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Abstract

In view of regional house prices drifting apart, we examine whether regionally differentiated macroprudential policies can address financial stability concerns and moderate house price differences. To this end, we disaggregate both the household sector and the housing stock in a two-region DSGE model with out of sync subnational housing markets and compare four macroprudentail policy types: standard monetary policy by means of a standard Taylor rule, leaning against the wind monetary policy, national macroprudential policy or one that targets region-specific LTV ratios. In terms of reducing variances of house prices, regionally differentiated macroprudential policy performs best, provided the policy authorities are concerned with stabilising output and house prices rather than simply minimising the variance of inflation. Thus the findings point to a critical role for policy in regionalising macroprudential tools.

JEL-Codes: E320, E440, E520, E580.

Keywords: macroprudential policies, housing, DSGE, Great Britain.

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1. Introduction

In the aftermath of the global financial crisis, macroeconomic research has argued that house price movements are the source of - rather than the consequence of - business cycle fluctuations.[1] The fact that property is bought with large amounts of debt is one reason why housing market outcomes over the past ten years have been so volatile. In an upswing, when expectations are that house prices will continue to rise, the returns from using debt to finance house acquisitions look very high. And supplying mortgages will constitute a low risk as long as house prices continue to rise. However, all those forces go into reverse once the expectation that house prices will rise evaporates and the perceived probability that house prices might fall substantially becomes significant. Against this background, understanding the transmission channels between the stance of monetary policy and the emergence of housing bubbles has become an important and topical issue for policymakers.

In retrospect, central banks have been widely criticised for having kept interest rates too low for too long prior to the global financial crisis. Several authors have argued that exceptionally low interest rates spurred excessive risk-taking in the banking sector, leading to the build-up of imbalances and finally the crisis.[2] What does this mean for policymakers? Since Assenmacher-Wesche and Gerlach (2014) have shown that using standard monetary policy to lean against asset-price fluctuations and emerging housing bubbles may not be a sensible strategy, macroprudential measures are called for. Macroprudential policies are meant to reduce this procyclicality and to mitigate boom-bust patterns in financial markets. Many countries, advanced and emerging, have accepted this new paradigm and macroprudential policy has become increasingly popular, leaving interest rates focused on the needs of inflation and aggregate economic activity.[3]

Inter alia, the impacts of macroprudential tools have been studied in dynamic stochastic general equilibrium (DSGE) models. Much of this literature is concerned with determining whether introducing macroprudential tools can help policymakers better achieve their mandates of inflation targeting and employment. Lambertini et al. (2013) have incorporated news shocks into the housing market model of Iacoviello and Neri (2010), and find that a combination of a countercyclical loan-to-value (LTV) rule responding to credit growth, in addition to a standard Taylor rule, reduces the volatility of house prices and the debt-to-GDP ratio, relative to a baseline policy based off of a typical Taylor type rule.

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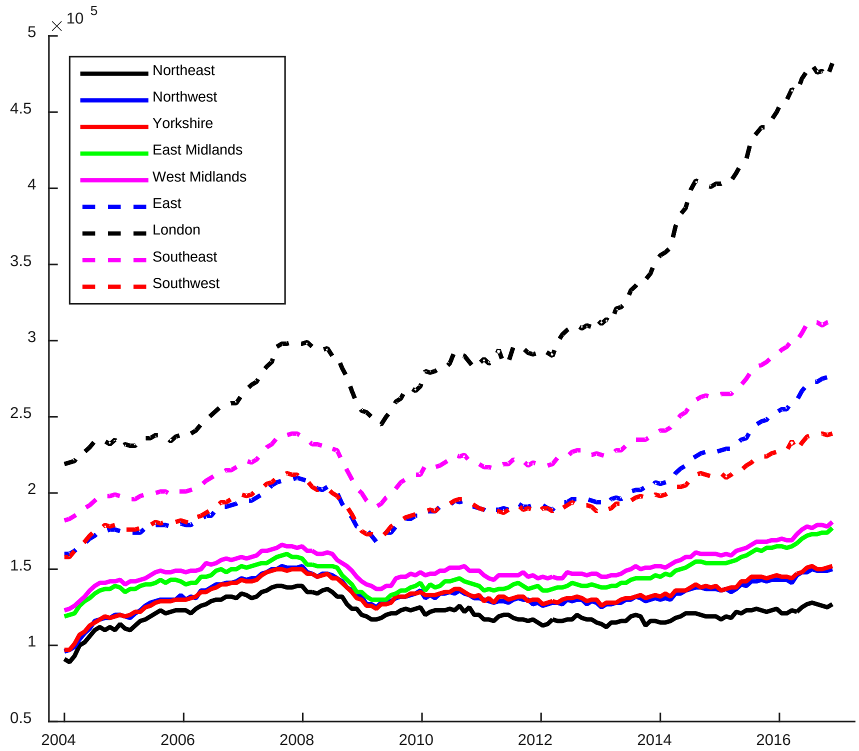
[1] Leamer (2015) has even argued that housing is the business cycle.

[2] See, for example, Altunbas et al. (2014) and Ciccarelli et al. (2015). Both papers are some of the major papers in this literature, by no means an exhaustive list though.

[3] The classic study of financial crises by Carmen Reinhart and Ken Rogoff (2009) has taught us persuasively “this time is different”. A growing literature has documented the use of macroprudential policies across countries and analysed their effects. Galati and Moessner (2012) have provided a review of the macroprudential housing-finance toolkit. Cerutti et al. (2017) have documented the use of macroprudential policies for 119 countries over the period 2000 - 2013 and covering many instruments. To be fair, one must concede a lack of previous track record of macroprudential regulation in most countries as of today.

A look at the regional UK house price indices in Figure 1 reveals the lack of synchronicity and is indicative of three clusters of regions. The first cluster – gloom – consists of five regions (Northeast, Northwest, Yorkshire, East Midlands, West Midlands) in which house prices fell substantially during the global financial crisis and have remained on the low level. The second – bust and boom – consists of three regions (East, Southeast, Southwest) in which housing markets have rebounded since 2009 after falling sharply during 2008 - 2009. The third cluster – boom – comprises London, in which the pronounced drop in house prices in 2008 - 2009 was followed by a quick rebound and a significant rise. Figure 2 reveals that a similar clear split is apparent when Scotland and Wales are taken into account.[4] Overall, the sharp differences in house price trends across the UK suggest that it makes little sense to talk of a national housing cycle.

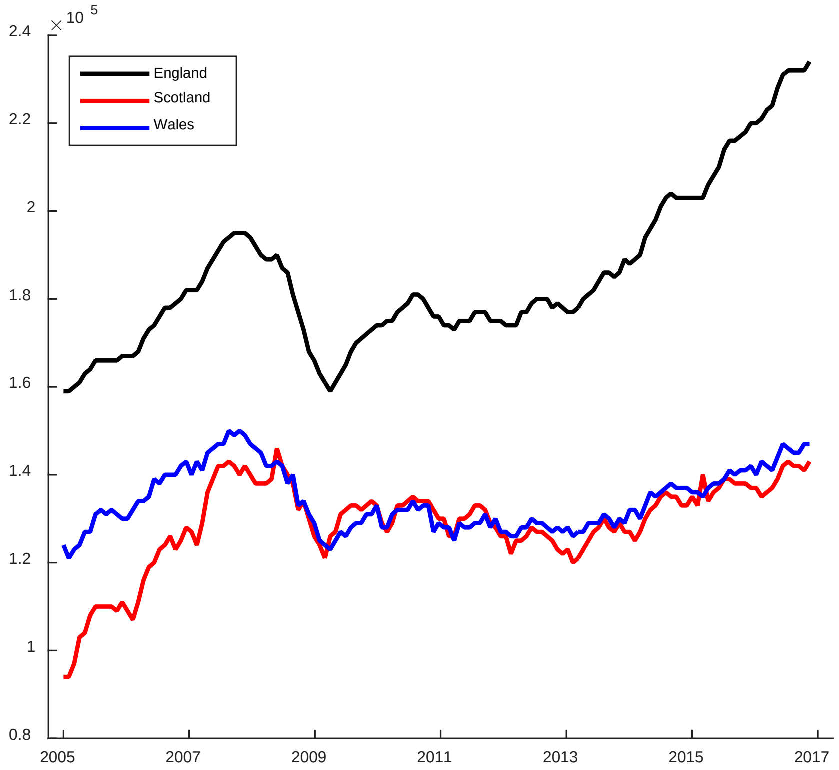
Figure 1: Average House Prices by English Region, January 2004 to November 2016



Source: UK Office for National Statistics

[4] For empirical evidence of segmentation in UK house prices see, for example, Cook (2003) and Tsai (2015) and the literature cited therein. The UK is not alone. House prices in many cities worldwide have been rising much faster than the national market.

Figure 2: Average House Price by UK Country, January 2005 to November 2016



Source: UK Office for National Statistics

At the same time the empirical facts confirm the well-known feature from urban economics that housing markets are geographically disconnected.[5] Put another way, national house price indices mask tremendous variation at the regional and metropolitan area level. These uneven house price dynamics can present problems for macroprudential policies. Short, precise and exactly to the point: Is it a problem? How to fix it? Are region-specific macroprudential measures better suited than a national regulation to reduce or remove the risk of emerging regional housing bubbles?[6]

When regional house price divergences are significant, then this may matter for the efficacy of monetary policy. For example, the policy response to a regional housing shock will depend on the region where the shock originated. Similarly, the response to a policy tightening will depend on issues such as whether the most rapidly expanding regions are the most interest sensitive. More generally, the aggregate effects of macroprudential policy depend on the distribution of regional sensitivities and on the initial distribution of regional economic conditions at the time of tightening. See in this context Carlino and DeFina (1999). Fratantoni and Schuh (2003) have demonstrated that the transmission of

[5] See, for example, Van Nieuwerburgh and Weill (2010) for an analysis of the level and dispersion of house prices across US metropolitan areas in a calibrated dynamic general equilibrium model. Hernández-Murillo et al. (2015) have estimated a Markov switching model of US housing cycles that allows for idiosyncratic departures from a national housing cycle.

[6] In many macroprudential studies, the uneven house price dynamics is mostly discussed as an afterthought.

monetary policy to house prices is heterogeneous across US states, and that regional housing market conditions respond differently to a common monetary policy shock. However, no reasons for the differences in the responses are explicitly estimated. Vansteenkiste (2007) and Vansteenkiste and Hiebert (2011) have studied the impact of interest rate shocks on regional U.S. and Euroland house prices, as well as spillovers of house price shocks in a common monetary policy setting.

In this context we develop a prototype multi-regional DSGE model to analyse exuberant house price dynamics in subnational areas in the face of national versus region-specific macroprudential measures. Disaggregating not only the household sector but also the housing stock in a two-region DSGE model with out of sync subnational housing markets may provide valuable insights into the transmission of region-specific fundamental and/or policy shocks across localised metropolitan regions. Great Britain's regional house price differences may ultimately indicate that there is no one-size-fits-all-national macroprudential policy. Instead region-specific macroprudential policies might be advisable. While modelling macroprudential policy at the national level is reaching a mature stage, the assessment of macroprudential policies at the subnational level is still an emerging science. Finally, spillovers of macroprudential policies differentiated at the regional level are unchartered territory. Consequently, understanding out of sync subnational house price developments and appropriate policy responses remains a fertile area for future research. In particular, we shall investigate whether a country-wide monetary policy and region-specific macroprudential policies can be a helpful combination, favouring macroeconomic performance and financial stability at both the regional and country-wide level.

The roadmap to the reminder of the paper is as follows. Section 2 describes the DSGE modelling framework. The main strength of this model-based DSGE approach is that it provides a theoretically grounded framework which one allows to distinguish between statistical correlation and economic causation. Section 3 puts forward the calibration, while section 4 presents the results. Section 5 summarises and discusses policy implications. Some tables and figures have been placed in appendices.

