context-specific, and among others, related to the price responsiveness of housing construction. When $\beta_1 = \beta_1^{critical}$ the LRS effect balances the demand effect, making $R_0 = R_1$, while $R_0 > R_1$ comes about if $\beta_1 > \beta_1^{critical}$.

owner-occupiers since house prices have increased relative to a situation without a rental subsidy: $P_1 > P_0$.[11,12]

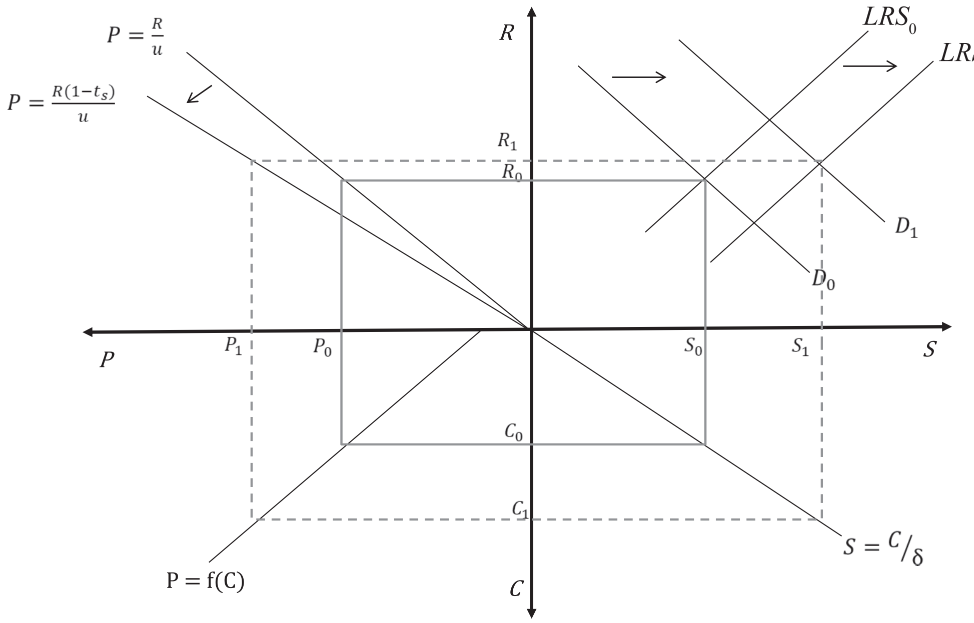


**Figure 7.** The effect of a rental subsidy.

We now proceed to discuss the two extreme situations, i.e., $\omega = 1$ and $\omega = 0$.

(i) Perfectly elastic long-run supply of space

In Figure 8, we illustrate a situation in which the LRS curve is perfectly elastic. This may occur in situations where there is ample access to regulated land, low cost of construction, and low rate of depreciation, ref. equation 8.

A permanent rental subsidy issued by the government will induce demand and alter the long-run supply of space. Hence, as illustrated in the north-east quadrant of Figure 8, the demand and the LRS curve will both shift. The subsidy will thus lead to a new long-run equilibrium situation in which the equilibrium market rent is lower, the prices are higher, and the construction and stock of space are higher compared to a situation without a subsidy, i.e., $R_1 < R_0$, $P_1 > P_0$, $C_1 > C_0$ and $S_1 > S_0$.

In this situation, the subsidy will benefit not only tenants through a lower market rent, but also homeowners through higher house prices.

11 It may be argued that a rental subsidy may ease investors' required capitalisation rate in the rental market compared to a situation without a subsidy. In such a situation, there will be a discrepancy between the per euro user cost of owner-occupied housing and the required rate of return by investors in the rental market: $u \neq i$, *cet. par.* This may be illustrated by two different rays in the north-west quadrant of the diagram.

12 As stated earlier, we have abstracted away from potential overshooting as we consider long-run equilibriums. Short-run market dynamics, and overshooting, may be especially complicated to assess with a wedge between the rent paid by tenants and the rent received by landlords as the two create different incentives across market participants. Wheaton (1999) studies real estate cycles and finds that if demand is less elastic than supply, the stock-flow model is more stable.

