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A welfare analysis?**

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Macroprudential Policies and Brexit: A Welfare Analysis

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Abstract

Brexit will bring many economic and institutional consequences. Among other, Brexit will have implications on financial stability and the implementation of macroprudential policies. One immediate effect of Brexit is the fact that the United Kingdom (UK) will no longer be subject to the jurisdiction of the European Supervisory Authorities (ESAs) nor the European Systemic Risk Board (ESRB). This paper studies the welfare implications of this change of regime, both for the UK and the European Union (EU). By means of a Dynamic Stochastic General Equilibrium model (DSGE), I compare the pre-Brexit scenario with the new one, in which the UK sets macroprudential policy independently. I find that, after Brexit, the UK is better off by setting its own macroprudential policy without taking into account Europe's welfare as a whole. Given the small relative size of the UK, this implies just slight welfare loss in the EU.

Keywords: Brexit, macroprudential policy, DSGE, welfare

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"The ESAs and ESRB are an important part of the EU's joint framework for the regulation and supervision of financial services. Once the UK has left the EU, the UK will be outside of this framework".

European Supervisory Authorities and the European Systemic Risk Board: HM Treasury Brexit guidance

1 Introduction

On June 23, 2016, the UK decided via referendum to leave the EU. The full economic and institutional consequences of this decision, for both the UK and the EU, are still to come and they are surrounded by great uncertainty. These are for sure challenging times to policy makers, who have to negotiate the terms and conditions. The outcome of bilateral negotiations and how they will in practice be implemented will be key to assess the impact of Brexit.

The economic consequences of Brexit have been widely studied. Most studies published to date conclude that Brexit will reduce economic growth, although the scale of the predicted reduction varies. However, while the Brexit-related analysis of many authors has focused on trade issues, the financial market perspective has been largely neglected. One of the issue that remains open to debate is how Brexit will affect macroprudential regulation and financial stability. Brexit is not only a historical chapter of the British – EU relationship, but it also carries immense challenges for financial market stability in the short and medium run, for Britain and for the member states of the European Union.

Broadbent et al. (2019) look at the consequences of Brexit on economic activity by developing and estimating a small open economy model with tradable and non-tradable sectors. They find that Brexit brings negative news about tradable sector productivity and this leads to a reduction in investment, while employment remains relatively stable. Dhingra et al. (2016) also find that Brexit would lower trade between the UK and the EU because of higher tariff and non-tariff barriers to trade. In the long-run, this would also translate to lower productivity. Similarly, Pisano and Caffarelli (2018) find that the macroeconomic costs of Brexit are particularly high if the lower UK trade openness resulting from the imposition of tariffs reduces the UK's total factor productivity. However, Brexit has negative, but quite limited, effects on euro area economic activity. Nonetheless, all these papers are silent about macroprudential policies and the effects of Brexit on financial stability. The present paper aims at filling this gap in the literature.

The arguments posed in favour of Brexit often referenced the possibility of lower levels of financial regulation. This could be possible only to a certain extent because part of financial regulation is global

in nature, coming from Basel accords. Nevertheless, there is still scope for some impact. In the UK, the Parliament has given the Financial Policy Committee at the Bank of England responsibility for “the identification of, monitoring of, and taking of action to remove or reduce systemic risks with a view to protecting and enhancing the resilience of the UK financial system.” However, in 2010, the EU created the European Systemic Risk Board (ESRB) to closely monitor the build-up of risks in the EU’s financial system, and to issue warnings and recommendations to national and EU regulators if it believes action is necessary to preserve the stability of that system. That is, the ESRB has some sort of “soft powers” to supervise or coordinate macroprudential policies within the EU members. While the UK has been part of the ESRB, Brexit brings a new macroprudential institutional framework; the ESRB loses its power over the UK in terms of formal coordination. According to the HM Treasury, “On exit day, the UK will no longer be subject to the jurisdiction of the ESAs and ESRB.” Although the Bank of England loses its seat and voting rights on the ESRB when the UK ceases to be an EU Member State, the exact institutional implications of this fact are unclear. There is so far no clear assessment of the value of the ESRB’s work for the UK, and in particular for the Financial Policy Committee of the Bank of England, which performs a similar function to the ESRB at UK level.