2. The Model Setup

In this section we set out a formal mathematical treatment for the underlying DSGE model. While a visual exploration of the house price evolution gives a sense of the situation, it does not provide evidence of the specific effect of the adoption of macroprudential policies. Isolating the effect of macro-prudential policies and their impact, from complementary policies and/or other economic developments, constitutes a significant challenge and requires cautious interpretations. To address this difficulty, a large strand of the literature employs DSGE frameworks. Precisely in this tradition, this section models the macroprudential toolkit in the UK in a two-region open-economy DSGE framework.[7]

Following the common practice in the housing DSGE literature, we split the households into two groups: borrowers and savers. The latter are the lenders in the economy, have access to the country's complete asset market and own firms and land. In contrast, the borrowers face a borrowing constraint whereby the amount of funds they are able to obtain is a function of the value of their collateral. Macroprudential policy directly impacts the amount of borrowing by means of a binding Taylor-like rule for the loan-to-value ratio. In terms of the deep parameters of the model, however, the only difference between the two household types is the value of the discount factor, which is assumed to be larger for savers. Thus, concerning the households, our modelling framework closely resembles that of Iacoviello (2005), Monacelli (2009) and Iacioviello and Neri (2010), among many others.[8]

Each region's housing construction sector consists of firms producing intermediate housing structures and firms that use these intermediate structures to produce final housing structures. These are then combined by a housing construction firm with land to form new houses. In contrast, the non-durable consumption good is produced by a common production sector in which intermediate goods firms use labour from both regions as an input. All workers in the present setup are equally productive, but the elasticity of the labour supply across sectors is limited. Final non-durable consumption good firms operating in a perfectly competitive environment bundle intermediate goods and sell those to households. Pricing of all intermediate goods firms, in the non-durable consumption sector as well as in the housing construction sector, conforms to the standard Calvo case. Finally, monetary policy is conducted by a common central bank, which steers the short-term nominal interest rate.

In what follows, we describe in detail the maximisation problems and the respective first-order conditions of the first region; however, those of the second region are analogous. Both regions share mostly the same structural parameter calibration but face region-specific shocks. The weight of the household living in the first region is $\lambda \in [0,1]$, the weight of the borrowers $\omega \in [0,1]$ is equal for both regions, and all variables of the household in the second region are indicated by an asterisk. Furthermore, we interpret and calibrate the first region to match London and the second region to the rest of the UK (thereinafter abbreviated by "L" and "R", respectively).

2.1. Households

Two types of households, borrowers and savers, living in London maximise

[7] The descriptive evidence in Figure 1 suggests the existence of three house price clusters. No further conclusions can be drawn from a three-region modelling framework in comparison with a two-region framework. For the sake of brevity we therefore limit ourselves to a two-region DSGE model.

[8] Our two-region model structure is similar to the open economy models of Benigno and Benigno (2003) and Galí and Monacelli (2005).

$$E_0 \sum_{t=0}^{\infty} \beta_i^t \left[\frac{1}{1-\sigma} (X_t^i)^{1-\sigma} - \frac{\nu_i}{1+\varphi} \left(N_t^i \right)^{1+\varphi} \right], \tag{1}$$

where $i \in \{b, s\}$ indicates the household type, X_t^i is the consumption bundle, $N_{j,t}^i$ represents an aggregate labour index, φ and σ are the corresponding intertemporal elasticities of substitution with respect to labour and consumption, ν_i allows for differences in the weighting of utility losses from labour, depending on the household type, and is calibrated in a way that in the steady state it holds $N^s \approx N^b \approx 1/3$. β_i represents the household's discount factor. The savers are assumed to be more patient compared to the borrowers, that is $\beta_s > \beta_b$. Following Funke and Paetz (2013), as well as Monacelli (2009), the consumption index is a weighted average of the flow of non-housing consumption expenditures and the stock of housing,

$$X_t^i = C_t^{i\,(1-\gamma\varepsilon_{\gamma,t})} D_t^{i\,\gamma\varepsilon_{\gamma,t}}, \tag{2}$$

where C_t^i and D_t^i represent composite indices of non-housing and housing consumption, respectively, γ is the share of housing in utility and $\varepsilon_{\gamma,t} = \exp(e_{\gamma,t})$ is a housing preference shock that affects the marginal rate of substitution between non-housing and housing goods. Housing consumption is given by the standard CES aggregator

$$D_t^i \equiv \left[(1-\alpha)^{\frac{1}{\eta}} D_{L,t}^{i\;\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} D_{R,t}^{i\;\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}. \tag{3}$$

Thus, each household derives utility from consuming both housing in the home region of London, $D_{L,t}^i$, and housing in the rest of the UK, $D_{R,t}^i$, but with a home bias equal to $(1-\alpha)$. The inverse home bias parameter α has a different calibration in London than in the rest of the UK; that is, in exception to all structural parameters, there exists also an α^*. η stands for the intratemporal elasticity of substitution between housing in London and housing in the rest of the UK. Like in Horvath (2000), the aggregate labour index is given by

$$N_t^i = \left[N_{C,t}^{i\;\frac{1+\zeta}{\zeta}} + N_{DL,t}^{i\;\frac{1+\zeta}{\zeta}} \right]^{\frac{\zeta}{1+\zeta}}, \tag{4}$$

where $N_{j,t}^i$ is labour supplied in sector j. Overall, there are three production sectors, indicated by $j \in \{C, DL, DR\}$, that are the consumption sector common to both regions, the housing production sector in

London and the housing production sector in the rest of the UK. But the households in London can only supply labour in the common consumption and the housing production sector in London. ζ determines the elasticity of labour supply across the two sectors. If $\zeta = \infty$, hours worked in both sectors are perfect substitutes from the perspective of the household.

Savers

The patient household's budget constraint is given by

$$C_t^s + Q_{L,t}H_{Lt}^s + Q_{R,t}H_{Rt}^s + B_t^s + F_t = \Re_{t-1}\frac{B_{t-1}^s}{\pi_{C,t}} + \Re_{t-1}\frac{F_{t-1}}{\pi_{C,t}} + Q_{\mathcal{L},t}\mathcal{L} + \sum_{j=C,DL}\frac{W_{j,t}N_{j,t}^s}{P_{C,t}} + \sum_{j=C,DL}\frac{Z_{j,t}}{P_{C,t}} + T_t^s, \tag{5}$$

where $\pi_{C,t+1} = \frac{P_{C,t+1}}{P_{C,t}}$ is the inflation rate of the non-durable consumption good, $Q_{L,t}$ and $Q_{R,t}$ are real housing prices in London and in the rest of the UK, respectively, B_t^s represents the stock of real domestic debt (both denominated with the domestic non-housing price index), $\Re_t$ the nominal interest rate and $Q_{\mathcal{L},t}$ is the real price that a firm has to pay to the household for the fixed factor land $\mathcal{L}$. $W_{j,t}$ denotes the sector-specific nominal wage rate, $H_{L,t}^s = D_{L,t}^s - (1-\delta)D_{L,t-1}^s$ defines housing investment in London, whereas δ represents the depreciation rate of the housing stock. H_{Rt}^s is the similarly defined housing investment in the rest of the UK. Furthermore, we assume savers to have access to a complete set of contingent claims, whereby F_t denotes the nominal payoff in period *t+1* of Arrow securities purchased in period *t*. In addition, $Z_{j,t}$ stands for the profits earned by savers for owning intermediate good firms and T_t^s indicates government lump-sum taxes paid by savers. Maximising (1) subject to (5) yields the following first order conditions:

$$\tau_t^s = \left(1 - \gamma\varepsilon_{\gamma,t}\right)X_t^{s^{-\sigma}}\left(\frac{D_t^s}{C_t^s}\right)^{\gamma\varepsilon_{\gamma,t}} \tag{6}$$

$$\frac{W_{j,t}}{P_{C,t}} = \frac{\nu_s\,(N_t^s)^{\varphi}\frac{\partial N_t^s}{\partial N_{j,t}^s}}{\tau_t^s} \tag{7}$$

$$Q_{L,t}\tau_t^s = \frac{\gamma\varepsilon_{\gamma,t}}{1-\gamma\varepsilon_{\gamma,t}}\frac{C_t^s}{D_t^s}\frac{\partial D_t^s}{\partial D_{L,t}^s}\tau_t^s + \beta_s(1-\delta)E_t\left\{Q_{L,t+1}\tau_{t+1}^s\right\} \tag{8}$$

$$Q_{R,t}\tau_t^s = \frac{\gamma\varepsilon_{\gamma,t}}{1-\gamma\varepsilon_{\gamma,t}}\frac{C_t^s}{D_t^s}\frac{\partial D_t^s}{\partial D_{R,t}^s}\tau_t^s + \beta_s(1-\delta)E_t\left\{Q_{R,t+1}\tau_{t+1}^s\right\} \tag{9}$$

$$\tau_t^s = \beta_s \Re_t E_t \left\{ \frac{\tau_{t+1}^s}{\pi_{t+1}} \right\} \tag{10}$$

Equation (6) equates the Lagrangian multiplier, τ_t^s, with the marginal value of non-durable consumption, equation (7) is the labour supply condition, equalising the real wage to the marginal rate of substitution between consumption and leisure, equation (8) and (9) set the marginal value of housing in terms of non-durable consumption equal to its payoff and equation (10) is the standard Euler equation, which, in our case, is the optimality condition for one-period bond holdings and for holdings of Arrow securities as well.

Borrowers

The utility maximisation of the impatient household is subject to the budget constraint

$$C_t^b + Q_{L,t} H_{L,t}^b + Q_{R,t} H_{R,t}^b + \Re_{t-1} \frac{B_{t-1}^b}{\pi_{C,t}} = B_t^b + \sum_{j=C,DL} \frac{W_{j,t} N_{j,t}^b}{P_{C,t}} + T_t^b, \tag{11}$$

where, similar to the savers' case, H_t^b is the flow of new housing demanded by borrowers, $N_{j,t}^b$ stands for the labour supply provided by borrowers at the prevailing market wage rate in both the consumption and housing industry and T_t^b denotes lump-sum taxes paid by borrowers. In addition, the latter optimally choose the level of real domestic debt, denoted by B_t^b, and pay the nominal interest rate R_{t-1} for the amount of credit borrowed in the previous period. It is worth mentioning that borrowers in both regions have access to credit provided by both savers and not just the saver in their respective region. That implies in equilibrium $B_t^b + B_t^{b*} + B_t^s + B_t^{s*} = 0$. A salient feature of the modelling framework is the borrowing constraint, in the spirit of Kiyotaki and Moore (1997), which borrowers face each period:

$$\Re_t B_t^b \leq \kappa_t \, (1-\delta) E_t \left(Q_{L,t+1} D_{L,t}^b + Q_{R,t+1} D_{R,t}^b \right) \pi_{C,t+1} \tag{12}$$

Equation (11) relates the amount that will be repaid by a borrower in the following period, relative to the expected future value of the housing stock (adjusted for depreciation). Thus, the borrower's debt can be interpreted as mortgage contracts. κ_t represents the time-varying LTV ratio, which is a policy variable (its evolution is described in detail later). Assuming that borrowers in the United Kingdom can only access domestic mortgage markets, given that $\beta_s > \beta_b$ and that there is no or sufficiently small uncertainty, the LTV constraint is binding in and around the steady state (for discussion see Iacoviello, 2005).

