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Mortgage credit and house prices: The housing market equilibrium revisited[☆]

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ABSTRACT

Over the last decade, house prices have increased substantially in nearly all OECD countries. These house price increases frequently coincided with changes in mortgage credit conditions; i.e., decreases in the interest rate and increases in income. This is in line with existing literature, which finds an equilibrium relationship between mortgage credit and house prices. The literature, however, lacks an analysis of what drives the equilibrium, which we assess in this paper. Moreover, we propose a combination of two explanations discussed in the literature. That is, we argue that lower-income households are bound by credit constraints, while higher-income households have a preference for spending a fixed fraction of income on mortgage payments. We develop theoretical models for all three explanations and test the models using data on the Dutch property market. The empirical results clearly support the combined approach. Overall, the results suggest that it is important to differentiate between types of households when forecasting house prices or assessing the effectiveness of policy interventions.

1. Introduction

On average, real house prices have increased by roughly 46% in OECD countries over the last two decades. As a result, house prices today are higher than at their peak prior to the global financial crisis (OECD, 2022). This sharp increase raises concerns regarding housing bubbles and potential overvaluation of the housing market.

An important factor contributing to the increase in house prices during the last two decades has been the decrease in interest rates. Houses are durable goods that are often purchased through a mortgage – in contrast to most consumer goods, such as food and clothing, which are bought directly. Therefore, it can be argued that (monthly) mortgage payments are the relevant costs for consumer decisions, rather than the purchase price of a house. Mortgage payments are essentially the purchase price of a house discounted over the term of the mortgage.[1] As a result, a drop in the interest rate mechanically decreases monthly mortgage costs, enabling home seekers to take out a larger mortgage without increasing monthly housing payments. With the higher mortgage consumers can take on, the price of the house they can afford increases. Thus, a decrease in the interest rate results in an increase in house prices through the decreasing effect it has on the monthly mortgage payments of home seekers.[2]

Boelhouwer et al. (2001, 2004) were the first to incorporate the above-described relationship into a house price model. In particular, they found that in equilibrium households spend a fixed fraction of their income on mortgage costs. In recent years, more house price models have been built based on this presumed equilibrium relationship between mortgage credit and house prices.[3] These models rely, however, on different explanations of the equilibrium. That is, McQuinn and O'Reilly (2008) and Madsen (2012) state that the equilibrium might be caused by credit constraints. They argue that households would prefer to spend more on housing, but are restricted by banks not willing to lend more.[4] When the limit on household indebtedness is calculated as the percentage of income spent on mortgage payments (i.e., a cap on the debt-service-to-income ratio) and the limit is binding, it undoubtedly results in a fixed fraction of income being spent on housing.

In contrast, Damen et al. (2016) argue that households' preferences, rather than lending regulations, explain the equilibrium. They argue that households prefer to spend a fixed fraction of their income on housing. At first glance, this might seem odd; why would households want

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[1] Discounting is a simple calculation performed to determine how much one must pay today to receive a given amount in the future. The discount rate (or interest rate) is used to convert future values into present values and vice versa.

[2] The magnitude of the house price increase depends on the interplay between the demand curve and the supply curve. We elaborate on this topic in Section 2.

[3] See for example Damen et al. (2016), Madsen (2012), and McQuinn and O'Reilly (2008).

[4] This restriction could be caused by either a credit rationing bank or stringent financial regulations (i.e., lending criteria).

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to spend a set proportion of their income on housing costs? One can, however, think of this as households budgeting their largest expense (i.e., housing) and spending the remainder on food, cars, vacations, et cetera. When income increases households will spend the same share of income on housing costs simply because they have become accustomed to it and know they will have enough money left for other expenses.

In this paper, we propose a third explanation. This explanation essentially combines the two previously discussed explanations. In particular, we argue that in reality only a fraction of households are constrained in their borrowing behavior. We assume that the remainder of households are not restricted, but have preferences that would imply a fixed fraction of income spent on housing (as described above). Therefore, both types of households spend a fixed share of their income on mortgage payments, albeit for different reasons.

In addition to developing a new explanation of the equilibrium, we contribute to the literature by analyzing which of the three explanations could be considered the 'driver of the equilibrium'. At first, the distinction between these explanations might seem like a semantic dispute. However, as shown in this paper, this distinction influences the equilibrium relation of house prices and consequently our understanding of the housing market. Therefore, knowing what drives the equilibrium is particularly useful when forecasting house prices or evaluating policy interventions. This analysis is performed as follows: first, a theoretical house price model for each explanation of the equilibrium is derived. We then empirically test which explanation fits the data best and could be considered the driver of the equilibrium. In line with the empirical literature on this topic, we estimate a model that allows for short-run deviations from the equilibrium (i.e., an error correction model). In this model, house prices are allowed to drift apart temporarily as long as they tend to return to the equilibrium.

We conduct this empirical test of the model for the Netherlands. The Dutch housing market provides a unique opportunity to analyze the equilibrium because it is characterized by stringent debt-service-to-income caps. These caps are generally binding for first-time home-buyers; however, due to accumulated home equity, the caps are often slack for existing homeowners. Thus, in the Netherlands these caps are not too tight in that everyone is restricted by lending regulations, and also not too slack such that no one is affected by them. Therefore, the Dutch context allows for any of the three discussed explanations of the equilibrium to occur.

The remainder of this paper is organized as follows. Section 2 derives a theoretical model for each explanation of the equilibrium between mortgage credit and house prices. Section 3 briefly discusses the Dutch housing market and the data sources. Section 4 tests the three models empirically and Section 5 concludes the paper.

2. Theoretical models of house prices

In this section, three theoretical frameworks are developed that explain house price dynamics along the three lines of reasoning discussed in the introduction. These different lines of reasoning result in a different housing demand function (h_t^d) and it is important to note that this is the sole difference between the three models.

Before diving into the derivation of these demand functions, we discuss what the models have in common. First, to allow for heterogeneity in housing quality, houses are assumed to consist of units of housing and households can buy these units of housing (e.g., bricks) for a fixed price per unit (e.g., the brick price). Second, all three frameworks start off with decisions at the micro (household) level and these micro outcomes are then aggregated to provide insight into the evolution of house prices at the macro level. Moreover, for each model, we assume a national market exists where the aggregate supply of housing (H_t^s) meets its demand (H_t^d) and the housing market clears ($H_t^d = H_t^s$).