The post-Brexit new institutional setting may signify considerable implications in terms of financial stability. The ESRB plays a critical role in macroprudential supervision, a crucial policy challenge for the EU. However, there are doubts as to whether it will fulfill its mandate under the new framework. The cost of Brexit could become larger than studies suggest, due to the lack of cooperation in macroprudential supervision and economic policy between the soon to be post-Brexit UK and the EU27. The Bank of England may, according to suggestions from the British government and indications from Brexit-related legislation, take a different regulatory path than that of the EU by orienting itself toward a looser regulation, more in line with its specific financial markets. These risks should be more thoroughly analyzed.

Following this debate, in this paper I address the following research question: What are the welfare consequences, both for the UK and the EU, of the change in the macroprudential framework after Brexit? I focus specifically on this issue and I abstract from other economic or political consequences of Brexit. So far, the only related paper that touches upon macroprudential policies and Brexit is Jerger and Körner (2019). They use a DSGE model to compare the dynamics of the economy after a Brexit related shock, under flexible and non-flexible macroprudential regulation. Their paper, however, does not touch upon the topic of optimal macroprudential policy nor welfare related issues. The approach of

this paper is positive, rather than normative. The present paper, however, provides a welfare analysis of the change in macroprudential regulation due to Brexit, both for the UK and for the EU. To my knowledge, my paper is the first one that evaluates the effects of Brexit for macroprudential policies and financial stability both for the UK and for the rest of the EU, both from a positive and a normative perspective.

To answer my research question, I build a two-country dynamic stochastic general equilibrium (DSGE) model that features a housing market. The two countries represent the UK and the rest of the EU and are calibrated accordingly. There is a group of individuals in each country that are credit constrained and need housing collateral to obtain loans. Countries trade goods, and savers in each country have access to foreign assets. Across countries, I allow for housing market heterogeneity; in particular different cross-country loan-to-value ratios (LTV), and in the structure of mortgage contracts (fixed vs. variable rate). Monetary policy is country specific. Macroprudential policies are represented by a national Taylor-type rule for the setting of the LTV, allowing for cross-country coordination. The modelling framework is related to the literature on DSGE models and macroprudential policies, especially the ones including policy coordination. Brzoza-Brzezina et al. (2014), Quint and Rabanal (2014), and Rubio (2018) study how to implement macroprudential policies in the core and periphery of the euro area. In particular, Rubio (2018) considers the two alternative scenarios contemplated in this paper, ESRB supervision versus independent macroprudential policies.

Within this framework, I calculate optimal macroprudential policy before and after Brexit, both for the UK and the EU. In the pre-Brexit macroprudential setting, the UK is supervised by the ESRB and thus, it takes into account the whole EU's welfare for macroprudential policy optimality. After Brexit, the optimal policy in the UK is calculated to only maximize UK's welfare. I find that, post Brexit, the UK is better off by setting its own macroprudential policy independently. Optimal macroprudential policy in the UK advocates for a less strong reaction to credit developments and a separation of objectives between macroprudential and monetary policies. Given the small relative size of the UK, optimal policy and welfare in the EU are barely unaffected.

The paper is organized as follows. Section 2 presents the baseline model. Section 3 presents the dynamics of the model. Section 4 analyzes macroprudential policies and welfare. Section 5 concludes.

2 The Model

I consider an infinite-horizon, two-country economy with a flexible exchange rate regime. The two countries represent the UK and Europe, and are denoted by UK and EU , respectively. Households consume, work and demand real estate. There is a financial intermediary in each country that provides mortgages and accepts deposits from consumers. Each country produces one differentiated good but households consume goods from both countries. For simplicity, housing is a non-traded good. I assume that labor is immobile across countries. Firms follow a standard Calvo problem. In this economy, both final and intermediate goods are produced. Prices are sticky in the intermediate goods sector. The central bank in each country sets the interest rate to respond to domestic inflation. I allow for mortgage and housing heterogeneity across countries.