Recent literature emphasises the role of fixed and adjustable-rate mortgage contracts for monetary and macroprudential policy transmission. We assume all mortgage contracts to be adjustable, because, in the UK, the predominant mortgage contract is an adjustable-rate mortgage.[9] We define τ_t^b and $\tau_t^b\psi_t$ as the Lagrangian multipliers on the constraints, equations (11) and (12), with the result that the first-order conditions of the respective optimisation problem become:

$$\tau_t^b = \left(1-\gamma\varepsilon_{\gamma,t}\right)X_t^{b^{-\sigma}}\left(\frac{D_t^b}{C_t^b}\right)^{\gamma\varepsilon_{\gamma,t}} \tag{13}$$

$$\frac{W_{j,t}}{P_{C,t}} = \frac{\nu_s\left(N_t^b\right)^{\varphi}\frac{\partial N_t^b}{\partial N_{j,t}^b}}{\tau_t^b} \tag{14}$$

$$Q_{L,t}\tau_t^b = \frac{\gamma\varepsilon_{\gamma,t}}{1-\gamma\varepsilon_{\gamma,t}}\frac{C_t^b}{D_t^b}\tau_t^b\frac{\partial D_t^b}{\partial D_{L,t}^b} + \beta_b(1-\delta)E_t\left\{Q_{L,t+1}\tau_{t+1}^b\right\} + \psi_t\kappa_t(1-\delta)E_tQ_{L,t+1}\tau_t^b\pi_{C,t+1} \tag{15}$$

$$Q_{R,t}\tau_t^b = \frac{\gamma\varepsilon_{\gamma,t}}{1-\gamma\varepsilon_{\gamma,t}}\frac{C_t^b}{D_t^b}\tau_t^b\frac{\partial D_t^b}{\partial D_{R,t}^b} + \beta_b(1-\delta)E_t\left\{Q_{R,t+1}\tau_{t+1}^b\right\} + \psi_t\kappa_t(1-\delta)E_tQ_{R,t+1}\tau_t^b\pi_{C,t+1} \tag{16}$$

$$\psi_t\Re_t = 1-\beta_bE_t\left\{\frac{\tau_{t+1}^b}{\tau_t^b}\frac{\Re_t}{\pi_{t+1}}\right\} \tag{17}$$

The interpretation of the above-stated equations is similar to the first-order conditions of the savers, except for the presence of ψ_t, which can be interpreted as the marginal value of borrowing. With ψ_t being positive, from equation (17) follows $\tau_t^b > \beta_b\Re_tE_t\{\tau_{t+1}^b/\pi_{t+1}\}$, or in words, the borrower's present is larger than his future marginal value of non-durable consumption. This again implies that the borrower would be willing to plunge deeper into debt to increase current consumption if he could. Therefore, and as one can see in equations (15) and (16), the borrower gets additional utility from owning houses, because he can use these as collateral. If $\psi_t = 0$, the first-order conditions of the borrower would essentially reduce to the saver's first-order conditions.[10]

[9] Adjustable rates are periodically reset to the current benchmark. Figure 2 in Campbell and Cocco (2003) shows the evolution of the share of fixed-rate mortgages, which is strongly negatively correlated with long-term interest rates. Andrews et al. (2011) provide evidence on mortgage contracts across OECD countries. Rubio (2011) introduces long-term debt in a model without capital and shows that effects of monetary policy are stronger with variable rate mortgages, since real interest rate movements have larger effects. Calza et al. (2013) present SVARs evidence that monetary policy has larger effects in countries with more variable mortgages.

[10] See Monacelli (2009) for further discussion of ψ_t.

2.2. Regional Risk Sharing

Although the modelling framework assumes borrowers are constrained, savers from both regions have access to complete securities markets, where they can share region-specific risks via trading of contingent claims. By equating the optimality conditions of both regions with respect to holdings of Arrow securities, we obtain

$$\frac{(1-\gamma\varepsilon_{\gamma,t})X_t^{S^{-\sigma}}\left(\frac{D_t^S}{C_t^S}\right)^{\gamma\varepsilon_{\gamma,t}}}{(1-\gamma\varepsilon_{\gamma,t}^*)X_t^{S*^{-\sigma}}\left(\frac{D_t^{S*}}{C_t^{S*}}\right)^{\gamma\varepsilon_{\gamma,t}^*}} = \varrho, \tag{18}$$

where ϱ depends on initial conditions and is assumed to be 1.06, which is approximately the per capita wealth ratio of London to the rest of the UK. This can be seen as a lower bound, since incomes in London are much larger than in the rest of the UK. It is interesting to note that equation (18) could simply be interpreted as the result of having complete markets in a closed economy setup with two agents. Here the real exchange rate has a unitary value, since both regions use one single currency.

2.3. Firms

We model the consumption goods sector as common to both regions. Thus, consumers face only one price of the non-durable consumption good independent of their location or their type. In contrast, the production of housing is region-specific. The structure of the production sector is as follows: monopolistically competitive firms produce either (exclusively) intermediate consumption goods or residential structures. Pricing of these firms is the familiar Calvo case. In the consumption sector, they sell these intermediate goods to firms producing final consumption goods; whereas in the housing production sector, they sell it to firms producing final residential structures. Out of these final residential structures, combined with land, another firm then constructs final houses. The consumption sector is standard in the New Keynesian literature, the housing production sector is similar to Davis and Heathcote (2005) and Iacoviello and Neri (2010).

2.3.1. Housing Construction Firms

Unlike non-durable consumption goods firms, which are common to both, we assume the presence of region-specific housing construction firms. This allows us to account for differences in land and regulatory restrictions in London and the rest of the UK. The reason these differences are important lies in the fact that the UK has a particularly strict planning regime. In the first instance, the allocation of land to housing construction is limited. Furthermore, there is significant discretion allocated to local planners when dealing with applications and granting permissions to build. The upshot of these procedures is that there is significant uncertainty associated with the process in terms of outcomes, as they are products of protracted negotiations between developers and planners. A special feature is the Green Belt land. Land designated to be within the Green Belt is intended to prevent urban sprawl, and is largely protected from development. The current system of development dates back to the Town and Planning Act 1947. The various updates to the Act since then have changed several details, but did little to substantially affect the severity of housing planning restrictions created by the original policy (see Hilber and Vermeulen, 2016). Wolf (2015) has recently urged a relaxation of green belt planning restrictions to tackle the housing crisis.

Quantitatively, house prices in the most regulated English region, the South East, would have been about 25% lower in 2008 if this region had the same regulatory restrictiveness as the North East, according to the estimates of Hilber and Vermeulen (2016). Moreover, in the absence of land restriction constraints, they estimate house prices in the South East would have been approximately 10% lower. As they also show, land restrictions especially are a problem in highly urbanised areas like Greater London. Given the large but regional differentiated housing supply impacts of regulation and scarcity of land, it is natural also to look at the influence of these differences on business cycle dynamics.

Here, we only present the problem of the housing construction firms in London, but the firms in the rest of the UK face a similar maximisation problem. The housing construction firms maximise their profit in a perfect competitive environment. To construct new houses, they combine land and final residential structures through the Cobb-Douglas production function

$$Y_{HL,t} = {Y_{DL,t}}^{1-\vartheta_L} \mathcal{L}_L^{\vartheta_L}. \tag{19}$$

$Y_{HL,t}$ denotes new houses produced, $Y_{DL,t}$ is residential structures produced by final goods firms, $\mathcal{L}_L$ is land bought from patient households and ϑ_L is a parameter that weights the importance of land and labour in the production of new housing. Similar to Davis and Heathcote (2005), we assume a constant acreage of new land being available for residential development in each period.[11] But unlike previous literature, in our model, constant newly available acreages, $\mathcal{L}_L$ and $\mathcal{L}_R$, as well as the weighting parameters, ϑ_L and ϑ_R, are not equal, but region-specific. Differences in $\mathcal{L}_L$ and $\mathcal{L}_R$ lead to price disparities of housing in the steady state. However, they influence business cycle dynamics only indirectly through their influence on steady state ratios. The weighting parameters ϑ_L and ϑ_R, on the

[11] The fixity of newly available developed land arises from the time horizon of the model. Our focus is not on the long run. Long-run housing models, unlike this one, embed the housing sector within a model of the overall economy that endogenises growth, saving and asset prices. Any long-run framework has to model the changing supply of housing taking into account the fixity of land mass and the way in which endogenous shifts in the cost of land relative to structures changes the way in which houses are constructed. One paper in this spirit is Deaton and Laroque (2001).

other hand, have an effect similar to housing supply adjustment costs. As Iacoviello and Neri (2010) note, a larger weighting of land in the production function leads to lower volatility of housing investment, but raise the volatility of housing prices. The housing construction firm maximises its profit by solving the static problem

$$Max\ P_{L,t}Y_{HL,t} - P_{DL,t}Y_{DL,t} - P_{\mathcal{L},t}\mathcal{L}, \tag{20}$$

where $P_{L,t}$ is the market price for housing in London, $P_{DL,t}$ is the price for final residential structures and $P_{\mathcal{L}}$ is the price the firm has to pay to the household for using land. The resulting housing price in London can be represented in real terms by

$$Q_{L,t} = (1-\vartheta)^{-(1-\vartheta)}\vartheta^{-\vartheta}\, {Q_{DL,t}}^{1-\vartheta}{Q_{\mathcal{L},t}}^{\vartheta}. \tag{21}$$

2.3.2. *Final Goods Firms*

In each sector $j \in \{C, DL, DR\}$, a continuum of perfectly competitive firms on the interval $\Omega_{\mathrm{j}} = [\underline{\Omega}_j, \overline{\Omega}_j]$, produces final non-durable consumer goods or residential structures. Firms in the non-durable consumption sector are distributed over the whole country, so they are on the interval $\Omega_{\mathrm{C}} = [0,1]$, firms producing final residential structures in London are on the interval $\Omega_{\mathrm{DL}} = [0, \lambda]$ and firms producing in the rest of the UK are on the interval $\Omega_{\mathrm{DR}} = (\lambda, 1]$. Their production function is given by

$$Y_{j,t} = \left[\left(\frac{1}{\overline{\Omega}_j - \underline{\Omega}_j}\right)^{\frac{1}{\epsilon_j}} \int_{z\in\Omega_{\mathrm{j}}} Y_{j,t}(z)^{\frac{\epsilon_j - 1}{\epsilon_j}}\, dz\right]^{\frac{\epsilon_j}{\epsilon_j - 1}} \tag{22}$$

where $Y_{j,t}$ denotes aggregate output of non-durable consumption goods or residential structures, $Y_{j,t}(z)$ is the input produced by intermediate goods firm z and ϵ_j is the elasticity of substitution among intermediate goods. Profit maximisation leads to the demand curve

$$Y_{j,t}(z) = \frac{1}{\overline{\Omega}_j - \underline{\Omega}_j}\left(\frac{P_{j,t}(z)}{P_{j,t}}\right)^{-\epsilon_j} Y_{j,t}, \tag{23}$$

where $P_{j,t}(z)$ denotes the price of the intermediate good produced by firm z and $P_{j,t} = \left(\int_0^1 P_{j,t}(z)^{\,1-\epsilon_j}\, dz\right)^{\frac{1}{1-\epsilon_j}}$ is the respecting price index.