Furthermore, in all three models, housing supply is modeled as a flexible function of the price of housing. This supply function is in line with the literature on this topic and it relies on the notion that higher house prices could make building homes more attractive for landowners, project developers, and construction companies. [5] In each of the three models, the supply function is defined as:

$$H_t^s = \delta {p_{ht}}^{\psi} \tag{1}$$

where δ is a supply-side shifter and ψ reflects the price elasticity of supply.

Although the housing demand function is different for each model, they have one thing in common; all demand functions are unitary elastic. These unitary elastic demand functions imply that households spend a fixed fraction of their income on housing. One could, however, argue that inelastic housing supply would also imply this spending behavior. Nonetheless, since there is evidence of households spending a fixed fraction of their income on housing costs in the United States (a country with fairly elastic housing supply), we argue that unitary elastic demand is more likely than inelastic supply. We elaborate on this, and other arguments, in Appendix C.

Finally, it is of note that for all models, the derivation is kept as simple as possible as the main goal is to demonstrate the differences between the three frameworks.

2.1. Borrowing constrained households

We now turn to the first model, i.e., lending regulations. This model relies on the notion that households are constrained in their borrowing ability. Following McQuinn and O'Reilly (2008), we assume that financial institutions use a debt-service-to-income cap to calculate the maximum borrowing amount. As a result of the cap, the maximum borrowing amount (b_t^{max}) of the representative household in period t, is some fraction (κ_t) of household income (y_t) discounted at the mortgage interest rate (i_t) for a period equal to the mortgage length (n). Therefore, the maximum borrowing amount is given by:

$$b_t^{max} = \kappa_t y_t \frac{1-(1+i_t)^{-n_t}}{i_t}. \tag{2}$$

Furthermore, in line with McQuinn and O'Reilly (2008), we assume that houses are fully mortgage financed. Thus, the purchase price of a house must be smaller than or equal to the maximum borrowing amount (b_t^{max}):

$$p_{ht} h_t^d \leq b_t^{max}, \tag{3}$$

where the purchase price ($p_{ht} h_t^d$) is defined as the units of housing services consumed (h_t) multiplied by the unit price of housing (p_{ht}).

When this constraint is binding, households will borrow as much as they can. Consequently, Eq. (3) will hold with equality and the demand of housing for the representative household comes down to:[6]

$$h_t^d = \frac{b_t^{max}}{p_{ht}}. \tag{4}$$

The demand function works as follows: all households are confronted with the same unit price of housing (p_{ht}) (Muth, 1960). However, households with a larger borrowing capacity might opt for a bigger property, or a property of 'better quality', which provides more units of housing services (h_t) than a smaller property.

[5] E.g., Caldera and Johansson (2013), Glaeser et al. (2008), Malpezzi and Maclennan (2001) and McQuinn and O'Reilly (2008). Note that, in the model, supply is assumed to be fixed in the short run. A delayed supply reaction is incorporated in most economic models, but it is especially important for housing market models as it takes a while to build houses; consequently, housing reacts to price changes sluggishly (Malpezzi and Maclennan, 2001; Wheaton, 1990).

[6] Note that, in contrast to McQuinn and O'Reilly (2008), we do not assume that housing demand is a flexible function of the maximum borrowing amount. Instead we assume that the majority of households are constrained by a maximum borrowing amount.

As discussed above, an equilibrium is supposed to exist where aggregate housing demand meets aggregate housing supply (i.e., the housing market clears). Thus, in order to find this equilibrium, we must first aggregate the demand function h_t^d. Aggregation is done by summing over a number of I_t households that demand housing, which results in the aggregate demand function of the population H_t^d:

$$H_t^d = \sum_{i=1}^{I_t} h_t^d = \frac{I_t b_t^{max}}{p_{ht}}. \tag{5}$$

In Eq. (5), the variable I_t indicates that aggregate housing demand not only increases when the maximum borrowing amount increases or if the unit price of housing decreases, but also when there is an inflow of population which could be caused by immigration or perhaps a baby boom.

Having formulated a function of aggregate housing demand, we now derive the long-run equilibrium by equating the supply of housing to aggregate housing demand (i.e., $H_t^d = H_t^s$). Supply is formulated in Eq. (1) and hence we are left with:

$$p_{ht}^* = \left(\frac{I_t b_t^{max}}{\delta}\right)^{\frac{1}{1+\psi}}. \tag{6}$$

The housing market literature frequently uses an equation similar to Eq. (6), i.e., an equation in terms of the unit price of housing (p_h^*), in the empirical estimation of the model. In this paper, we take a different approach. We rewrite the model in terms of the purchase price of housing $p_{ht}^* h_t^*$, rather than the unit price of housing p_{ht}^*. There are two reasons for this. The first reason is practical. One cannot observe h_t^* and p_{ht}^* separately for the purchasing period t.[7] Second – and perhaps more importantly – even if we could observe p_{ht}^*, we argue that the purchase price of housing, rather than the unit price of housing, is more useful for assessing over- or undervaluation of the housing market. That is the case as large housing expenditures relative to income indicate whether prices are unsubstantiated, rather than merely a high unit price over income.[8]

An analysis in terms of the purchase price of housing ($p_{ht}^* h_t^*$) requires information on the optimal amount of housing services. This can be found by substituting Eq. (6) into Eq. (1) or (5) and dividing by the number of households that demand housing (I_t). The units of housing services consumed at the equilibrium by the representative household are then equal to:

$$h_t^* = \left(\frac{\delta}{I_t}\right)^{\frac{1}{1+\psi}} \left(b_t^{max}\right)^{\frac{\psi}{1+\psi}}. \tag{7}$$

When we multiply Eq. (7) with (6), we obtain a function for the purchase price of housing:

$$p_{ht}^* h_t^* = b_t^{max}. \tag{8}$$

From this equation, it follows that a one unit increase in the maximum borrowing amount (b_t^{max}) prompts the purchase price of housing to increase by one unit as well. It is important to note that housing supply does not affect this equilibrium relationship. Even if housing supply were perfectly elastic ($\psi \to \infty$), an increase in the maximum borrowing amount would always be captured in the purchase price of housing.[9] This is due to the fact that in this model all households are constrained in their buying behavior. Thus, although elastic housing supply decreases the unit price of housing (p_{ht}^*), households would offset this decrease in price by consuming more units of housing (h_t^*). Consequently, the purchase price of housing ($p_{ht}^* h_t^*$) remains the same.