2.1 The Consumer's Problem

There are three types of consumers in each country: unconstrained consumers, constrained consumers who borrow at a variable rate and constrained consumers who borrow at a fixed rate. Consumers can be constrained or unconstrained in the sense that constrained individuals need to collateralize their debt repayments in order to borrow from the financial intermediary. Interest payments for both mortgages and loans next period cannot exceed a proportion of the future value of the current house stock. In this way, the financial intermediary ensures that borrowers are going to be able to fulfill their debt obligations next period. As in Iacoviello (2005), I assume that constrained consumers are more impatient than unconstrained ones.¹ The financial intermediary in UK accepts deposits from domestic savers and it extends both fixed- and variable-rate loans to domestic borrowers.²

The proportion of each type of borrower, i.e. fixed or variable rate, is constant and exogenous.³ This assumption allows me to account for different proportions of variable-rate mortgages. In the UK, most consumers borrow at a variable rate, as opposed to mostly fixed rates in the large countries of the EU. This should affect the conduct of both monetary and macroprudential policies. For instance, with fixed-rate mortgages, monetary policy is less efficient to stabilize the macroeconomy. A macroprudential policy

¹This assumption ensures that the borrowing constraint is binding in the steady state and that the economy is endogenously split into borrowers and savers.

²There are no explicit intermediaries for international bonds.

³I follow Rubio (2011) in leaving this proportion fixed and exogenous. According to the European Mortgage Federation, the different types of mortgage contracts offered across countries are largely a response to institutional or cultural factors, which are out of the scope of the present model. In the short run, the proportion of each type of mortgage contract can fluctuate, but typically it does not imply a change in the fixed- or variable-rate proportion at the country level.

responding to macroeconomic changes may compensate the lack of effectiveness of monetary policy.⁴

2.1.1 Unconstrained Consumers (Savers)

Unconstrained consumers in UK maximize as follows:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^u + j_t \ln H_t^u - \frac{(L_t^u)^\eta}{\eta} \right), \quad (1)$$

Here, E_0 is the expectation operator, $\beta \in (0, 1)$ is the discount factor, and C_t^u , H_t^u and L_t^u are consumption at t , the stock of housing and hours worked respectively. j_t represents the weight of housing in the utility function. We assume that $\log(j_t) = \log(j) + u_{Jt}$, where u_{Jt} follows an autoregressive process, where j is the steady-state value of the weight of housing. A shock to j_t represents a shock to the marginal utility of housing. These shocks directly affect housing demand and, therefore, can be interpreted as a proxy for exogenous disturbances to house prices or, in other words, as a house price shock.⁵ $1/\eta - 1$ is the aggregate labor-supply elasticity.

Consumption is a bundle of domestically and foreign produced goods. The consumption index is defined as: $C_t^u = (C_{UKt}^u)^n (C_{EUt}^u)^{1-n}$ where n is the size of Country UK.

The budget constraint, in units of Country UK's currency, is:

$$P_{UKt}C_{UKt}^u + P_{EUt}C_{EUt}^u + Q_t H_t^u + R_{UKt-1}B_{t-1}^u + e_t R_{EUt-1}D_{t-1} + \frac{\psi}{2} e_t D_t^2 \leq Q_t H_{t-1}^u + W_t^u L_t^u + B_t^u + e_t D_t + P_{UKt}F_t + P_{UKt}S_t, \quad (2)$$

where P_{UKt} and P_{EUt} are the prices of the goods produced in Countries UK and EU, respectively, Q_t is the housing price in Country UK, and W_t^u is the wage for unconstrained consumers. Unconstrained consumers can hold bonds. B_t^u represents domestic bonds denominated in home currency. R_{UKt} is the nominal interest rate in Country UK. Positive bond holdings mean borrowing and negative mean savings. However, as we will see, this group will choose not to borrow at all, they are the savers in this economy. D_t are foreign bond holdings by savers in Country UK. R_{EUt} is the nominal rate of foreign bonds, which are denominated in foreign currency. e_t is the exchange rate between currency in Country UK and Country EU. To ensure stationarity of net foreign assets, I introduce a small quadratic cost of

⁴See Rubio (2011) and Calza et al. (2013) for a detailed discussion on this issue.