2.3.3. *Intermediate-Goods firms*

Each monopolistic competitive firm z produces intermediate goods according to the constant returns to scale production function

$$Y_{j,t}(z) = A_{j,t}N_{j,t}(z), \tag{24}$$

where $N_{j,t}(z)$ stands for the firm's labour input, $A_{j,t} = \exp(a_{j,t})$ denotes labour productivity and $a_{j,t}$ is a shock process for labour productivity. We assume a common labour productivity shock in the housing sector for both regions, so that $a_{DL,t} = a_{DR,t} = a_{D,t}$. The firms solve the following static cost minimisation problem:

$$Min\ W_{j,t}N_{j,t}(z) \tag{25}$$

$$\text{s.t.} \quad A_{j,t}N_{j,t}(z) \geq \frac{1}{\overline{\Omega}_j - \underline{\Omega}_j}\left(\frac{P_{j,t}(z)}{P_{j,t}}\right)^{-\epsilon_j} Y_{j,t} \tag{26}$$

Real marginal cost is equal for all firms of the same intermediate goods production sector and can be represented by the relationship

$$MC_{j,t} = \frac{1}{A_{j,t}}\frac{W_{j,t}}{P_{j,t}} = \frac{1}{A_{j,t}}\frac{P_{C,t}}{P_{j,t}}\frac{\nu_S\,(N_t^S)^{\varphi}\frac{\partial N_t^S}{\partial N_{j,t}^S}}{\tau_t^S} \tag{27}$$

Because of staggered price setting, the profit maximisation of the intermediate goods producers is a dynamic problem. A randomly selected fraction of intermediate firms in each sector $(1-\theta_j)$ is allowed to adjust prices, while the remaining fraction of firms θ_j does not adjust. The profit maximisation problem of a firm *k* that is able to update its price in period t is given by:

$$\max_{P_{j,L,t}} \quad \sum_{k=0}^{\infty} \theta_j^z\, E_t\ \left\{\Lambda_{t,t+k}\left(P_{j,t}\, Y_{j,t+k}(z) - NMC_{j,t+k}(\, Y_{j,t+k}(z))\right)\right\} \tag{28}$$

$$\text{s.t.} \quad Y_{j,t+k}(z) = \frac{1}{\overline{\Omega}_j - \underline{\Omega}_j}\left(\frac{P_{j,t}(z)}{P_{j,t}}\right)^{-\epsilon_j} Y_{j,t+k}, \tag{29}$$

where $NMC_{j,t}$ denotes the nominal marginal cost in sector *j*. Since they are owned by the savers, firms make use of their stochastic discount factor represented by $\Lambda_{t,t+z}$. Given that marginal costs are the same for all firms the FOC of this problem is given by:

$$\sum_{k=0}^{\infty} \theta_j^z \, E_t \left\{ \Lambda_{t,t+k} \, Y_{j,t+k}(z) \left(P_{j,t} - \frac{\epsilon_j}{\epsilon_j - 1} NMC_{j,t+k} \right) \right\} = 0. \quad (30)$$

Log-linearizing and combining the condition for aggregate price evolution and the profit maximisation condition yields the familiar New Keynesian Phillips curve expressions:

$$\hat{\pi}_{C,t} = \beta_s \hat{\pi}_{C,t+1} + \frac{(1-\theta_C)(1-\theta_C \beta_s)}{\theta_C} \widehat{MC}_{C,t} + e_{\pi_C,t} \quad (31)$$

$$\hat{\pi}_{DL,t} = \beta_s \hat{\pi}_{DL,t+1} + \frac{(1-\theta_D)(1-\theta_D \beta_s)}{\theta_D} \widehat{MC}_{DL,t} + e_{\pi_{DL},t} \quad (32)$$

$$\hat{\pi}_{DR,t} = \beta_s \hat{\pi}^*_{DR,t+1} + \frac{(1-\theta_D)(1-\theta_D \beta_s)}{\theta_D} \widehat{MC}_{DR,t} + e_{\pi_{DR},t} \quad (33)$$

The stochastic processes $e_{\pi_C,t}$, $e_{\pi_{DL},t}$ and $e_{\pi_{DR},t}$ can be interpreted as cost push shocks.

2.4. Market Clearing and Foreign Demand

Aggregate market clearing in the housing market in London requires that the supply of housing goods is equal to demand in each period:

$$Y_{HL,t} = \lambda \left[D_{L,t} - (1-\delta) D_{L,t-1} \right] + (1-\lambda) \left[D^*_{L,t} - (1-\delta) D^*_{L,t-1} \right] + \varepsilon_t^F \quad (34)$$

$\varepsilon_t^F = \exp(e^F)$ denotes a foreign demand shock. The influence of foreign demand is evident in the frothiness of London's property market, where the eagerness of Chinese, Russian and Arab country buyers drives a wedge between house prices and local fundamentals. They are willing to pay above the odds to secure a safe haven for their savings. A study in 2013 found that increased political risk worldwide explained 8 percent of the variation in London's house prices since 1998 (Badarinza and Ramadorai, 2013). The demand shock is assumed to only affect London. Thus, the housing market clearing in the rest of the UK is given by

$$Y_{HR,t} = \lambda \left[D_{R,t} - (1-\delta) D_{R,t-1} \right] + (1-\lambda) \left[D^*_{R,t} - (1-\delta) D^*_{R,t-1} \right] \quad (35)$$

The stock of housing in London owned by Londoners is given by $D_{L,t} = \omega D^b_{L,t} + (1-\omega) D^s_{L,t}$. The housing stock in the rest of the UK owned by households from London, $D_{R,t}$, the housing stock in the rest of the UK owned by households from the rest of the UK, $D^*_{R,t}$, and the housing stock in London owned by households from the rest of the UK, $D^*_{L,t}$, are defined the same way. Moreover, aggregate output of non-durable consumption goods has to equal aggregate consumption, $Y_{C,t} = C_t^T$, where aggregate consumption is given by $C_t^T = \lambda C_t + (1-\lambda)C_t^*$, with $C_t = \omega C_t^b + (1-\omega)C_t^s$ and C_t^* analogous. Aggregate labour supply of borrowers and savers in London is given by $N_t^b = N_{C,t}^b + N_{DL,t}^b$ and $N_t^s = N_{C,t}^s + N_{DL,t}^s$, respectively. Moreover, aggregate labour supply in the intermediate goods sectors is given by $N_{DL,t} = \omega N_{DL,t}^b + (1-\omega)N_{DL,t}^s$ for housing in London and, because there is only one consumption good sector for both regions, by $N_{C,t} = \lambda\left(\omega N_{C,t}^b + (1-\omega)N_{C,t}^s\right) + (1-\lambda)\left(\omega N_{C,t}^{b*} + (1-\omega)N_{C,t}^{s*}\right)$ for intermediate non-durable consumption goods. Labour market clearing requires $N_{j,t} = \int_0^1 N_{j,t}(z)\,dz$. For every definition or market clearing equation that is only presented for London there exist a similar equation for the rest of the UK.

2.5. The Steady State with Price Disparity in Housing Markets

As we already described in the introduction, there are large region-specific differences in house prices in the UK. Such a price disparity is especially pronounced for London compared to the rest of the UK. To reconcile our model with this fact, we allow for region-specific price differences in the steady state. Given our model, equal house prices in the steady state are a special case. Here, we describe which parameters affect steady state house price disparity and under which parameter choices the special case of equal steady state prices would arise. Influences on steady state house price disparities in our model can be sorted into three categories: first, regional differences in land and regulatory restrictions; second, the relation between the size of the regions and the home bias in housing consumption; and third, regional differences in initial wealth.

If we assume perfect home bias and equal initial wealth, steady state house prices are obviously driven by land and regulatory restrictions, that are the parameters $\mathcal{L}_L, \mathcal{L}_R, \vartheta_L$ and ϑ_R. The more land is available each period, the lower the price of housing in the respecting region.

Next, let us assume $\mathcal{L}_L = \mathcal{L}_R$ and $\vartheta_L = \vartheta_R$ and again equal initial wealth. In this case a further reason for price disparity can emerge from the inverse home bias parameters, α and α^*, which interact with the weight of the regions λ. With perfect home bias, $\alpha = \alpha^* = 0$, house prices would be equal independent of λ. Given the more general case of equal home bias, $\alpha = \alpha^*$, house prices would only be equal if both regions have the same size, that is $\lambda = 1/2$. Whenever the households of one region have a lower size-weighted home bias than those of the other region, their demand will drive-up house prices in the latter region to a higher level than in their home region.

Finally, we again assume equal land and regulatory restrictions and perfect home bias, but now $\varrho > 1$. This means that the savers in in London hold more initial wealth than savers in the rest of the UK, or in other words, they hold a larger share of the bonds provided by the borrowers. In this case they use their larger income through interest payments to drive up house prices in London. A similar mechanism leading to house price differences could also come from the borrower's side, if we assume different steady state LTV-ratios, and thereby different steady state debt levels.

We obtain the steady state of the model numerically using the build-in matlab function fsolve. The system of equations consists of 76 equations and just as many variables.[12]

2.6. Monetary and Macroprudential Policy

We compare three different policy regimes. In all three cases, monetary policy is conducted in exactly the same way and also with exactly the same parametrisation, calibrated to match the United Kingdom.[13] As proposed by Rubio and Comunale (2017), macroprudential policy is introduced via a Taylor-like LTV rule. That is, the higher the house prices, the lower the LTV ratio and vice versa.[14] This is a simple way to introduce macroprudential policy in a two-region DSGE model and keep the framework tractable. Additionally, it will allow us to consider different scenarios and to discuss optimal policy.[15]

Case 1: Only monetary policy by means of a standard Taylor rule

As a reference case, we assume the loan-to-value (LTV) ratio, κ_t, to be fixed and monetary policy to be conducted by the Taylor rule

$$\frac{\Re_t}{\Re} = \left(\frac{\Re_{t-1}}{\Re}\right)^{\rho_r} \left[\pi_{CPI,t}{}^{\phi_\pi}\left(\tilde{Y}_t\right)^{\phi_y}\right]^{1-\rho_r} \varepsilon_t^m. \tag{36}$$

where $\varepsilon_t^m = \exp(e_t^m)$ stands for a monetary policy shock, $\rho_r \in [0,1]$ determines the interest-rate inertia, ϕ_π and ϕ_α are parameters associated with the sensitivity of interest rates to current inflation and the output gap, respectively. Similar to Monacelli (2009), monetary policy reacts to a composite inflation index, comprising inflation of non-durable consumption goods and housing inflation, which

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[12] The system of equations is provided in the online Appendix.

[13] Rule-based policies require a sufficient degree of confidence that the predefined variables would always correctly perform as intended, without noisy signals. A less disciplined discretionary framework successfully addresses this issue, by allowing policymakers to learn. However, flexibility and adaptability of discretion do not come without costs. They entail limited predictability of decisions as well as an incentive for policymakers to postpone unpopular decisions. Therefore, the finding of Boar et al. that non-systematic macroprudential interventions tend to be detrimental to growth is not surprising. Given the trade-off between ex-ante efficiency of discretion and ex-post efficiency of rules the Bank of England (2009) has proposed a constrained discretion macroprudential regime: this is discretional, but still systematic, transparent and accountable due to pre-defined numerical objectives, decision-making frameworks, and accountability measures.

[14] The Bank of England has not yet imposed LTV limits. Instead the Bank of England has employed loan-to-income (LTI) limits. LTI flow limits can effectively constrain the proportion of high LTV lending since an individual borrower's LTI and LTV are mechanically linked through the house price to income ratio. In other words, limits on high LTI lending effectively constrain high LTV, too. See Bank of England (2017), p. 12.

[15] The appropriate modelling of LTV rules is subject to discussions in the literature. Even if a central bank favors early intervention, it is reasonable to assume it will move, if at all, only after house price inflation exceeds a defined threshold. For the implementation of a threshold-type LTV policy in a DSGE framework, see Funke and Paetz (2018).

is given by $\pi_{CPI,t} = \pi_{C,t}{}^{(1-\chi)}\left(\pi_{D,t}{}^{\lambda}\,\pi^{*}_{D,t}{}^{(1-\lambda)}\right)^{\chi}$.[16] Moreover, we assume that monetary policy reacts to the output gap $\tilde{Y}_t = \frac{Y_t^a}{Y_t^n}$, where Y_t^n is the output under flexible prices and $Y_t^a = Y_c + \frac{P_{DL}}{P_C} Y_D + \frac{P_{DR}}{P_C} Y_D^*$ is aggregate real output.

Case 2: Leaning against the wind Taylor rule policy

Furthermore, we will analyse a Taylor rule which reacts more strongly to aggregate house price inflation. This rule is given by

$$\frac{\Re_t}{\Re} = \left(\frac{\Re_{t-1}}{\Re}\right)^{\rho_r} \left[\breve{\pi}_{CPI,t}{}^{\phi_\pi}\left(\tilde{Y}_t\right)^{\phi_y}\right]^{1-\rho_r} \varepsilon_t^m, \tag{37}$$

where $\breve{\pi}_{CPI,t} = \pi_{C,t}{}^{(1-\gamma)}\left(\pi_{D,t}{}^{\lambda}\,\pi^{*}_{D,t}{}^{(1-\lambda)}\right)^{\gamma+\phi_D}$ and ϕ_D measures the additional weight of aggregate house price inflation. Notice the interpretation of ϕ_D as additional weight instead of a shift in relative weight. The central bank does not assign a larger relative weight to the house price inflation, but it reacts strongly to house price inflation without diminishing the response to non-durable inflation.