That said, this does not mean that price-responsive housing supply is not important. When supply is elastic, households do enjoy the benefit of consuming more units of housing (h_t^*). That is, they purchase a larger home or a property of better quality. Thus, with elastic housing supply the purchase price of housing remains the same, yet the quality-adjusted purchase price decreases.

2.2. Cobb–Douglas preferences

For the second potential explanation, i.e., housing preferences, it is assumed that households have preferences that result in a fixed fraction of income being spent on housing. Inspired by Damen et al. (2016), we build a simple model that is consistent with such preferences.[10] In this model, we consider a stylized world in which households spend their money on two goods: housing and a composite 'other product', which are purchased in period t at quantities h_t and c_t, respectively. Preferences over these two goods are represented by the Cobb–Douglas utility function, as this utility function results in a fixed fraction of income being spent on both goods.

Cobb–Douglas preferences might seem like an oversimplification of reality; it essentially implies that higher-income households spend the same share of income on housing as lower-income households. Nonetheless, on the macro level, there is evidence in support of Cobb–Douglas preferences for consumption and housing. Data from the Netherlands and the United States show that the fraction of income spent on housing (i.e., the Cobb–Douglas expenditure share) is constant over time (Davis and Ortalo-Magné, 2011; De Vries and Boelhouwer, 2009). Moreover, Davis and Ortalo-Magné (2011) find rent expenditure shares to be constant across areas in the United States. The sufficient income variation across time and areas strengthens the case for assuming Cobb–Douglas preferences. Consequently, macroeconomic housing models often specify Cobb–Douglas preferences over consumption and housing.[11]

The Cobb–Douglas utility specification has the following functional form:

$$U(h_t, c_t) = c_t^{1-\theta} h_t^{\theta}, \tag{9}$$

where θ is a preference parameter.

In line with the previous section, we assume that the representative household takes out an annuity mortgage. This yields the following monthly borrowing cost (b_t);

$$b_t = p_{ht} h_t \left(\frac{i_t}{1-(1+i_t)^{-n}} - i_t \tau_t\right). \tag{10}$$

[7] The literature often uses a price index to approximate the unit price of housing (p_h^*). These analyses imply, however, that the number of units of housing households consume is fixed. That is, all households consume a fixed unit of housing services and this does not change over income cohorts, nor over time. When we look at the data, however, we find that the units of housing people consume increased tremendously over time. Moreover, more prosperous households consume more units of housing than less prosperous households. Therefore, assuming that h_t^* is fixed does not seem plausible.

[8] In particular, if the unit price is relatively low and people buy large houses, it would yield high purchase prices compared to income. An analysis in terms of the purchase price would point to potential default risk, while an analysis in terms of the unit price would fail to indicate this risk.

[9] Note that this is in contrast to McQuinn and O'Reilly (2008). The authors specify a nonlinear demand function (i.e., $h_t^d = (b_t^{max}/p_{ht})^{\mu}$). Therefore, the effect of an increase in the maximum borrowing amount does depend on the elasticity of supply. This demand function is, however, not in line with the notion that the majority of households are constrained by lending regulations.

[10] With regard to simplicity we do not formulate a multi-period utility problem. This is in contrast to the model presented by Damen et al. (2016). However, please note that it does not affect the outcome of the model, as Damen et al. assume that borrowers exhaust their budget every period without accumulating assets. Consequently, the discount factor (β) does not enter the demand function. Moreover, also in contrast to Damen et al. (2016), but in line with McQuinn and O'Reilly (2008) and the Dutch context, we assume that houses are fully mortgage financed.

[11] E.g., Damen et al. (2016), Davis and Heathcote (2005), and Kiyotaki et al. (2011).

As in the previous section, p_{ht} reflects the unit price of housing services, i_t is the interest rate, and n_t is the duration of the mortgage. τ_t is the mortgage interest deduction rate.[12]

Although we often refer to this model as the unconstrained model, it is important to note that the model (like any economic model) does include a constraint, namely a budget constraint. This budget constraint is necessary as not including a budget constraint would result in households consuming infinite amounts of housing. In particular, the budget constraint reflects that households can spend their income y_t on consuming the composite at price p_{ct} or making mortgage payments b_t. Therefore, the budget constraint is given by:

$$y_t = p_{ct}c_t + b_t. \tag{11}$$

Substitution of Eq. (10) into (11) and maximization of Eq. (9) subject to the budget constraint, yields the following housing demand function:

$$h_t^d = \frac{\theta y_t}{p_{ht}(\frac{i_t}{1-(1+i_t)^{-n}} - i_t\tau_t)} = \frac{\theta b_t^{cd}}{p_{ht}}. \tag{12}$$

From this expression, it follows that households demand more units of housing when income (y_t) increases, and demand less housing when its unit price (p_{ht}) or the interest rate (i_t) increases. For computational sake, we define, $\frac{y_t}{\frac{i_t}{1-(1+i_t)^{-n}} - i_t\tau_t} = b_t^{cd}$. Henceforth, we refer to this variable as households' ability to pay.

As in the previous section, summing over I_t households results in the aggregate demand function:

$$H_t^d = \sum_{i=1}^{I_t} h_t^d = \frac{\theta I_t b_t^{cd}}{p_{ht}}. \tag{13}$$

When we equate the demand function to the supply function defined in Eq. (1), we find that the unit price of housing equals:

$$p_{ht}^* = \left(\frac{\theta I_t b_t^{cd}}{\delta}\right)^{\frac{1}{1+\psi}}. \tag{14}$$

The corresponding number of housing services consumed by the representative household is given by:

$$h_t^* = \left(\frac{\delta}{I_t}\right)^{\frac{1}{1+\psi}} \left(\theta b_t^{cd}\right)^{\frac{\psi}{1+\psi}}. \tag{15}$$

Hence, the purchase price of housing equals:

$$p_{ht}^* h_t^* = \theta b_t^{cd}. \tag{16}$$

As in the previous section, the price elasticity of supply (ψ) does not alleviate a high house price level. The reasoning is different, however. In the previous section, supply did not enter the equation because households are constrained. In this section, households are not constrained, but they prefer to spend a fixed fraction of their income on housing costs. These Cobb–Douglas preferences imply a unitary elastic demand function, inferring that if households' ability to pay (b^{cd}) increases by 1% households will spend 1% more on housing. More specifically, from Eq. (16) it follows that if the ability to pay increases by one unit, households will spend a fixed fraction θ more on housing.