⁵In this way, I can study the dynamics of the model following a housing-related shock.

deviating from zero foreign borrowing $\frac{\psi}{2}e_tD_t^2$. They obtain interests for their savings. S_t and F_t are lump-sum profits received from the firms and the financial intermediary in Country UK, respectively.

Dividing by P_{UKt} , we can rewrite the budget constraint in terms of the good in the UK:

$$C_{UKt}^u + \frac{P_{EUt}}{P_{UKt}} C_{EUt}^u + q_t H_t^u + \frac{R_{UKt-1} b_{t-1}^u}{\pi_{UKt}} + \frac{e_t R_{EUt-1} d_{t-1}}{\pi_{UKt}} + \frac{\psi}{2} e_t d_t^2 \leq q_t H_{t-1}^u + w_t^u L_t^u + b_t^u + e_t d_t + F_t + S_t, \quad (3)$$

where π_{UKt} denotes the inflation rate for the good produced in Country UK, defined as P_{UKt}/P_{UKt-1} . Lower-case letters denote real variables.

Maximizing (1) subject to (3), we obtain the first-order conditions for the unconstrained group:

$$\frac{C_{UKt}^u}{C_{EUt}^u} = \frac{n P_{EUt}}{(1-n) P_{UKt}} \quad (4)$$

$$\frac{1}{C_{UKt}^u} = \beta E_t \left(\frac{R_{UKt}}{\pi_{UKt+1} C_{UKt+1}^u} \right), \quad (5)$$

$$\frac{1 - \psi d_t}{C_{U \setminus Kt}^u} = \beta E_t \left(\frac{R_{EUt} e_{t+1}}{\pi_{UKt+1} C_{UKt+1}^u e_t} \right), \quad (6)$$

$$w_t^u = (L_t^u)^{\eta-1} \frac{C_{UKt}^u}{n}, \quad (7)$$

$$\frac{\dot{j}_t}{H_t^u} = \frac{n}{C_{UKt}^u} q_t - \beta E_t \frac{n}{C_{UKt+1}^u} q_{t+1}. \quad (8)$$

Equation (4) equates the marginal rate of substitution between goods to the relative price. Equation (5) is the Euler equation for consumption. Equation (6) is the first-order condition for net foreign assets. Equation (7) is the labor-supply condition. These equations are standard. Equation (8) is the Euler equation for housing and states that, at the margin, the benefits from consuming housing have to be equal to the costs.

Combining (5) and (6) we obtain a non-arbitrage condition between home and foreign bonds:

$$R_{UKt} = \frac{R_{EUt} E_t e_{t+1}}{(1 - \psi D_t) e_t}. \quad (9)$$

Since all consumption goods are traded and there are no barriers to trade, I assume in this paper that the law of one price holds:

$$P_{UKt} = e_t P_{UKt}^*, \quad (10)$$

where variables with a star denote foreign variables.

2.1.2 Constrained Consumers (Borrowers)

There are two types of constrained consumers in the UK: those who borrow at a variable rate and those who do so at a fixed rate. The difference between the two groups is the interest rate they are charged. The variable-rate constrained consumer faces R_{UKt} , which will coincide with the rate set by the central bank. The fixed-rate borrower pays \bar{R}_{UKt} , derived from the financial intermediary's problem. The proportion of variable-rate consumers in UK is constant and exogenous, and is equal to $\alpha_{UK} \in [0, 1]$.

Constrained consumers are more impatient than unconstrained ones, i.e. $\tilde{\beta} < \beta$. Constrained consumers face a collateral constraint: the expected debt repayment in the next period cannot exceed a proportion of tomorrow's expected value of today's housing stock:⁶

$$E_t \frac{R_{UKt}}{\pi_{UKt+1}} b_t^{cv} \leq k_{UK} E_t q_{t+1} H_t^{cv}, \quad (11)$$

$$E_t \frac{\bar{R}_{UKt}}{\pi_{UKt+1}} b_t^{cf} \leq k_{UK} E_t q_{t+1} H_t^{cf}, \quad (12)$$

where equations (11) and (12) represent the collateral constraint for the variable- and fixed-rate borrowers, respectively. k_{UK} can be interpreted as the LTV ratio in UK.⁷ Note that in models with collateral constraints, the LTV ratio is typically considered to be exogenous. At the macroeconomic level, LTV ratios depend partly on exogenous factors, including regulation. This parameter is usually calibrated to match the average LTV ratio in the country analyzed. However, in this paper, when we introduce macroprudential policies, it will be able vary, depending on economic conditions, because it will be utilized as a macroprudential policy variable. As we will see when we introduce the problem of the financial

⁶The superscript *cv* signifies “constrained variable” and *cf* signifies “constrained fixed.”