Leaning against the wind policies are controversial. The most prominent opponent of leaning against the wind policies is Lars Svensson, who has argued that the costs of such policies far outweigh any potential benefit; see Svensson (2014, 2016). The IMF (2015) reaches similar conclusions to Svensson (2014, 2016). Several authors, in contrast, reach the opposite conclusion and argue that the costs of a slowdown are likely to exceed the gains from preventing a crisis (see, e.g., Gambacorta and Signoretti, 2014 and Filardo and Rungcharoenkitkul, 2016). Filardo and Rungcharoenkitkul (2016) study optimal monetary policy in an environment of recurring, endogenous financial booms and busts. In their environment, leaning systematically over the whole cycle is justified because the policy also smooths the financial cycle, resulting in less virulent boom and bust episodes.

Case 3: Monetary policy by means of a standard Taylor rule and national macroprudential policy

The focus upon macroprudential policies reflects the increasing scepticism towards standard monetary policy in tempering housing booms in support of financial stability. We introduce macroprudential policy in our model via the Taylor-like LTV rule

[16] The UK Office for National Statistics reports two consumer price indices, CPI and CPIH, with the only difference between them that the CPIH also includes imputed rentals (see Beeson, 2016). To hold our model analytical tractable, housing in our model is always owned by the consumer and never rented. Therefore, it is more consistent with our model structure to use the CPIH, where housing is weighted by about 27% instead of 12% in the CPI.

$$\kappa_t = \kappa_t^* = \kappa_{ss} \left(\frac{Q_t^n}{Q_{ss}^n}\right)^{-\xi}, \tag{38}$$

which reacts to deviations of the national real house price index $Q_t^n = \lambda Q_{L_t} + (1-\lambda)Q_t^*$ from its steady state value Q_{ss}^n. The sensitivity of this reaction is determined by the parameter ξ and κ_{ss} is the steady state LTV ratio.

Case 4: Monetary Policy by means of a standard Taylor rule and regional differentiated macroprudential policy

The regional housing market divergence may call for regionally differentiated macroprudential policies. Such a strategy has recently been applied in, for example, New Zealand, where restrictions on high-LTV lending were tightened specifically for the Auckland housing market (Reserve Bank of New Zealand, 2015). The experience of Korea concerning this matter is also very instructive. Fifteen years ago, in order to tighten policy more quickly in areas more prone to overheating, Korea put in place a differentiated application of LTV ratios in Seoul (according to zip-codes). As explained in detail by Igan and Kang (2011), limits are set differently for so-called speculative and non-speculative zones. Moreover, in response to the sustained run-up in house prices, the Chinese authorities also imposed several market-cooling measures and restrictions intended to bring house prices down to a “reasonable level”. In doing so, policymakers have so far avoided applying a blanket nationwide property tightening program, likely for fear of overdoing policy cooling and triggering a sudden property sentiment reversal. Instead, housing policy tightening remains differentiated, targeting cities where the price dynamics have been most pronounced. Where house price rises exceeded city price control targets, branches of the People’s Bank of China were asked to increase down-payment requirements. Furthermore, tighter mortgage restrictions on second home purchases were introduced, and buyers without a local hukou registration were barred from buying more than one property.

To examine the possibility of regional differentiated macroprudential policy, we introduce two region-specific LTV rules, which constitute the third policy regime. These LTV rules are given by

$$\kappa_t = \kappa_{ss} \left(\frac{Q_{L,t}}{Q_{L,ss}}\right)^{-\xi} \tag{39}$$

and

$$\kappa_t^* = \kappa_{ss}^* \left(\frac{Q_{R,t}}{Q_{R,ss}}\right)^{-\xi}, \tag{40}$$

respectively. In other words, the regional-specific LTV rules react to deviations of regional real house prices, $Q_{L,t}$ and $Q_{R,t}$, from their particular steady state. The 4th policy approach can be referred to as an attempt to square the circle of monetary policy at the national level and macroprudential policy at the sub-national level.

2.7. Stochastic Processes

We analyse how our model economy reacts to certain shocks $\nu_{l,t}$. Here we give a short summary of the underlying stochastic processes, which are given by

$$a_{C,t} = \rho_{a_C} a_{C,t-1} + \nu_{a_C,t}, \tag{41}$$

$$a_{D,t} = \rho_{a_D} a_{D,t-1} + \nu_{a_D,t}, \tag{42}$$

$$e_{\gamma,t} = \rho_{\gamma} e_{\gamma,t-1} + \nu_{\gamma,t}, \quad e_{\gamma^*,t} = \rho_{\gamma^*} e_{\gamma^*,t-1} + \nu_{\gamma^*,t}, \tag{43}$$

$$e_{\pi_C,t} = \nu_{\pi_C,t}, \quad e_{\pi_{DL},t} = \nu_{\pi_{DL},t} \;, \; e_{\pi_{DR},t} = \nu_{\pi_{DR},t}, \tag{44}$$

$$e_{m,t} = \nu_{m,t}, \tag{45}$$

$$e_{F,t} = \rho_F e_{F,t-1} + \nu_{F,t}, \tag{46}$$

where all $\nu_{l,t} \sim N(0, \sigma_l^2)$ and all ρ_l are parameters associated with the persistency of the respecting autoregressive process. Labour productivity in the non-durable consumption goods sector evolves according to equation (41), the labour productivity in the housing goods sectors evolves according to equation (42). Region-specific housing preference shocks are defined by (43) as exogenous shocks to the marginal rate of substitution between non-durable consumption and housing. The equations (44) and (45) denote the cost push shocks and the monetary policy shocks, respectively. Equation (46) is the process for the foreign demand shock. So much for theory using the bells-and-whistles of modern macroeconomics. In the following sections we shall map out the policy implications. We first discuss the parameters used for our model, then illustrate the model dynamics using impulse response and welfare analysis.

3. Calibration

Our goal is to calibrate the model with UK data and use it to explore the mechanism and efficiency of subnational macroprudential policies. The size of the first region, λ, is set to 0.25, which is approximately London's gross value added share of the UK. Also, the share of borrowers, ω, is assumed to be a quarter of the working population. For the time frame from July 2012 to June 2014, 61 percent of British households had some form of debt, with a median value of 37000£, according to the Office of National Statistics (2016). 36 percent of British households had mortgage liabilities, with a median value of 85000£. Given that not all households are constrained, the share of 25 percent of constrained borrowers seems appropriate.

The saver's discount factor, β, which pins down the steady state interest rate, takes on the value of 0.99 which is viewed as standard in the literature, whereas the borrower's discount factor, β_b, is assumed to be 0.96. In that respect, it is worth mentioning Lawrence (1991), who estimates the discount factor of poor households to be in-between 0.95 and 0.98 for the US. The risk aversion coefficient, σ, is assumed to be 1, which in effect leads to a log-log specification of consumption and housing preferences, which is in line with most of the literature (i.e. Iacoviello and Neri, 2010; Rubio and Comunale, 2017). Moreover, the inverse elasticity of labour supply, φ, is set to $1/2$, while the elasticity of substitution across working hours in the two production sectors ζ is assumed to be $3/2$, corresponding to Iacoviello and Neri's (2010) estimates for the US.

Parameters for home bias, in our case α and α^*, were not estimated until now. A similar parameter is the degree of openness in open economy models, which is set by Galí and Monacelli (2005) to 0.4. They use Canada as a prototype of an open economy, and calibrate this number to match the import/GDP ratio. In order to set appropriate values for the home bias parameters with respect to housing, denoted with α and α^*, we take into account the stock of housing rather than the flow value. Moreover, since most people prefer to live near to their workplace, the home bias should be quite large and we allow it to be different in the two regions. That is, we set the inverse home bias of London, α, to $0.1(1-\lambda)$ and α^* takes on the value of 0.01λ. It is useful to think of the inverse home bias in terms of λ, since in the case of complete openness α would equal $(1-\lambda)$ and α^* would equal λ.

As regards housing depreciation, denoted with δ, we directly base our calibration on the housing economics literature. Recent estimates vary from 0.77 percent per year for well-maintained property in Stockholm, Sweden (Wilhelmsson, 2008), to 2.5 percent per year for US housing when maintenance is not included (Harding et al, 2007). We choose to set δ to 1 percent per quarter, which is above these estimates, since our case entails maintenance be included. Ogaki and Reinhart (1998a) estimate the intratemporal elasticity of substitution to be above one for quarterly US data, whereas the estimates of Ogaki and Reinhart (1998b) yield an elasticity between 0.96 and 3.95 for annual US data. We assume η to be two; however, our results do not change for values between 0 and 4. Furthermore, we choose the share of housing consumption in the utility function, γ, such that our model approximately matches the ratio of non-durable consumption to a GDP of 0.66 percent (see table 2).

Turning our attention to price mark-ups in both the housing and consumption industries, it is of primary importance to note the difference between calibrated versus estimated values. DiCecio and Nelson (2007) estimate a price markup for the UK of slightly above 2. Notwithstanding, the authors argue that their estimates can be interpreted as markup above nominal wages and conclude that they are consistent with the value of 1.1 assumed by Britton et al. (2000). To match a labour income share of 70 percent, a value close to that is also assumed by Harrison and Oomen (2010). However, since we abstract from including physical capital in the production functions in both sectors, we cannot match the labour income share of the UK. In all three production sectors we set the elasticity of substitution to 6, implying a price mark-up value of 1.2. Regarding the Calvo parameter, which takes part in the New Keynesian Phillips Curve, we adhere to the bulk of the literature and set it equal to 0.75 for all production sectors.

Our parameter choice regarding land in the production function is directed towards matching the ratio of steady state house prices, Q_L/Q_R, incorporating slower housing supply adjustment in London compared to the rest of the UK. To achieve a reasonable steady state price ratio, we set land, which is a fixed factor of production, to 0.005 in London and 0.1 in the rest of the UK. Hence, we obtain a steady state house price ratio of 1.76. Given that land is per capita in the model, this ratio can also be justified by the actual ratio of population density of the UK relative to the population density of London, which is also about 5 percent. As regards the housing supply adjustment, it is of primary importance to properly pin down ϑ and ϑ^*, which denote the weighting of land. We set the weight for the rest of the UK to 0.1, in line with Iacoviello and Neri (2010), and 0.2 in London in order to obtain a lower short-term supply elasticity.

Before calibrating the steady state LTV ratios, it needs some clarifications. Misunderstandings about the two different types of LTV ratios often create confusion in discussions about macroprudential policy. Information on LTV ratios is typically gathered from bank lending surveys and periodic household surveys. In doing so, countries get information on the stock of mortgages and report average LTV ratios granted by banks. When interpreting these numbers, it is important to bear in mind the long duration of mortgage contracts. In contrast, the maximum permissible LTV ratio currently in force targets the interface between lender and borrower at the point in time at which the mortgage is granted. In other words, the average LTV ratio is a measure for all outstanding mortgage loans, while the LTV limit is the LTV ratio for new borrowers after some cut-off date, also called LTV ratio at origination. This implies that the LTV ratios at origination measure the degree to which LTV limits affect household (or business) economic incentives to invest in housing and curb speculative incentives. According to the Bank of England (2017), approximately 20 percent of new mortgage lending at origination had an LTV ratio larger than 90 percent in 2015, and above 80 percent of stock of mortgages had an LTV ratio lower than 75 percent. Thus, the relevant LTV limit should be at about 75 percent. We set κ_{ss} and κ_{ss}^* to 0.75 in all policy regimes and in both regions.