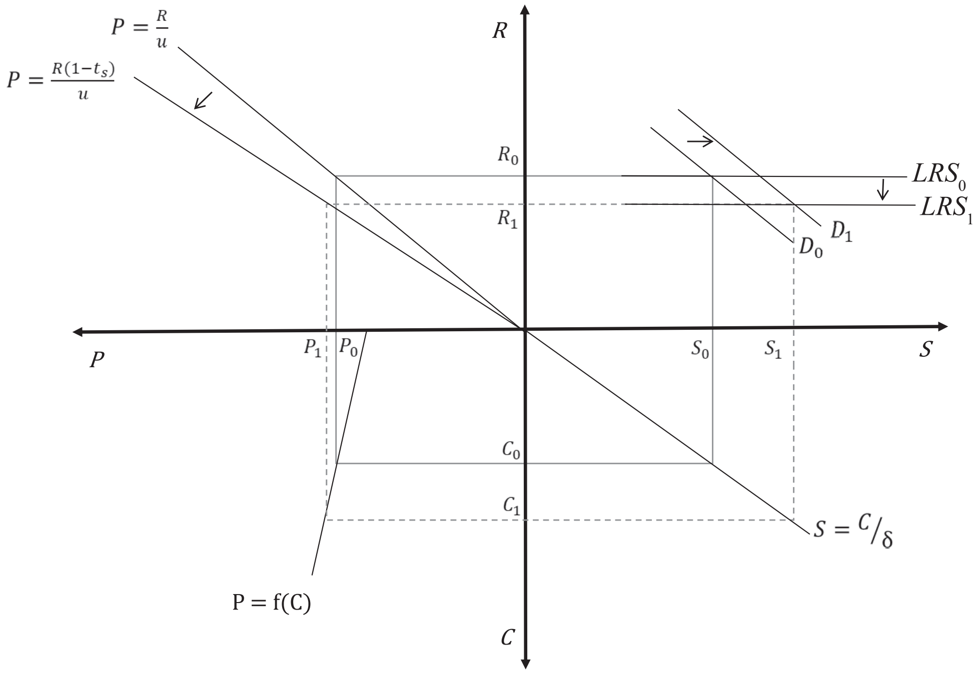


**Figure 8.** The effect of a rental subsidy when the long-run supply is perfectly elastic.

(ii) Perfectly inelastic long-run supply of space

Figure 9 describes the long-run equilibrium in which the LRS is perfectly inelastic. This may occur in situations in which there is limited access to regulated land, a high cost of construction, and a high rate of depreciation, ref. equation 8. As shown in the south-west quadrant, construction is depicted as not very price-elastic. Assuming that demand for space is elastic, then introducing a permanent subsidy will lead to higher rent, higher prices, higher level of construction, and a higher stock of space. As illustrated, while the increase in rent and prices are relatively large, the increase in construction and the addition of space is relatively small. Under these assumptions, the subsidy in the new long-run equilibrium will fully benefit landlords – and not tenants (who indeed pay a higher rent compared to the situation without a subsidy), i.e., $R_1 > R_0$, $P_1 > P_0$, $C_1 > C_0$ and $S_1 > S_0$.