[12] Note that the mortgage interest deduction rate is included in this model, whereas it is generally not included when calculating the maximum borrowing amount. This component deserves an explanation, given the fact that the benefit of the interest deduction decreases over the term of the mortgage. This decrease is, however, not captured in the model as we assume that households only look at the first mortgage payment. That is, they are irrational in the sense that they do not acknowledge that the tax benefit decreases over time. Put differently, they assume that their income will increase (as most incomes do over the span of a lifetime) so that the reduction in the tax benefit becomes irrelevant. This seems plausible since for an average mortgage (450,000 euros, 30 years, 1.67% interest) the difference between the first and the last payment is merely 194 euros.

2.3. Borrowing constrained households and households with Cobb–Douglas preferences

In reality we see that some households are constrained in their borrowing while others are not. Therefore, in this section, we assume – in contrast to the existing literature – that some households are constrained by lending regulations and other (perhaps more prosperous) households are not constrained. In this model, the unconstrained households are assumed to have Cobb–Douglas preferences over housing and consumption.[13] Thus, this section combines the results of Sections 2.1 and 2.2.

Having two groups of households requires us to combine the demand function previously defined (Eqs. (5) & (13)). In line with the literature on two-agent models, we define the aggregate demand as the weighted sum of the demand of constrained ($H_t^{d,c}$) and unconstrained households ($H_t^{d,u}$).[14] Thence, aggregate housing consumption becomes:

$$\begin{aligned} H_t^d &= \gamma H_t^{d,c} + (1-\gamma)H_t^{d,u} \\ H_t^d &= \gamma \frac{I_t b_t^{max,c}}{p_{ht}} + (1-\gamma)\frac{\theta I_t b_t^{cd,u}}{p_{ht}}, \end{aligned} \tag{17}$$

where γ is the spending share of constrained households.[15] $b_t^{max,c}$ & $b_t^{cd,u}$ respectively reflect the maximum borrowing capacity of constrained households and unconstrained households' ability to pay. It is important to note that – due to differences in, for example, the income levels of constrained and unconstrained households – these variables are not equal to b^{max} & b_t^{cd}.

As previously discussed, in equilibrium the demand of housing must be equal to the supply of housing ($H_t^d = H_t^s$). Hence, we have:

$$p_{ht}^* h_t^* = \gamma b_t^{max,c} + (1-\gamma)\theta b_t^{cd,u}. \tag{18}$$

From this equation, it follows that if the share of constrained households is zero ($\gamma = 0$), the model collapses to the model in Section 2.2. On the other hand, if there are no unconstrained households ($\gamma = 1$), the model returns to the one presented in Section 2.1. In reality, some households will be constrained by lending regulations while others are not. Therefore, we would expect this spending share to be between zero and one ($0 < \gamma < 1$).

3. Case study: The Dutch housing market

We apply the three models discussed in Section 2 to the Dutch residential property market. It is important to keep in mind that the Dutch housing market is highly regulated and can differ in various aspects from housing markets in less-regulated countries (Tu et al., 2017). In particular, the Dutch housing market is characterized by stringent lending restrictions, regulated housing supply, a small private rental sector, and households' tenure choice is influenced by tax-deductible mortgage interest. Moreover, Dutch households are heavily indebted. Apart from Denmark and Norway, the Netherlands has the highest debt rate relative to disposable income of all OECD countries.

[13] This model is only applicable to countries with a binding debt-service-to-income ratio. Otherwise, the model simply returns to the Cobb–Douglas model presented in the previous section.

[14] E.g., Bacchetta and Gerlach (1997), Campbell and Mankiw (1989), and Iacoviello (2004).

[15] The spending shares are empirically estimated, hence the analysis does not require data on the relative consumption shares. However, this implicitly assumes that these shares remain constant over time. In Appendix B we test whether this assumption is plausible by allowing for time-varying parameters.

3.1. Data

The data used in this study are quarterly and cover the period 1995Q1–2020Q4. For all three models, data, are required on the purchase price of housing (i.e., house prices) and the mortgage interest rate; these are published by the Netherlands' Association of Realtors (NVM) and the Central Bank of the Netherlands (DNB), respectively.

To calculate the maximum borrowing amount (b_t^{max}), additional information is needed on the debt-service-to-income caps, household income, and the distribution of income within the household (i.e., the income share of the principal earner). The former is provided by the National Institute for Family Financing (NIBUD) and is calculated as a fraction of gross income.[16] Gross income and the distribution of income within the household are provided by Statistics Netherlands (CBS). CBS only publishes these figures on a yearly basis. Given the short time span of the data (merely 25 years), the income figures have been interpolated to match the quarterly time series.

For the calculation of the Cobb–Douglas model (b_t^{cd}), additional information is needed on income, as well as the interest deductibility rate. In this model, income reflects after-tax or disposable income, as is generally the case for Cobb–Douglas models. Disposable household income is obtained from CBS. The interest deductibility rate is calculated on the basis of the previously mentioned income figures and government tax documents, and as a result changes in the deductibility rate are accounted for.

The mixed model requires data on constrained ($b_t^{max,c}$) and unconstrained ($b_t^{cd,u}$) households. Many variables might be used to distinguish between constrained and unconstrained households. For example, one could look at existing homeowners versus first-time buyers or approximate home ownership by people below and above the age of 30. Data limitations, however, restrict us to only consider a distinction based on household income. In particular, we assume that households with a low income (up and until the 4th decile) are constrained in their buying behavior and that households with a higher income (above the 4th decile) are unconstrained.[17] These income figures are provided by CBS. For the interest rate and the income share of the principal earner, it is not possible to make a distinction between constrained and unconstrained households. Consequently, they are equal to the figures discussed above.

All data sources are summarized in Table 1 and the variables of interest (i.e., $p_{ht}h_t$, b_t^{max}, b_t^{cd}, $b_t^{max,c}$ & $b_t^{cd,u}$) are plotted in Fig. 1.