⁷I assume, for simplicity, that the LTV is the same for fixed and variable-rate mortgages.

intermediary, \bar{R}_{UKt} is an aggregate interest rate that contains information on all the past fixed-interest rates associated with past debt. In each period, this aggregate interest rate is updated with a new interest rate, linked to the new amount of debt originating in that period.

Without loss of generality, we present the problem only for the variable-rate borrower because the optimization problem for the fixed-rate borrower is symmetrical. Variable-rate borrowers maximize their lifetime utility function as follows:

$$\max E_0 \sum_{t=0}^{\infty} \tilde{\beta}^t \left(\ln C_t^{cv} + j_t \ln H_t^{cv} - \frac{(L_t^{cv})^\eta}{\eta} \right), \quad (13)$$

where $C_t^{cv} = (C_{UKt}^{cv})^n (C_{EUt}^{cv})^{1-n}$, subject to the budget constraint (in term of goods in UK):

$$C_{UKt}^{cv} + \frac{P_{EUt}}{P_{UKt}} C_{EUt}^{cv} + q_t H_t^{cv} + \frac{R_{UKt-1} b_{UKt-1}^{cv}}{\pi_{UKt}} \leq q_t H_{t-1}^{cv} + w_t^{cv} L_t^{cv} + b_t^{cv}, \quad (14)$$

and subject to the collateral constraint (11). Note that variable-rate borrowers repay all debt every period and acquire new debt at the current new interest rate. This assumption implies that the interest rate on variable-rate mortgages is revised every period for the whole debt stock and changed according to the policy rate.⁸ To make the problem for fixed-rate borrowers symmetrical and analogous to existing models with borrowing constraints, we assume the same debt-repayment structure for this type of borrower. Obviously, fixed-rate contracts are not revised every period. However, to make the model more realistic, but still tractable, the fixed-interest rate will be such that a revised fixed rate will be applied only on new debt, keeping the interest rate related to existing debt constant. In this way, we reconcile the structure of the model with the fact that fixed-rate contracts are long term.⁹

The first-order conditions for these consumers are:

$$\frac{C_{UKt}^{cv}}{C_{EUt}^{cv}} = \frac{n P_{EUt}}{(1-n) P_{UKt}} \quad (15)$$

$$\frac{n}{C_{UKt}^{cv}} = \tilde{\beta} E_t \left(\frac{n R_{UKt}}{\pi_{UKt+1} C_{UKt+1}^{ci}} \right) + \lambda_{UKt}^{cv} R_{UKt}, \quad (16)$$

⁸This assumption is consistent with reality as variable interest rates are revised very frequently and change according to an interest-rate index that is tied to the interest rate set by the central bank.

⁹Another option would be to have an overlapping generations model in which we are able to keep track of the debt issued each period. However, the model would become more complex and less comparable with the standard collateral constraint DSGE models, such as that of Iacoviello (2005).

$$w_t^{cv} = (L^{cv})^{\eta-1} \frac{C_{UKt}^{cv}}{n}, \quad (17)$$

$$\frac{j_t}{H_t^{cv}} = \frac{n}{C_{UKt}^{cv}} q_t - \tilde{\beta} E_t \frac{n}{C_{UKt+1}^{cv}} q_{t+1} - \lambda_{UKt}^{cv} k_{UK} E_t q_{t+1} \pi_{UKt+1}. \quad (18)$$

These first-order conditions differ from those of the unconstrained individuals. In the case of constrained consumers, the Lagrange multiplier on the borrowing constraint (λ_t^{cv}) appears in the equations. As in Iacoviello (2005), the borrowing constraint is always binding, so that constrained individuals borrow the maximum amount they are allowed to and their saving is zero.¹⁰

The problem for consumers in EU is analogous to that for consumers in UK.