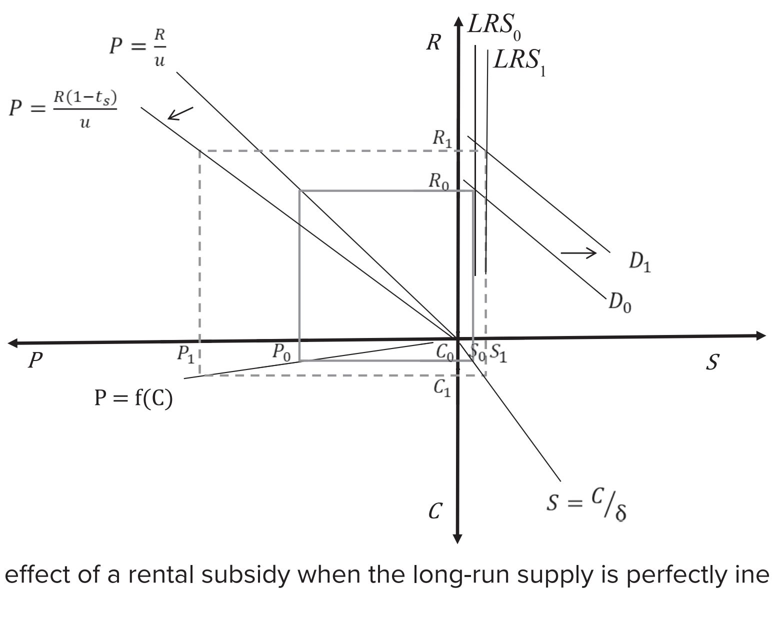


**Figure 9.** The effect of a rental subsidy when the long-run supply is perfectly inelastic.

**Income affordability**

Measures to improve housing affordability as discussed by Leishman and Rowley (2012) or Hedlund (2019) can be analysed similarly to the business cycle effect and illustrated as in Figure 2. Increased affordability $t_a > 0$ stimulates the demand for rental housing and lifts rents, and, using the PR ratio argument, also house prices.[13] When house prices increase, higher profitability in the housing industry stimulates construction, and as the number of housing starts increase, so, ultimately, does the housing stock too.

**Public housing**

The original DPW model assumes a fixed housing stock in equilibrium, i.e., $\Delta S = 0$. This assumption constrains the effect of any supply-side intervention, as all supply-side interventions imply complete crowding-out. Sinai & Waldfogel (2005) argue a successful housing program to either increase the number of housing units or lift the quality of the housing stock.

Therefore, we consider a social housing policy intervention where the aim is to increase the housing stock by a net amount of $n$. Hence, the aggregate housing supply now consists of the commercial housing supply $\left(\frac{C}{\delta}\right)$ and the supply of public housing: $S = \frac{C}{\delta} + n$. Graphically, this is illustrated by a rightward shift in the curve relating the housing stock to the flow of housing in the south-east quadrant in Figure 10. The new LRS curve equals $S = n + \frac{c_0}{\delta} + \frac{c_1 R}{\delta u}$, and there will be a shift in the LRS curve from $LRS_0 \rightarrow LRS_1$ in the north-east quadrant.

Figure 10 shows how this supply-side intervention "rumbles through" the housing market. The initial housing market equilibrium is given by ($R_0$, $P_0$, $C_0$, $S_0$). As the government supply public housing, the aggregate housing supply increases $S_0 \rightarrow S_1$ and pushes down equilibrium rent $R_0 \rightarrow R_1$. The equilibrium condition for the housing market, as given by

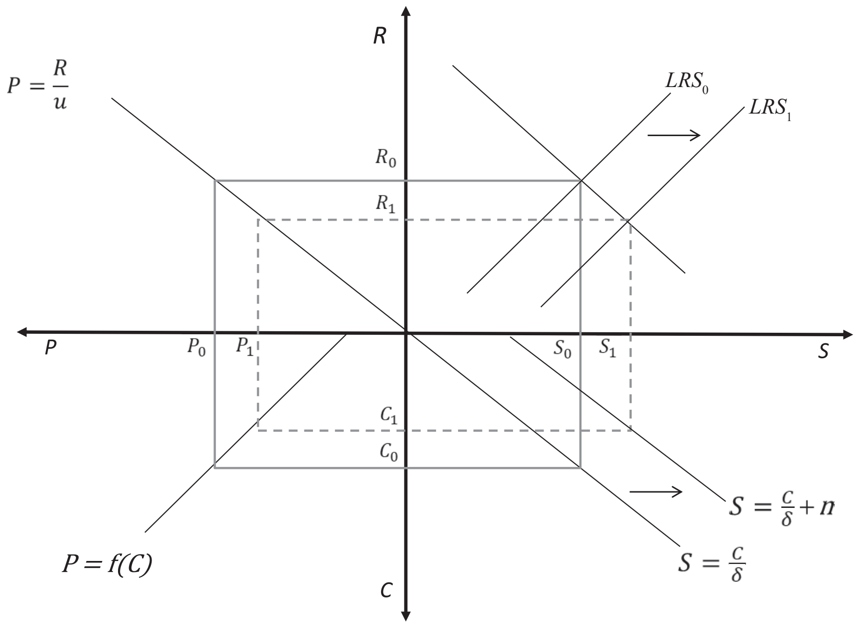


**Figure 10.** The effect of a public supply of housing.

13 Comparative statics on equation 1 shows how income affordability lifts the rental price $\frac{\delta R}{\delta t_a} = \frac{\beta_0}{\beta_1(1-t_a)} > 0$.

the PR ratio, reduces house prices $P_0 \rightarrow P_1$. Lower house prices reduce construction activity $C_0 \rightarrow C_1$, which impacts the housing stock negatively. This crowding-out effect reduces the aggregate effect on the housing stock of public housing programs as $(S_1 - S_0) < n$. The new housing market equilibrium is given by $(R_1, P_1, C_1, S_1)$.