Table 1
Data.

Variable	Abbr.	Source	Freq.	Converting
Median house prices	$p_{ht}h_t$	NVM	Q	N/a
Mortgage interest rate	r_t	DNB	Q	N/a
Debt-service-to-income caps	κ_t	NIBUD	Q	N/a
Gross Household income	y_t^{gross}	CBS	A	DC
Income share of the principal earner	ζ_t	CBS	A	DC
Household disposable income	y_t^{disp}	CBS	A	DC
Mortgage interest deductibility rate	τ	CBS & Tax	Q	N/a
Gross Household income, low-income	$y_t^{gross,c}$	CBS	A	DC
Household disposable income, high-income	$y_t^{disp,u}$	CBS	A	DC

Note: NVM stands for the Netherlands' Association of Realtors, DNB is the central bank of the Netherlands, NIBUD is the National Institute for Family Financing, Tax refers to Dutch tax documents, and CBS stands for Statistics Netherlands.

[16] Appendix A provides background information on the use of debt-service-to-income caps in the Netherlands.

[17] This divide in income is based on micro data from the Mortgages Data Network (HDN). From the data it follows that, on average, households with an income up to the 4th decile are bound by lending regulations, while higher-income households are not. A sensitivity analysis of this distinction is provided in Appendix B.

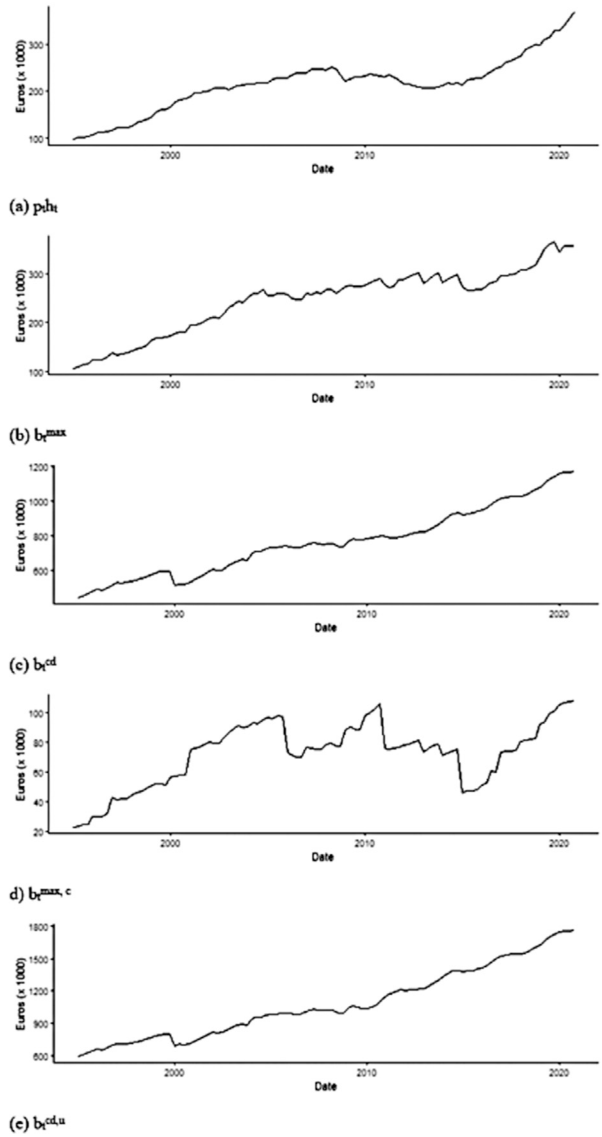


Fig. 1. Time series charts.
Note: The subfigures reflect the data used in the regression models. All variables are expressed in units of one thousand euros.

3.2. Stationarity

Before estimating the models empirically, we must examine the time-series properties of the variables used. Table 2 shows the results from two nonstationarity tests: the Augmented Dickey–Fuller (ADF) and the Phillips–Perron (PP) test, and one stationarity test: the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. From all tests, it appears that in levels all variables are nonstationary. Repeating the tests for the first-order differences we find conclusive evidence of stationarity, for all but one case. Only the ADF test of the first-order difference of house prices fails to reject the null hypothesis of nonstationarity. Nonetheless, since the other tests point to stationarity and the ADF test has been known to suffer from lack of power (Afriyie et al., 2020), we conclude that all the series are nonstationary, but integrated at order one.

Table 2
Nonstationarity & stationarity tests.

	Test statistic levels				
	$p_{ht}h_t$	b_t^{max}	b_t^{cd}	$b_t^{max,c}$	$b_t^{cd,u}$
ADF	−1.72	−2.05	−1.46	−2.18	−1.18
PP-τ	−0.39	−1.95	−1.38	−2.09	−1.14
PP-α	−1.04	−6.12	−5.46	−7.51	−3.75
KPSS	1.67***	1.94***	2.09***	0.81***	2.10***
	Test statistic first-difference				
	$\Delta p_{ht}h_t$	Δb_t^{max}	Δb_t^{cd}	$\Delta b_t^{max,c}$	$\Delta b_t^{cd,u}$
ADF	−1.86	−3.98***	−4.78***	−4.12***	−5.37***
PP-τ	−8.12***	−9.85***	−7.93***	−9.96***	−7.43***
PP-α	−93.73***	−94.29***	−78.16***	−103.20***	−71.43***
KPSS	0.36	0.18	0.17	0.14	0.26

Note: This table presents the test statistics of the Augmented Dickey–Fuller (ADF) test, the Phillips–Perron test (PP), and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. Tests include a trend and an intercept. $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$.

Table 3
The long-run equation.

	Constrained	Cobb–Douglas	Cobb–Douglas & Constrained
	(1)	(2)	(3)
b_t^{max}	0.841***		
	(0.097)		
b_t^{cd}		0.288***	
		(0.026)	
$b_t^{max,c}$			1.455***
			(0.166)
$b_t^{cd,u}$			0.107***
			(0.008)
N	99	99	99

Note: Newey–West standard errors are reported in parentheses. Two leads and lags of the differenced regressor(s) are included in the regression as controls, the coefficients of these regressors are not reported in the table. $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$.