Table 1: Calibrated Parameters

Parameter	Value	Definition	Parameter	Value	Definition
λ	0.25	Size of first region, calibrated to match London	**Policy Parameters**		
ω	0.25	Share of borrowers	χ	0.27	Share of housing in CPI inflation index (see section 2.6)
ϱ	1.06	Saver's relative marginal value of consumption	κ_{ss}	0.75	Steady State LTV ratio for UK
Preference Parameters			κ_{ss}^{*}	0.75	Steady State LTV ratio for the rest of the UK
β_s	0.99	Discount factor of savers	ϕ_π	1.87	CPI Inflation coefficient in the Taylor rule
β_b	0.96	Discount factor of borrowers	ϕ_y	0.11	Output gap coefficient in the Taylor rule
σ	1	Risk-aversion coefficient	ϕ_D	0 or 0.3	Housing price coefficient in the Taylor rule
φ	0.5	Inverse Frisch elasticity of labour supply	ξ	0.75	Parameter determining the responsiveness of macroprudential policy to house price deviations
ζ	1.5	Elasticity of substitution across hours in the two production sectors	**Shock Persistency**		
α	$0.1(1-\lambda)$	Inverse of home bias for London	ρ_r	0.87	Autoregressive parameter (AR) – interest rate inertia
α^{*}	0.01λ	Inverse of home bias for the rest of UK	ρ_{a_C}	0.89	AR – technology process consumption sector
ν_b	4	Weighting parameters for labour disutility calibrated to	ρ_{a_D}	0.89	AR – technology process housing sector in London
ν_s	6	obtain $N^s \approx N^b \approx N^{s*} \approx N^{b*} \approx 1/3$	ρ_Y	0.98	AR – Housing preference shock in London
η	2	Elasticity of substitution between London and rest of the UK housing	ρ_Y^{*}	0.98	AR – Housing preference shock in rest of the UK
γ	0.15	Weight of housing in utility	ρ_F	0.7	AR – Foreign demand shock
Technology parameters					
δ	0.01	Depreciation rate of residential stock	**Shock variances**		
ϵ_C	6	Elasticity of substitution between differentiated non-durable goods	σ_m	0.003	Standard deviation (STD) of monetary policy shock
ϵ_D	6	Elasticity of substitution between differentiated durable goods	σ_Y	0.040	STD of housing preference shock in London
$\mathcal{L}_L$	0.005	Land being available each period in London	σ_{Y^*}	0.040	STD of housing preference shock in the rest of the UK
$\mathcal{L}_R$	0.1	Land being available each period in the rest of the UK	σ_{a_C}	0.006	STD of technology shock in consumption sector
ϑ	0.2	Weight of land in the production function in London	σ_{a_D}	0.012	STD of technology shock in housing sector
ϑ^{*}	0.1	Weight of land in the production function in the rest of the UK	σ_F	0.01	STD of foreign demand shock
θ_C	0.75	Probability of price remaining sticky (consumption sector)	σ_{π_C}	0.012	STD of cost push shock (nun-durable consumption sector)
θ_D	0.75	Probability of price remaining sticky (housing sector)	$\sigma_{\pi_{LD}}, \sigma_{\pi_{RD}}$	0.012	STD of cost push shock (housing sectors)

Regarding the parameters entering the interest rule of the Central Bank, we choose values consistent with the interest rate steering behaviour of the Bank of England. Henceforth, we follow Harrison and Oomen (2010), and set $\rho_r = 0.87$, $\phi_\pi = 1.87$ and $\phi_Y = 0.11$, as well as the persistency parameters of productivity shocks ($\rho_{a_C}, \rho_{a_D}, \rho^*_{a_D}$), and set them equal to 0.89. The latter tend to range in the literature from 0.82 for the Euro area (Smets and Wouters, 2003) to 0.95 for the US (Smets and Wouters, 2007). In order to remain consistent with this particular strand of the literature, we set the standard deviation of the housing technology shock twice as high as the standard deviation of the productivity disturbance in the non-durables industry, that is, 0.012. This corresponds to the findings of Iacoviello and Neri (2010) and Ng (2015), who employ Bayesian methods in order to estimate the shocks' standard deviations, reaching similar conclusions. The parameter determining the responsiveness of macroprudential policy to house price deviations, ξ, takes on the value of 0.75 for the impulse response analysis. Later on, we will numerically assume a large set of values for this parameter in order to deliberate upon the effectiveness of macroprudential policy for certain combinations of inflation, output and house prices variations. As regards the persistence of housing preference shocks, we assume it is rather high and set it equal to 0.98 for both of them, which is corroborated by the estimates of Iacoviello and Neri (2010). The latter, despite the fact that they conduct their estimation using US data, consider all the disturbances we do, except for the foreign demand shock. We set the standard deviation of the latter equal to 1 percentage point, which corresponds to 10 percent of steady state production of housing, or a thousandth of the steady state housing stock.

Crucial to creating a trade-off in the model between the variance of inflation and the variance of output are the cost push shocks. Their variances are estimated by Liu and Mumtaz (2011), in different regimes of a Markov switching model, from 0.34 to 1.66 percent. We set the respecting variances to 1.2 percent. All remaining variances are obtained from Iacoviello and Neri (2010).

Table 2: Important Steady State Ratios implied by the Calibration

	Ratio	Actual	Model
(1)	Consumption to GDP[1]	65.67	64.77
(2)	Gross fixed capital formation, housing volume to GDP[1]	5.26	5.23
(3)	(2)/(1)	8.01	8.08
(4)	Newly built Dwellings in London to total newly built dwellings in the UK[1]	12.27	14.33
(5)	(I_k+G+NX) to GDP[2,3]	30	30
(6)	Q_L/Q_R	1.6 - 2.2	1.76

[1] UK Department for Communities and Local Government, available at https://www.gov.uk/, in percentage terms

[2] OECD, in percentage terms

[3] The steady state sum of business investment, government spending and net exports amounts to roughly 30% of GDP. For the purposes of this paper, however, we assume these macreconomic variables remain constant throughout the stochastic analysis and thus do not exhibit any steady state deviations.

Table 1 summarizes the calibration and table 2 gives an overview of the ability of the model to match actual ratios. The next section sheds light upon the propagation of various supply and demand shocks and identifies the variables acting as main conduits in the propagation process.[17]

4. Impulse Response Analysis

To illustrate the dynamic properties of the model, we provide impulse responses, focusing on the impact of a housing preference shock, a foreign demand shock and a technology shock in the housing industry. In addition, for each shock we consider the four policy cases and elaborate on their impact on house price and debt dynamics. As before, the asterisk indicates variables in the rest of the UK.

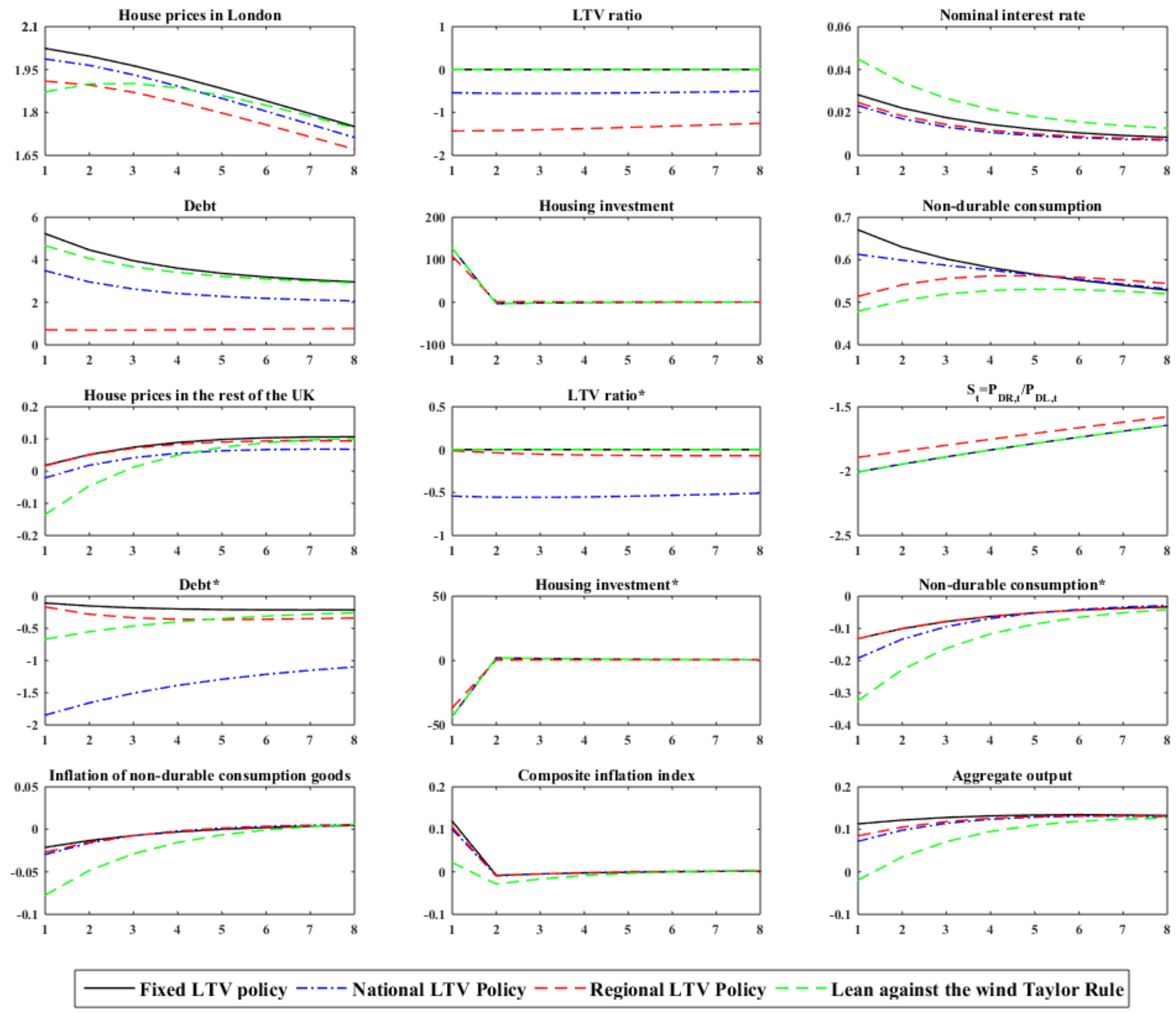
We begin with the housing preference shock, which nicely illustrates the effect of the different macroprudential policy regimes. Figure 3 shows the impulse responses to a one standard deviation housing preference shock affecting households in London. As expected, the shock increases house prices in both regions and, thus, policymakers decrease the LTV ratios except for the case when the latter remains fixed. In the case of regional LTV policy, London house prices and, consequently, London LTV ratios exhibit a stronger response. In contrast, LTV ratios in the rest of the UK behave in the opposite manner and fall accordingly. In all four policy cases, borrowers in London respond to higher house prices incurring more debt, whereby this excessive borrowing can only be prevented by means of LTV policy. National LTV policy leads to an overreaction of the LTV constraint in rest of the UK, forcing borrowers there to immediately sell bonds. In contrast, the households in the rest of the UK invest less in housing because of the higher price. An important aspect is that the regional LTV policy dampens house price increases in London most; however, the overall effect still remains small. National LTV policy even leads to somewhat higher housing prices in London, since it tends to reduce national inflation. This, in turn, induces the central bank to lower the nominal interest rate. In general, the literature supports the effectiveness of macroprudential policies (such as LTV limits) in building resilience to financial cycles, though the evidence is stronger for reducing loan growth and improving debt servicing capacity than for curbing house price growth (see e.g. Jacome and Mitra, 2015).

Furthermore, it is worth scrutinising the modified Taylor rule in more detail. Due to the additional weight on housing inflation that is introduced in the Taylor rule, the nominal interest rate exhibits a relatively stronger increase compared to all other scenarios. This suppresses CPI inflation, and the latter drops below steady state for around five quarters, which, in turn, leads to a rise in the real interest rate. Borrowers in both regions are induced to curb their debt levels (and housing demand) relative to the benchmark scenario, whereas savers demand more durable goods (e.g. housing).

[17] The calibration reflects economic science's best understanding of the processes that govern the business cycle dynamics. The resultant scientific insights from the model simulations are therefore conditional knowledge, depending upon whether these calibrations are indeed valid.

Particularly prominent is this effect in the rest of the UK, since the rise in the debt level in the benchmark scenario is relatively modest compared to the debt response of borrowers in the first region. This induces borrowers in the rest of the UK to reduce their purchases of non-durable goods as well, which, in turn, reduces aggregate output relative to the benchmark case. In London, however, the small interest rate increase in the case of the modified Taylor rule is not sufficiently strong as to induce substantial debt reductions. As regards house prices in London, introducing a modified Taylor rule induces a small decline, which, due to the lower collateral value, leads to the abovementioned debt reduction. In the rest of the UK, house prices fall slightly on impact relative to the benchmark scenario, but quickly increase due to the rise in demand from borrowers living in the capital region.