Hence, even if we ease the initial DPW equilibrium assumption $\Delta S = 0$, the model still predicts some crowding-out, but crowding-out is now incomplete.

## Conclusion and discussion

The housing market system includes the market for rental housing, the market for owner-occupied housing and the housing construction industry. The link between the different parts might be subtle, bi-directional, and vary depending on the time horizon in question.

In our augmented version of the DPW model taking the PR ratio into account and allowing for a net of tax user cost, we aim to set out a non-technical framework for analysing the links between different parts of the housing market system. Using this ADPW model, we analyse a set of housing market policies to see how these affect the long-run equilibrium in the housing market. Our ambition is to provide a non-technical and pedagogical framework to structure housing policy arguments.

Allowing for both direct- and indirect effects between owner-occupied housing, rental housing markets and housing construction, our ADPW model produces some interesting arguments. The long-run effects are derived from the interaction between the direct effect and the indirect effects, the latter being related to how the housing construction industry responds to price signals, the depreciation of the existing housing stock and how the choice of tenure depends on the relation between the cost of rental housing and the cost of owner-occupied housing. The long-run effects of different type of policies are important when analysing tax reforms. Naturally, the long-run effects in our ADPW model are model-specific. The long-run effects of the different types of policy interventions in the ADPW model are summarised in Table 2. Arrows in red indicate the intervention's outset.

**Table 2**. Long-run equilibrium effects of policy interventions in an augmented DiPasquale-Wheaton framework

| | Rent | House price | Housing starts | Housing stock |
|---|---|---|---|---|
| Tax-deductible mortgage rate | ↓ | ↑↑ | ↑ | ↑ |
| Property tax | ↑ | ↓↓ | ↓ | ↓ |
| Rental subsidy – perfect elastic long-run supply | ↑↓ | ↑ | ↑ | ↑ |
| Rental subsidy – perfect inelastic long-run supply | ↑↑ | ↑ | ↑ | ↑ |
| Affordability subsidy | ↑↑ | ↑ | ↑ | ↑ |
| Public housing | ↓ | ↓ | ↓ | ↑↑ |

Our model identifies conventional effects on house prices following that of higher cost incurred by the industry due to restraints on regulated land for housing, and that of business cycles. House price effects rumble through the housing market system, affecting housing construction and the market for rental housing. Both types of shocks stimulate house prices in the long run, but short-run market dynamics may be characterised by overshooting.

We show that while tax deductibility of mortgage rates lifts house prices and stimulates activity in the housing industry, it will reduce rents in the rental market. Hence, such tax relief may in the long run potentially benefit *both* insiders and outsiders in the market for owner-occupied housing. While tax-deductible mortgage rates lift house prices and increase homeowners' housing wealth, they also benefit tenants through lower rent. The latter effect is often ignored as the indirect effect of such tax relief is overlooked in policy debates.

A residential property tax increases the user cost of owner-occupied housing and reduces house prices. When the construction industry responds to lower profitability, the number of housing starts falls and the reduced supply of housing leads to a higher rent in the rental housing market. Thus, in the long run, the property tax harms renters as their cost of housing consumption increases. Again, the indirect effect on the rental market is often ignored when discussing a tax on housing property.

Turning to social housing policy, our analysis includes policies aimed at both the supply and the demand side of the housing market. A public housing supply program is shown to partially crowd out the commercial housing supply. When stimulating affordability of rental housing, rental prices increase. As the cost of living is assumed equal across different forms of tenure, higher rental prices stimulate both house prices and housing construction.