4. Results

This section presents the empirical results and is organized as follows. First, the long-run equilibrium equations of the models derived in Section 2 are estimated and plotted. Subsequently, we analyze whether these long-run equations are stable, i.e., whether house prices are cointegrated. Thereafter, the long-run relationship is used to estimate an error correction model.

4.1. Long-run equation

The three potential long-run equilibrium relationships of house prices formulated in Section 2 (i.e., Eqs. (8), (16) & (18)), are estimated in this section. In line with McQuinn and O'Reilly (2008) we employ dynamic OLS.[18] Dynamic OLS has the advantage of controlling for potential endogeneity in the long-run equation of the model. In particular, it allows the maximum borrowing capacity (b_t^{max}) or households' ability to pay (b_t^{cd}) to be correlated with the error-term. Dynamic OLS involves adding leads and lags of the differenced regressors to the long-run equation (Stock and Watson, 1993).[19] Moreover, to control for serial correlation in the error term, Newey–West standard errors are calculated.

Consequently, the empirical long-run equation of the first model is defined as:

$$p_{ht}h_t = \beta_1 b_t^{max} + \sum_{j=-k}^{k} \beta_2 \Delta b_{j+t}^{max} + \varepsilon_t. \tag{19}$$

Please recall that this model relies on the notion that homebuyers are constrained by debt-service-to-income caps. Therefore, if the maximum borrowing capacity increases households are expected to use the full extent of the increase to buy a more expensive property, resulting in higher house prices. Thence, according to this model, a one unit increase in the maximum borrowing capacity increases house prices by one unit as well. Thus, we would expect β_1 to be close to one. The first column of Table 3 shows the results for this model. The results point to a parameter of 0.841, which is slightly lower than – yet still close to – one. In fact, one is included in the 95% confidence interval of the estimate. Therefore, we fail to reject that the parameter is equal to one, and consequently the results are in line with the theoretical set-up of this model.

The second model assumes that households prefer to spend a fixed fraction of their income (i.e., θ) on mortgage costs. The empirical equation for this model is:

$$p_{ht}h_t = \beta_1 b_t^{cd} + \sum_{j=-k}^{k} \beta_2 \Delta b_{j+t}^{cd} + \varepsilon_t, \tag{20}$$

where the parameter β_1 reflects the Cobb–Douglas expenditure share θ. From the second column of Table 3, it follows that this term equals 0.288, implying that households spend approximately 29% of their disposable income on mortgage costs. Thus, according to this model, a 1000 euro increase in households' ability to pay would increase house prices by circa 290 euros.

The third model essentially combines the above two models. It assumes that lower-income households (up and until the 4th income decile) are constrained by binding debt-service-to-income caps and that higher-income households (above the 4th decile) have preferences that result in a fixed fraction of income being spent on mortgage cost, that is:

$$p_{ht}h_t = \beta_1 b_t^{max,c} + \beta_2 b_t^{cd,u} + \sum_{j=-k}^{k} \beta_3 \Delta b_{j+t}^{max,c} + \sum_{j=-k}^{k} \beta_4 \Delta b_{j+t}^{cd,u} + \varepsilon_t. \tag{21}$$

Consequently, the model includes two parameters of interest: β_1 reflects the effect of the maximum borrowing amount of constrained households (γ) on house prices, and β_2 estimates the effect of the borrowing cost of unconstrained households ($\theta(1-\gamma)$) on house prices. From the third column of the table it follows that for unconstrained households, the parameter is equal to 0.107. If we assume that higher-income households spend 20% of their income on housing, the spending share equals 0.535 ($= \frac{0.107}{0.2}$). The magnitude of the spending share seems reasonable.

For the constrained households we find a value for γ of 1.455. This parameter reflects the spending share of constrained households and should lie between zero and one. We believe, however, that this anomaly is likely to be caused by our inability to approximate the maximum borrowing amount of constrained households perfectly. That is, due to data limitations we cannot differentiate all model variables (i.e., the interest rate and the income share of the principal earner) by income group. Consequently, the maximum borrowing capacity for lower-income households is less stringent than the one we approximate, biasing our estimate upwards.[20]

[18] Only dynamic OLS is employed in this paper as according to Kao and Chiang (2001) and Wagner and Hlouskova (2009), dynamic OLS outperforms all other tested cointegration methods, including single-stage OLS (e.g., Fully Modified OLS) and system estimators.

[19] The number of leads and lags (k) is set equal to 2. Alternative lag lengths were employed as well, but they did not significantly alter the results.

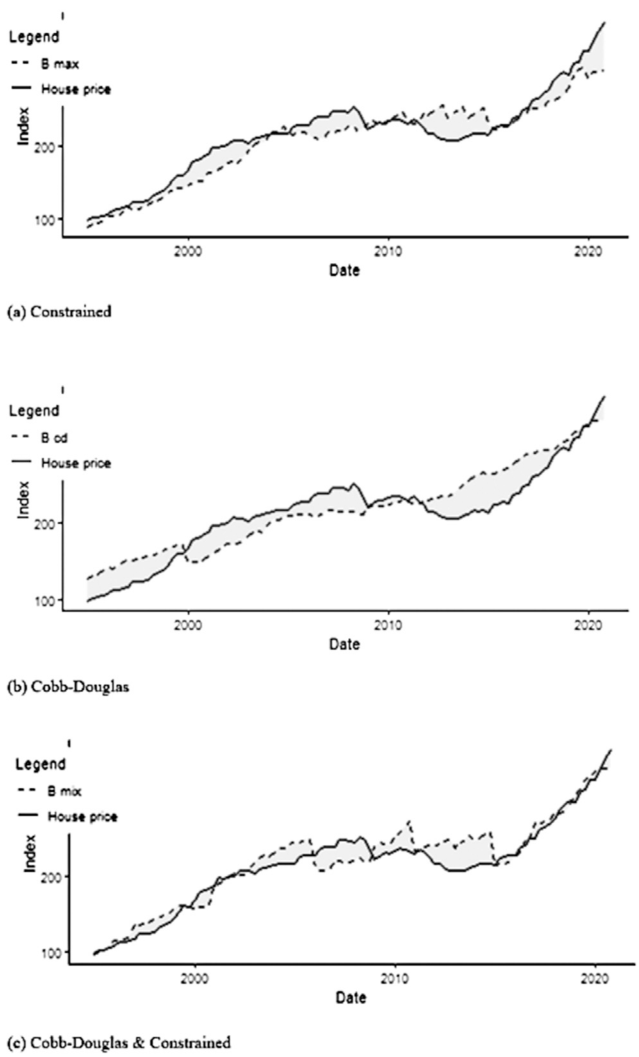
[20] In Appendix B we perform a scenario analysis where we use rules of thumb to differentiate these variables by income groups. The results point to an estimate of 0.870, which is more in line with our expectations. Moreover, provided that the follow-up estimates of the model do not seem to be affected by the rules of thumb, we find it plausible that the large parameter reported in Table 3 merely corrects our underestimation of the maximum borrowing amount. We do not present these results in the main text, however, as they are based on simple rules of thumb.