Figure 3: Impulse Responses to a One-Standard-Deviation Housing Preference Shock in London



Overall, comparing all four scenarios and the impulse responses after a positive housing preference shock in London, it is unequivocally clear that it is regional macroprudential policies targeting the LTV ratio combined with standard national monetary policy that turn out to be most effective for stabilising debt and CPI inflation. If the monetary authority sets a single monetary and macroprudential policy for the entire country, this one size fits all policy is too tight (loose) in the 1st region, and too loose (tight) in the 2nd region, relative to policy set optimally for each region, since the house price dynamics varies significantly across the country. Monetary policy that reacts strongly to house prices without macroprudential assistance is not only subject to the problem of the one size fits all policy. Additionally, it is quite ineffective in dampening the debt in the respecting region after a positive housing preference shock and results in severe deflationary pressure.[18]

Figure 4: Impulse Responses to a Foreign Demand Shock in London

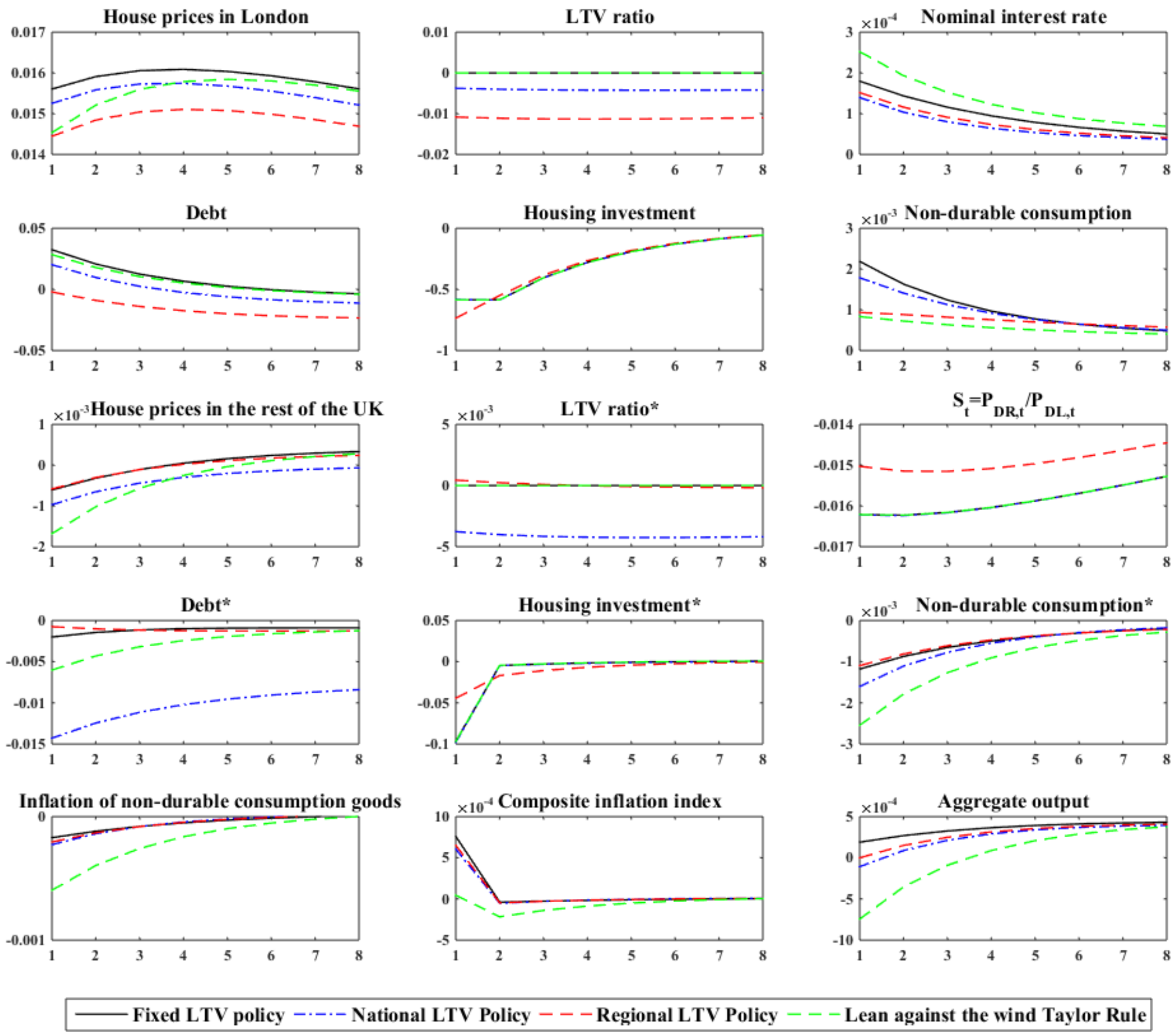


Figure 4 shows the impulse responses to a foreign demand shock in London. House prices in London rise and macroprudential policy responds with a lower LTV ratio to dampen the excessive borrowing of the impatient households. Due to higher house price inflation, the central bank intervenes, albeit to

[18] In other words, the modelling framework supports the Tinbergen principle saying that one has to employ different tools for different jobs.

a lesser extent in the case of macroprudential policy being in place. Households in London are induced to consume more non-durables, whereas the inhabitants of the in the rest of the UK curb their purchases of non-durable goods. As already mentioned, regional macroprudential policy can moderate the house price increase in a more efficient fashion relative to implementing it at the national level. The modified Taylor rule is quite ineffective in reducing the debt of the households and leads to a strong deflationary pressure regarding both house prices in the rest of the UK and prices of consumption goods.

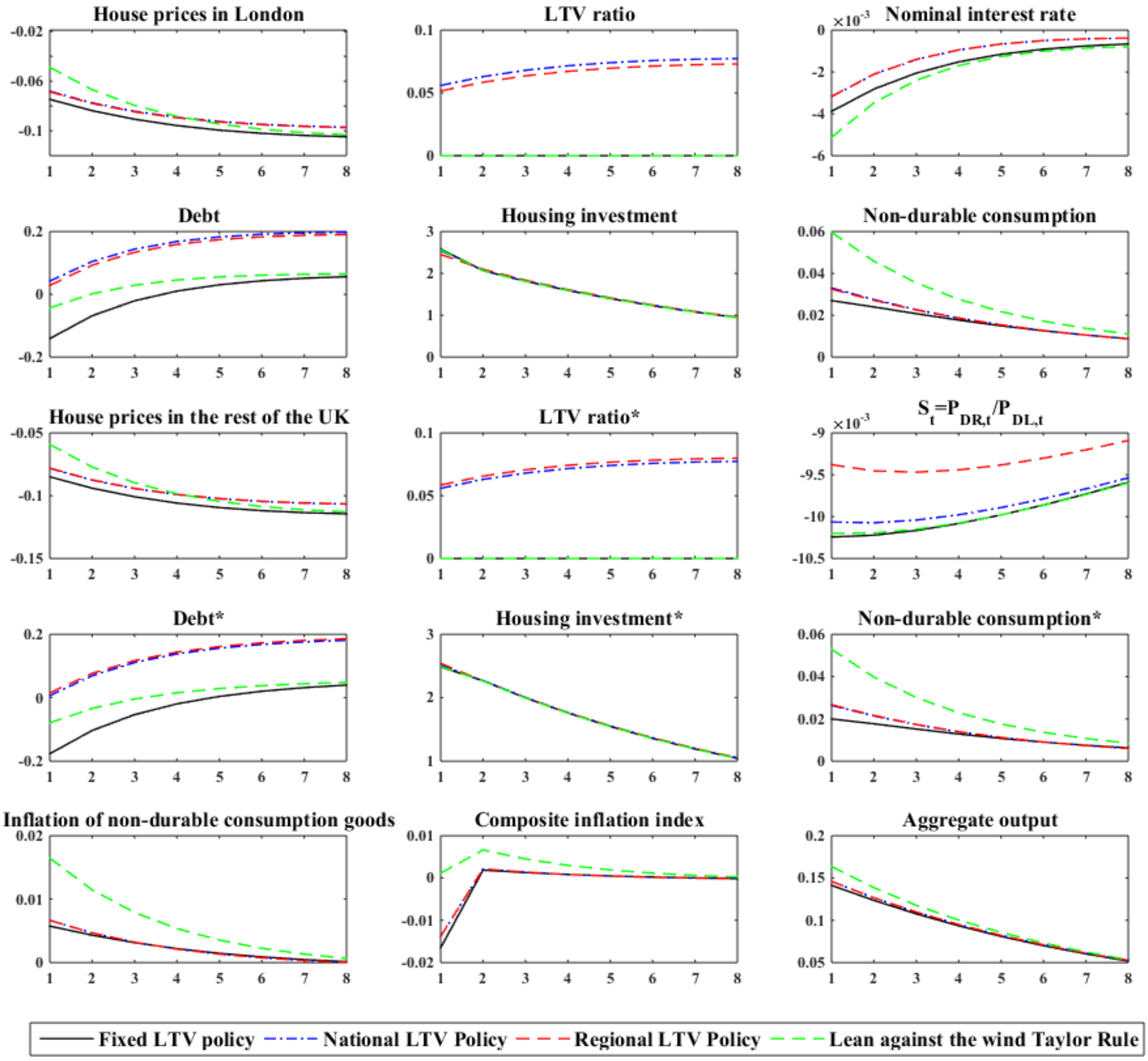
The reaction of the housing market in the rest of the UK looks surprising at first sight. It appears that households in London do not play a large role in the housing market in the rest of the UK. One obvious reason is that London is comparatively small. Furthermore, the home makes an impact. Beyond that, two further mechanisms are at work. Lower consumption leads to a larger marginal value of consumption, which leads to lower marginal cost and more production and employment in the housing industry. Thus, house prices in the rest of the UK fall, which reduces borrowers' debt. This effect is described by Monacelli (2009) in the context of a monetary policy shock. Notice that, for the rest of the UK, a sudden increase in demand for housing in London coming from abroad acts similarly to a monetary policy shock. The central bank increases the interest rate due to the rise of the composite inflation index. This reduces the collateral value and real debt falls, which reduces demand for durables. And while regional LTV policy can significantly moderate these effects, national LTV policy makes it even worse for the borrower in the rest of the UK.

The impulse responses of the model economy to a technology shock in both housing sectors are shown in Figure 5. In the benchmark scenario the results are largely standard, as output and housing investment rise, whereas the prices in the housing sector fall. This exerts a negative pressure on the nominal interest rate set by the central bank, which leads to a rise in the non-durable consumer price inflation. Agents thus shift their demand away from consumption goods towards housing and a rise in both real housing investment and housing stock ensues.

Turning to borrowers and savers, the positive income effect coming from an increase in residential supply and reduction in house prices generates a higher demand for both non-durable and housing goods. Furthermore, as noted by by Paries and Notarpietro (2008), the decrease in residential prices reduces the savers' user cost of housing, inducing them to substitute housing for consumption goods. Hence, savers' demand for residential goods rises comparatively more than the demand for non-durables. Furthermore, the asymmetry in agents' home bias with respect to housing generates additional dynamics. That is, savers' measure of openness for housing in London is high compared to the rest of the UK. As a result, the former increase their demand for residential goods produced in both regions. The reverse, however, is not true, since savers in the rest of the UK are subject to a very high level of home bias regarding housing. This exerts a positive pressure upon house prices in the rest of the UK and the latter do not fall as much as those in the capital region.

As far as borrowers are concerned, they are exposed to the so called "valuation effect". That is, the house price decline lowers the value of their collateral, generating a reduction in the debt they are able to obtain from savers, which, in turn, leads to a fall in their demand for housing. This is rather conspicuous in the capital region, where the strong fall in house prices substantially lowers the borrowers' debt level and consequently their demand for both non-durable goods as well as residential ones.