The abstraction away from short-run market dynamics is a limitation in our analysis. Expanding the model by allowing for short-run market dynamics, for instance when considering income affordability, would allow for stronger short-run effects than long-run outcomes. As the construction industry reacts to higher short-run prices, supply increases and dampens the initial increase in both house prices and rental prices, allowing housing markets to be characterised by overshooting.

Finally, a rental subsidy creates a gap between the rent paid by tenants and the rent received by the landlords. As supply is fixed in the short run, the subsidy is passed through to the landlord in full in the form of higher rental earnings. As the indirect effect of the subsidy is incorporated into housing starts and the market for owner-occupied housing, the share of the subsidy benefitting tenants over time is determined by the elasticities of supply and demand. While a rental subsidy unambiguously increases house prices and thus benefit homeowners, the question of whether a tenant benefits or not from the subsidy in the long run depends on market elasticities. When the long-run supply curve is perfectly inelastic, a tenant does not benefit from a rental subsidy in the long run, while a landlord does (alongside homeowners).

The model's reasoning allows for assessment on the tenure intensity as the user cost not only relates house prices to the price of rentals, but also to the structure of our housing market. A higher user cost is shown (ref. Appendix 1) to go together with a more rental (and a less owner-occupied) intensive housing market.

To sum up, the ADPW model presented in this paper links different parts of the housing market system in a comprehensive framework allowing shocks to have both direct and indirect effects. The long-run equilibrium is model-specific. Being non-technical in nature, the modelling framework aims however to help structure arguments related to housing market policies and serves as a benchmark for analyses of local housing markets.

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## Appendix 1: Market equilibrium and composition of housing tenure

In equilibrium, the user cost of owner-occupied housing, rental prices and price of owner-occupied housing are also related to the tenure intensity of the housing market. Hence, our equilibrium endogenously determines the rental price, the price of owner-occupied housing, and the housing stock across both types of tenure: $S^{own}$ and $S^{rental}$.

In the short run, the aggregate housing supply $S$ is fixed, and used either as rental or owner-occupied housing $S_0 = S^{rental} + S^{own}$. Turning to the demand side, we let $H$ denote the number of households in the economy. Households may choose between renting or owning shelter services. Housing services may be obtained in the rental market at a unit rental price $R$, or in the owner-occupied housing market at the prevailing user costs of homeownership $U$. Households are by assumption indifferent between shelter services provided in the rental or the owner-occupied housing markets. The quantity and quality of shelter services are furthermore assumed identical in the two markets and proportional to number of $m^2$ of residential space.

The fraction of households who would rent housing if the rental price were zero is given by parameter $\beta_0$, while the parameter $\beta_1$ is the responsiveness of this fraction to changes in the cost of renting $R$. Alternatively, the parameter $\beta_0$ could be interpreted as household income, giving us a conventional downward sloping demand curve for rental housing $D^{rental}$ proportional to $H$, $D^{rental} = H(\beta_0 - \beta_1 R)$. Including the two social housing policy parameters we consider in the rental market, a rental subsidy $t_s$ and an affordability subsidy $t_a$, rental demand equals $D^{rental} = H[\beta_0(1 + t_a) - \beta_1 R(1 - t_s)]$. The equilibrium rental price $R$ is found by the intersection of the rental supply curve $S^{rental}$ and the demand for rental housing:

$$R_0 = \frac{\beta_0(1+t_a) - (S^{rental} / H)}{\beta_1(1-t_s)}. \tag{1}$$

Comparative statics show how the equilibrium rental price is higher the larger the population $H$ but lower the larger the supply of rental housing $S^{rental}$. Both the affordability subsidy and the rental subsidy lifts the price of rental housing.

Assuming a symmetric demand structure across both forms of tenure, the demand for owner-occupied housing is negatively dependent on the annual cost of owning $U$ as: $D^{own} = H(\alpha_0 - \alpha_1 U)$. The fraction of household in the economy wishing to own shelter services at a zero-annual cost of owning, is given by the parameter $\alpha_0$. (Since, by assumption, only two types of tenure are available to the households (renting or owning), it follows that $\beta_0 + \alpha_0 = 1$.) The parameter $\alpha_1$ reflects the responsiveness of fraction $\alpha_0$ to changes in $U$. The slope of the demand curve depends on the responsiveness of the total share of the households wishing to own space ($H\alpha_1$) to changes in user cost $U\left(\frac{\partial U}{\partial D} = -\frac{1}{\alpha_1 H}\right)$. Hence, demand for owner-occupied space is sensitive to changes in user costs, i.e., demand is elastic, if $\alpha_1$ is high (i.e., the fraction of households wishing to own housing shelter is very responsive to changes in $U$). For a given stock of housing services available in the market for homeowners the equilibrium level of user cost $U$ (i.e., imputed rent), equals:

$$U = \frac{\alpha_0 - (S^{own} / H)}{\alpha_1}. \tag{2}$$

Now, using the relation given in section 3, where $U = uP$ and $u$ equals the per euro user cost of owner-occupied housing services, we may rewrite equation 2 as:

$$U = uP \Rightarrow P = \frac{\alpha_0 - (S^{own} / H)}{u\alpha_1} \tag{2'}$$

Comparative statics finds that the price of housing is higher the lower the stock of owner-occupied housing relative to the number of households. Conventionally, the higher the user cost, the lower the equilibrium house price.

When assuming perfect substitutability between rental and owner-occupied housing, and households being indifferent to the two types of tenure, the cost of owning space (i.e., imputed rent) should be equal to the cost of renting space:

$$uP = R. \tag{3}$$

This non-arbitrage condition is the equilibrium condition for our housing market model and used to derive the PR ratio in section 3 relating the PR ratio to the user cost.

Now, combining the expressions for the rental price (1), the user cost (2') and the non-arbitrage condition (3) the equilibrium condition may be written as

$$\frac{\alpha_0 - (S^{own} / H)}{u\alpha_1} = \frac{\beta_0(1+t_a) - (S^{rental} / H)}{\beta_1(1-t_s)}. \tag{4}$$

Using the supply constraint $S^{own} = S_0 - S^{rental}$ we rewrite expression 4 as

$$\frac{\alpha_0 - (S_0 - S^{rental} / H)}{u\alpha_1} = \frac{\beta_0(1+t_a) - (S^{rental} / H)}{\beta_1(1-t_s)}. \tag{4'}$$

Expression (4') determines the stock of rental housing (and correspondingly the stock of owner-occupied housing) as a function of the user cost, the exogenous number of households in the economy and the exogeneous parameters ($\alpha_0$, $\alpha_1$, $\beta_0$, $\beta_1$, $t_a$, $t_m$, $t_p$, and $t_s$) of the model.

The housing market equilibrium is characterised by a positive relation between the user cost and the housing stock available to renters. This relation may be reasoned as follows: A higher user cost reduces the left-hand side of the equilibrium condition in equation 4' and implies that $S^{rental}$ should increase to ensure that the equilibrium condition holds. Higher user cost thus goes together with a more rental-intensive (and a less owner-occupied-intensive) housing market structure.

However, the picture is more nuanced than described above, as $S^{rental}$ also is a component of the left-hand side of the equilibrium condition. The initial user-cost effect derived from the demand side of the housing market is somewhat dampened by housing market's supply-side response. A larger share of rental housing dampens the initial user cost effect on the left-hand side of the equilibrium condition. Intuitively, the changing supply side structure that follows from a shock to the user cost impact prices both on rental housing and on owner-occupied housing. That is, an increase in the rental housing supply will lower rental prices while a reduction in the owner-occupied housing supply will lift house prices compared to the initial equilibrium. These supply-side effects also impact the PR ratio as the changing tenure intensity dampens the initial demand-side effect from a higher user cost to the equilibrium PR ratio. Still, there is a net effect in equilibrium where higher user cost coincides with a more rental-intensive housing market and a lower share of owner-occupied housing.

As the rental intensity is positively related to the user cost, which is positively related to a tax on housing equity but negatively related to the tax-deductibility of mortgage rates, these policies towards homeowners have opposite effects on the tenure intensity in terms of relative shares of rental and owner-occupied housing respectively.

Furthermore, from the equilibrium condition we see how an increase in rental subsidies makes rental housing cheaper and, at each level of user cost, lifts the rental intensity and reduces the intensity of owner-occupied tenure. Again, the initial demand-side effect is somewhat dampened by the supply-side effect that comes about as the supply side adjusts. Subsidising income affordability has the same effect on the rental intensity of a housing market as a rental subsidy.