4.2. Under- or overvaluation

To get a better understanding of the differences between the estimated models, this subsection plots the long-run relations alongside house prices. This graphical analysis allows us to assess when the Dutch housing market may be under- or overvalued according to each model: when long-run house prices are above (below) actual house prices, house prices are undervalued (overvalued) and prices are expected to rise (drop) in the near future.

The first sub-figure of Fig. 2 pertains to the constrained model. According to this model, several periods of over- and undervaluation can be distinguished. For the second model, the results are quite different. The long-run relation does not follow the price pattern of house prices, but it is more or less a straight line that crosses houses price three times. Note that according to this model, there are only three small periods where house prices are equal to their fundamental value.

The third model, the mixed model, seems to produce a more approximate picture. It does not point to under- or overvaluation during periods of stable rising house prices (i.e.,1995–2002 & 2015–2020). The model does, however, indicate that house prices are overvalued in the run-up of the financial crisis. Moreover, it indicates that the drop in house prices after the financial crisis was ill-founded, given that house prices swiftly increased again.



(a) Constrained

(b) Cobb-Douglas

(c) Cobb-Douglas & Constrained

Fig. 2. Long-run relation.
Note: The three subfigures reflect the long-run relations as presented in Table 3.

4.3. Cointegration

We next test whether the long-run relations estimated and plotted in the previous sections are stable equilibria. Put differently, we test for cointegration. First, the Engle and Granger (1987) cointegration test is employed. The test statistics are presented in Table 4. For all three models, the test is unable to reject the null hypothesis of no cointegration at a 5% level. Nonetheless, for the third model, the test rejects the null hypothesis of no cointegration at a 10% level.

When we employ another cointegration test, the Phillips and Perron (1988) test, the results slightly change.[21] The results of this test are presented in Table 4 and both test statistics reject the null hypothesis of no cointegration at a 5% level for the third model. We also employ the Johansen (1995) cointegration test.[22] According to both the trace and the eigenvalue Johansen tests, the null hypothesis of no cointegrating vector is rejected for the third model only.

Thus, according to the tests performed in this section, there is some evidence of cointegration for the third model. There is, however, no evidence of cointegration for Models 1 and 2.[23] In other words, we do not find a stable long-run equilibrium for these models. Consequently, in the remainder of this article, to avoid invalid estimation, we solely present the results of the error correction model for the third model.

Table 4
Cointegration tests.

	Constrained	Cobb–Douglas	Cobb–Douglas & Constrained
Engle–Granger	−1.41	−1.95	−2.80*
Phillips–Perron			
Z_τ	−1.10	−1.35	−2.93**
Z_α	−4.63	−4.11	−17.38**
Johansen trace			
$r \le 2$			4.81
$r \le 1$	2.78	5.42	18.34*
$r = 0$	14.36	14.89	41.34***
Johansen eigen			
$r \le 2$			4.81
$r \le 1$	2.78	5.42	13.53
$r = 0$	11.58	9.47	23.00**

Note: This table presents test statistics of the Engle–Granger, Phillips–Perron, and Johansen test. All tests include an intercept. Tests with trend and intercept were performed as well, but due to the insignificance of the trend parameter, the trend is dropped. The optimal lag orders in the tests are determined by the Akaike information criterion with a maximum number of six lags. $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$.

4.4. The error correction equation

Finally, we estimate the full empirical model. When doing so we acknowledge that the housing market is a fickle market that – due to speculative or psychological effects – adjusts sluggishly to changing economic conditions. Consequently, the market cannot be expected to be in equilibrium constantly. Therefore, we employ an error correction model to allow for deviations from the equilibrium.[24] In particular, if a deviation from the equilibrium occurs, the model predicts that house prices will gradually return to equilibrium.

[21] The Phillips and Perron (1988) test is semi-parametric, i.e., it does not assume that the residuals follow a Dickey–Fuller distribution. This test yields higher power compared to an ADF-test when the variables are weakly exogenous (Haug, 1996).

[22] In contrast to the above-presented tests, this method generates the long-run relationship endogenously.

[23] In Appendix B several robustness checks are performed to test whether Models 1 and 2 are indeed not cointegrated. In any of the tests performed, we do not find evidence of cointegration.

[24] Error correction models have frequently been applied in the housing market literature. See, for example, Abraham and Hendershott (1994), Boelhouwer et al. (2004), Brown et al. (1997), Damen et al. (2016), Holly and Jones (1997), Hort (1998), Madsen (2012), Malpezzi (1999), McQuinn and O'Reilly (2008), and Meen (1998).

The error correction model is presented by:

$$\Delta(p_{ht}h_t) = \alpha + \lambda S2 + \sum_{i=1}^{4}\lambda_i \Delta(p_{h,t-i}h_{t-i}) + \sum_{i=1}^{4}\lambda_{i+4}\Delta b_{t-i}^{max,c} + \sum_{i=1}^{4}\lambda_{i+8}\Delta b_{t-i}^{cd,u} + \eta\left(p_{h,t-1}h_{t-1} - \hat{\beta}_{1,DOLS}b_{t-1}^{max,c} - \hat{\beta}_{2,DOLS}b_{t-1}^{cd,u}\right) + \epsilon_t. \tag{22}$$

The dependent variable ($\Delta p_{ht}h_t$) reflects changes in the purchase price of housing with respect to the previous period. α is a constant and $S2$ controls for seasonality.[25] In the short-run, house prices are explained by past changes in house prices ($p_{ht-i}h_{t-i}$), the maximum borrowing capacity of constrained households ($b_{t-i}^{max,c}$), and unconstrained households' ability to pay ($b_{t-i}^{cd,u}$). Based on the Akaike information criterion four lags of these short-run parameters are included. The λ's reflect the magnitude of these short-run deviations on house prices. The term in parentheses is the error correction term (ECT_{t-1}), and it represents the difference between actual house prices and its long-run equilibrium as estimated in Section 4.1. The coefficient η represents the speed at which house prices converge back to this equilibrium. Finally, ϵ_t is the error term.