Figure 5: Impulse Responses to a One-Standard-Deviation Technology Shock



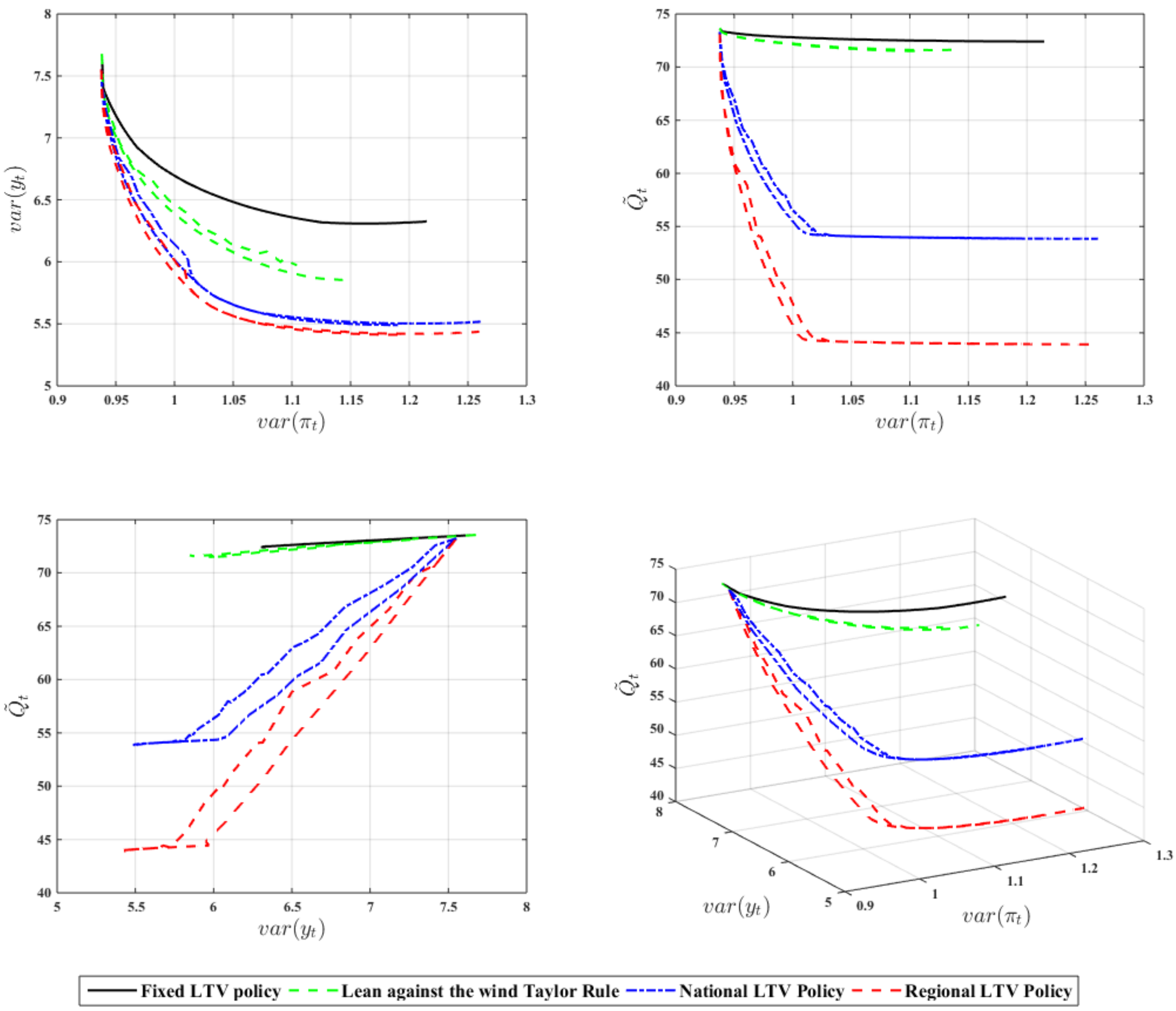
Last but not least, it is interesting to observe the policy implications of macroprudential and monetary policy scenarios. Starting off with the main aggregates, it is expected that an LTV ratio that varies negatively with real house prices amplifies the response of real output, consumer price inflation and the nominal interest rate. That is, the central bank relaxes the LTV constraint as a response to the falling house prices, which allows borrowers in both regions to increase their debt level, thus exerting a positive impact on their demand for both consumption and housing goods. By contrast, patient households face the opposite incentives and reduce their consumption of non-durable and residential goods in order to save (lend to borrowers) instead. Finally, it is important to note that, as far as national aggregates are concerned, it is irrelevant whether macroprudential policy is national or region-specific. This distinction, however, is quite important when we consider the cyclical deviations of region-specific variables. The relatively strong fall of house prices in the capital region makes region-specific macroprudential policy more effective in terms of stabilising house prices, borrowers' debt level and consumption, whereas real housing investment remains unaffected. House prices in the rest of the UK, in contrast, are only marginally affected by the presence of macroprudential policies. In other words, macroprudential policy primarily affects the within-region distribution of both residential and non-durable goods demanded by agents. Here again it is precisely region-specific macroprudential policy, rather than a national policy, that induces moderate responses of the region-specific variables with respect to borrowers' debt and agent-specific demand responses to the positive housing technology shock. Lastly, we demonstrate the effectiveness of introducing a modified Taylor rule instead of targeting the LTV ratio. That is, the central bank steers the nominal interest rate as a function of CPI inflation, the output gap and house price inflation. What becomes immediately obvious is that unlike in the case of the demand shocks previously analysed, the modified Taylor rule outperforms macroprudential policy as a tool for stabilising house prices. The channel through which that takes place is straightforward. Due to the fall in house price inflation, the central bank further reduces the nominal interest rate, which works similarly to an expansionary monetary policy shock. As a result, in the short run, house prices in both regions fall relatively less compared to all other scenarios.

5. Policy Frontiers

The policy authorities in our model economy face a trade-off between minimising the variances of inflation, output and house prices. A parsimonious way to characterise this trade-off and make normative policy statements is to compute efficient frontiers. When already on the frontier, the policy maker cannot further decrease the variance of a target variable without increasing the variance of another. We compute these efficient frontiers, also called Taylor curves, in a fashion similar to Levin et al. (1999) and Rubio and Carrasco-Gallego (2014). It is important to bear in mind that the policy authorities in our modelling framework not only optimise between inflation and output variances, but also consider house price variance as an additional target variable.

As a first step, we define a new target variable which is equal to the weighted average of both house price variances, that is $\tilde{Q}_t = \lambda\, var(Q_{L,t}) + (1-\lambda)\, var(Q_{R,t})$.[19] The procedure for computing the efficient policy frontiers is as follows. First, we compute the variances of the target variables with all possible combinations of the policy reaction parameters ϕ_y, ϕ_D and ξ, ranging from 0 to 5, or, in the case of ϕ_π, from 1.1 to 5 for all four policy types. Similar to Iacoviello (2005), we discard all possible combinations which yield a variance of the interest rate larger than 25 percent above the benchmark calibration. Then, we solve the optimisation problem to obtain the efficient frontiers. Figure 6 shows the results.[20]

Figure 6: Efficient Policy Frontiers



[19] Alternatively, it might seem natural to use the variance of the national house price index, $\text{var}(Q_t^n)$ as target variable. The drawback of this approach is that policy might lower the correlation between both house prices indices. This could decrease the variance of Q_t^n while holding constant or even increasing the variances of the regional house prices and thus we use $\tilde{Q}_t$ instead of $var(Q_t^n)$.

[20] Hence, in some areas we obtain a surface rather than a curve. In order to facilitate the surface interpretation, we plot two lines that depict the upper and lower boundaries of these surfaces whereby only the fixed LTV policy remains always a line.

The top left figure depicts the outcomes in the inflation-output variance region, which is essentially the classical Taylor curve representation. It can be seen that there are two curves in all policy cases, except of the fixed LTV policy, where monetary policy is conducted by means of a standard Taylor-type rule. An overall assessment is provided by the three-dimensional Taylor curve with all target variables of interest. We can see that all three alternative macroprudential policies are able to achieve a better outcome in terms of lower inflation and output variances. The regional LTV policy performs only slightly better than the national policy, but both are clearly better than the lean against the wind scenario. Notwithstanding, it is worth mentioning that the larger the weight placed on the variance of inflation, the smaller the discrepancy between the different policy scenarios. The top left figure illustrates that it is only region-specific LTV policies that are able to reduce the house price variances by a substantial amount. It must be noted, however, that only large values for the reaction parameter of LTV policy are able to substantially reduce this variance, as illustrated in Figure 6. Already, when we set $\xi = 0.7$, the house price variance declines by about 7 percent in the case of regional LTV policy and approximately 5 percent when national LTV policy is considered. This is more than what the augmented Taylor rule (in order to lean against the wind) can achieve, even with large values for ϕ_D. Last but not least, the bottom left panel makes it clear that no trade-off between minimising the variances of output and house prices exists, whereas the bottom right panel plots all axes against one another in the three dimensional space. In sum, the numerical results imply that a country-wide monetary policy and region-specific macroprudential policies can be a helpful combination, favouring macroeconomic performance and financial stability at both regional and country-wide level.

6. Conclusion

Financial stability is a necessity for economic growth. When the financial crisis burst out, it deeply reduced the trust in financial markets. The mix of macroprudential reforms undertaken since then has aimed at making financial institutions and the housing market safer.[21] Beyond that, understanding, diagnosing and reversing the rapid increase in house prices is critical for the cohesiveness of UK society. High house prices are one of the factors causing one of the great divides in society today: that is, between the haves and the have-nots; between the older property-owning generation and younger renters who have difficulty getting on to the property ladder.

The presented modelling framework provides a novel and quite suggestive view of the dynamics and effects of out of sync subnational house prices and macroprudential policies. Based on a DSGE model that emphasises out of sync house prices, we study the effects of national vs. subnational macroprudential policies. The impulse-response functions convey an unambiguous message. At the

[21] Lo (2012) has reviewed a number of major books on the global financial crisis.

business cycle frequency, stabilising house prices by means of targeting the region-specific LTV ratio proves to be the most effective tool, especially if the shocks originate on the demand side of the economy. We furthermore construct Taylor curves which enable us to make some normative statements regarding which type of policy is “better” in terms of minimising the variation of inflation, output and house prices. Curves that lie closer to the origin represent a more efficient outcome and are thus preferred. The efficient policy frontiers clearly indicate that the most efficient trade-offs, in terms of fulfilling our minimum variance criteria, are achieved when the macroprudential authority targets the region-specific LTV ratios. In other words, LTV policy should be enacted on regional base to slow down hot spots while not slowing down cold spots.[22] One can also put it like this: The regionalised macroprudnetial policy approach can be referred to as an attempt to square the circle of monetary policy at the national level and macroprudential policy at the sub-national level, addressing housing imbalances.

Finally, important open questions remain and there is ample opportunity for future research. By way of qualification, it must be conceded that, although the modelling framework provides a better understanding of business and housing cycle co-movements at the regional level, it is not able to endogenously identify changes in the patterns of regional synchronisation. A trigger for changes in the overall patterns of regional business cycle synchronisation may have been the global financial crisis. This is a limitation in evaluating the effect of macroprudential policies over time. Another issue is the tradeoff between tractability and detail faced by any macroeconomic modelling framework. For example, a well-known feature of urban economics is that the housing markets differ by geography as well as other attributes. Disaggregating not only the household sector but also the housing stock may therefore provide valuable insights into the transmission shocks and alter macroprudential policy conclusions.[23]

[22] Implementing such a regionally differentiated macroprudential policies requires a well-signalled and understood policy process. Monetary policymakers currently lack the granular data at the regional level that are indispensable when applying regionalized macroprudential measures. For a novel empirical approach to estimate time-varying regional house clusters in real time, see Funke et al. (2017).

[23] Matters are somewhat more complicated than the DSGE modelling framework suggests. A caveat, not analyzed in detail here, relates to further implications of regionalized macroprudential policies. Adopting an active macroprudential regulation in some regions may have negative externalities on other regions, especially if the regions adopting such a policy are economic heavyweights. Also, if many regions adopted these policies, the joint effect would be more limited than if fewer regions did so, and there could be fallacy of composition effects.

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