Table 5 presents the results for Eq. (22). The seasonal dummy is positive and significant at a 1% level. Hence, the second quarter yields a larger change in house prices compared to the first, third or fourth. Moreover, the coefficients of the lag of house price growth ($\Delta p_{ht}h_t$) are – for all but the third – lag positive and less than one. Thus, speculative and psychological house price dynamics presumably play a role; however, since the coefficients are smaller than one, they will eventually fade away. The maximum borrowing amount ($\Delta b_{t-i}^{max,c}$) does not significantly affect house prices in the short run. The third lag of changes in households' ability to pay ($\Delta b_{t-3}^{cd,u}$) is significantly different from zero at a 10% level. More importantly, however, the error correction term is significant at a 5% level. Thence, the model returns to the long-run equilibrium at a satisfying degree of significance.

Table 5
Error correction equation.

	Cobb–Douglas & Constrained
1	−1.012(0.656)
$S2$	5.049(1.212)***
$\Delta(p_{ht-1}h_{t-1})$	0.362(0.080)***
$\Delta(p_{ht-2}h_{t-2})$	0.208(0.083)**
$\Delta(p_{ht-3}h_{t-3})$	−0.035(0.081)
$\Delta(p_{ht-4}h_{t-4})$	0.371(0.112)***
$\Delta b_t^{max,c}$	0.101(0.065)
$\Delta b_{t-1}^{max,c}$	−0.007(0.063)
$\Delta b_{t-2}^{max,c}$	−0.016(0.061)
$\Delta b_{t-3}^{max,c}$	0.048(0.059)
$\Delta b_{t-4}^{max,c}$	0.037(0.060)
$\Delta b_t^{cd,u}$	−0.029(0.021)
$\Delta b_{t-1}^{cd,u}$	−0.005(0.022)
$\Delta b_{t-2}^{cd,u}$	−0.035(0.022)
$\Delta b_{t-3}^{cd,u}$	−0.039(0.022)*
$\Delta b_{t-4}^{cd,u}$	0.008(0.022)
ECT_{t-1}	−0.056(0.027)**
R^2	0.626
$Adj.R^2$	0.553
N	99

Standard errors are reported in parentheses. The lag length is based on the Akaike information criterion. $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$.

5. Conclusion

In this paper, we reexamined the housing market equilibrium between mortgage credit and house prices. In particular, our focus was on the explanation of the equilibrium. We built three theoretical models that would explain this equilibrium. The first model relied on the notion that households are restricted in the amount they can borrow from financial institutions to finance the purchase of a property. The second model stated that households prefer to spend a fixed share of income on housing. And the third combined the two: lower-income households are bound by lending regulations while higher-income households prefer to spend a fixed budget share on housing. As we expected, the results only provide evidence of a long-run relation for the third model. That is, the equilibrium between mortgage credit and house prices is most likely driven by both the maximum borrowing amount of constrained households and the ability to pay of unconstrained households.

The results yield significant policy implications. First, given the functional form of the demand function (unitary elastic housing demand), the model implies that additional housing supply cannot reduce the purchase price of housing. Additional housing supply does reduce the price per brick, or put more formally, the unit price of housing. Households will, however, use this lower brick price to buy more bricks. That is, they will trade off the lower unit price of housing by consuming more housing quality, leaving the purchase price of housing unaffected. Thus, an important takeaway from this paper is that if housing demand is unitary elastic, housing supply will reduce the quality-adjusted price of housing, but it cannot reduce the purchase price of housing. Nonetheless, this relies inevitably on the assumption of unitary elastic housing demand.[26]

A policy tool that could decrease the purchase price of housing is the tightening of the debt-service-to-income caps. A tightening of these caps decreases the mortgage sum constrained households can take out. The policy works as follows: if constrained households cannot get a mortgage for their desired property, they must opt for a cheaper home, and consequently house prices decrease. It is, however, important to acknowledge that this policy has severe feedback effects. First, due to the lower house prices, unconstrained households will consume more units of housing (in order to maintain a fixed budget share). This could result in adverse effects, including unequal wealth distribution across households. Second, lowering house prices will make it less profitable for companies to build houses. Consequently, the quality (or size) of the houses homebuyers purchase will decrease as well. In tight housing markets like the Netherlands, this policy will jeopardize the position of constrained households in the housing market heavily.

This study is subject to a few limitations. First, we assumed that all households take out an annuity mortgage, which is of course a simplification of reality. It would be interesting to include different mortgage types in the theoretical framework and see how they perform empirically. Moreover, although Cobb–Douglas utility seems to perform well, it would be interesting to include other (perhaps nonlinear) utility functions. Another aspect that is currently not included in the theoretical model is home equity. Home equity and house prices are intertwined; high house prices make it possible for existing homeowners to spend more on their next home. This feedback effect between current house prices and future house prices is captured in the short-run deviations of the error-correction model. It would, however, be interesting to incorporate it in the theoretical long-run equation as well. Finally, it is important to note that the empirical analysis is only performed for the Netherlands. In the Netherlands, households generally finance their purchase through a mortgage. Consequently,

[25] Only a dummy for the second quarter of the year is added because this dummy significantly improves the fit of the model. Dummies for the other quarters are not significant and removing them only decreases the R-squared of the model slightly. Hence, these dummies are not included in the regression.

[26] One could, however, argue that housing demand in the Netherlands might seem unitary elastic, but that this is in reality driven by the inelastic housing supply the Netherlands faces. I.e., we face an external validity issue. In Appendix C we argue that this is presumably not the case.

mortgage conditions are an important driver of housing demand. For countries where relatively more properties are bought outright or with less mortgage financing, mortgage conditions are unlikely to drive demand. For such countries, an analysis based on wealth, rather than credit, seems more applicable.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data and code are uploaded as supplementary material.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.econmod.2022.106136.

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