2.2 The Financial Intermediary

I assume a competitive framework and, thus, the intermediary takes the variable interest rate as given.¹¹ The profits of the financial intermediary are defined as follows:

$$F_t = \alpha_{UK} R_{UKt-1} b_{t-1}^{cv} + (1 - \alpha_{UK}) \bar{R}_{UKt-1} b_{t-1}^{cf} - R_{UKt-1} b_{t-1}^u, \quad (19)$$

where F_t are the profits of the financial intermediary. R_{UKt} and \bar{R}_{UKt} are the variable and the fixed rate, respectively.

In equilibrium, aggregate borrowing and saving must be equal, i.e.:

$$\alpha_{UK} b_t^{cv} + (1 - \alpha_{UK}) b_t^{cf} = b_t^u. \quad (20)$$

Substituting (20) into (19), we obtain:

$$F_t = (1 - \alpha_{UK}) b_{t-1}^{cf} (\bar{R}_{UKt-1} - R_{UKt-1}). \quad (21)$$

For the two types of mortgage to be offered, the fixed interest rate has to be such that the intermediary

¹⁰From the Euler equations for consumption of the unconstrained consumers, we know that $R_{UK} = 1/\beta$ in steady state. If we combine this result with the Euler equation for consumption for the constrained individual we have that $\lambda^c = n(\beta - \tilde{\beta})/C_{UK}^c > 0$ in steady state. This means that the borrowing constraint holds with equality in steady state. Since we log-linearize around the steady state assuming that uncertainty is low, we can generalize this result to off-steady-state dynamics.

¹¹See Andrés et al. (2013) or Boscá et al. (2020) for models in which banks are imperfectly competitive and are able to set optimal lending rates.

is indifferent between lending at a variable or fixed rate. Hence, the expected discounted profits that the intermediary obtains by lending new debt in a given period at a fixed interest rate must be equal to the expected discounted profits that the intermediary would obtain by lending at a variable rate:

$$E_\tau \sum_{i=\tau+1}^{\infty} \beta^{i-\tau} \Lambda_{\tau,i} \overline{R_{UK\tau}}^{OPT} = E_\tau \sum_{i=\tau+1}^{\infty} \beta^{i-\tau} \Lambda_{\tau,i} R_{UKt-1}, \quad (22)$$

where $\Lambda_{t,i} = \frac{C_{UKt}^u}{C_{UKt+i}^u}$ is the relevant discount factor for the unconstrained consumer. As the financial intermediary is owned by the savers, their stochastic discount factor is applied to the financial intermediary's problem. Note that, as stated previously, the variable-rate debt applies to one period, but the portion of new debt acquired at a fixed rate is associated with a long-term contract. As the agent is infinitely lived, I assume here that the maturity of fixed-rate mortgages is also infinity. We can obtain the equilibrium value of the fixed rate in period τ from expression (22) :

$$\overline{R_{UK\tau}}^{OPT} = \frac{E_\tau \sum_{i=\tau+1}^{\infty} \beta^{i-\tau} \Lambda_{\tau,i} R_{UKt-1}}{E_\tau \sum_{i=\tau+1}^{\infty} \beta^{i-\tau} \Lambda_{\tau,i}}. \quad (23)$$

Equation (23) states that, for every new debt issued at date τ , there is a different fixed-interest rate that has to be equal to a discounted average of future variable-interest rates. Note that this is not a condition on the debt stock, but on the new amount of debt obtained in a given period. New debt at a given point in time is associated with a different fixed interest rate than that applied to the debt stock. Both the fixed interest rate in period τ and the new amount of debt in period τ are fixed for all future periods. However, the fixed-interest rate varies depending on the date that the debt was issued so that, in every period, there is a new fixed interest rate associated with new debt in this period. If we consider fixed-rate loans to be long term, the financial intermediary obtains interest payments every period from the whole debt stock, not only from the new debt. Hence, we can define an aggregate fixed interest rate as the one that the financial intermediary effectively charges every period for the whole mortgages stock. This aggregate fixed interest rate is composed of all past fixed interest rates and past debt, together with the current-period equilibrium fixed-interest rate and the new amount of debt. Therefore, the effective fixed-interest rate that the financial intermediary charges for the fixed-rate debt stock every period is as follows:

$$\bar{R}_{UKt} = \left\{ \begin{array}{l} \frac{\bar{R}_{UKt-1} b_{t-1}^{cf} + \bar{R}_{UKt}^{OPT} (b_t^{cf} - b_{t-1}^{cf})}{b_t^{cf}} \text{ if } b_t^{cf} > b_{t-1}^{cf} \\ \bar{R}_{UKt-1} \text{ if } b_t^{cf} \leq b_{t-1}^{cf} \end{array} \right\}. \quad (24)$$

Equation (24) states that the fixed interest rate that the financial intermediary charges today is an average of what it charged in the previous period for the previous mortgages stock and what it charges in the current period for the new amount. If there is no new debt, the fixed interest rate will be equal to that of the previous period. Then, in the same way that variable rates are revised every period, fixed rates are revised by including the new optimal fixed interest rate for the new debt originating in this period. Importantly, this assumption is not crucial for the results. Both $\bar{R}_{UK\tau}^{OPT}$ and \bar{R}_{UKt} are practically unaffected by interest rate shocks.¹² This assumption is a way to make the model compatible with the fact that fixed-rate loans are not one-period assets but longer-term ones.

As noted above, any profits from financial intermediation are rebated to the unconstrained consumers every period. The financial intermediary is competitive and does not make profits in the absence of shocks but, should a shock occur, the fact that only the variable interest rate is directly affected can generate nonzero profits.¹³

The financial intermediary problem for EU is symmetrical.

2.2.1 Final Goods Producers

In Country UK, there is a continuum of final goods producers that aggregate intermediate goods according to the production function

$$Y_{UKt}^k = \left[\int_0^1 Y_{UKt}^k(z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}}, \quad (25)$$

where $\varepsilon > 1$ is the elasticity of substitution between intermediate goods.

The total demand of intermediate good z is given by $Y_{UKt}(z) = \left(\frac{P_{UKt}(z)}{P_{UKt}} \right)^{-\varepsilon} Y_{UKt}$, and the price index is $P_{UKt} = \left[\int_0^1 P_{UKt}(z)^{1-\varepsilon} dz \right]^{\frac{1}{\varepsilon-1}}$.

¹²In log-linearized terms, the new fixed interest rate is always equal to the past fixed interest rate and, therefore, equation (24) does not introduce a kink.

¹³This modeling of the fixed interest rate follows Rubio (2011).

2.2.2 Intermediate Goods Producers

The intermediate goods market is monopolistically competitive. Intermediate goods are produced according to the following production function:

$$Y_{UKt}(z) = Z_t (L_t^u(z))^\gamma (L_t^c(z))^{(1-\gamma)}, \quad (26)$$

where Z_t represents technology. I assume that $\log Z_t = \rho_Z \log Z_{t-1} + u_{Zt}$ where ρ_Z is the autoregressive coefficient and u_{Zt} is a normally distributed shock to technology. γ measures the relative size of each group in terms of labor.¹⁴

The first-order conditions for labor demand are the following:¹⁵

$$w_t^u = \frac{Z_t}{X_t} \gamma \frac{Y_{UKt}}{L_t^u}, \quad (27)$$

$$w_t^c = \frac{Z_t}{X_t} (1 - \gamma) \frac{Y_{UKt}}{L_t^c}, \quad (28)$$

where X_t is the markup, or the inverse of marginal cost.

The price-setting problem for the intermediate goods producers is a standard Calvo-Yun setting. An intermediate good producer sells good at price $P_{UKt}(z)$, and $1 - \theta$ is the probability of being able to change the sale price in every period. The optimal reset price $P_{UKt}^{OPT}(z)$ solves:

$$\sum_{k=0}^{\infty} (\theta\beta)^k E_t \left\{ \Lambda_{t,k} \left[\frac{P_{UKt+k}^{OPT}(z)}{P_{UKt+k}} - \frac{\varepsilon/(\varepsilon-1)}{X_{t+k}} \right] Y_{UKt+k}^{OPT}(z) \right\} = 0. \quad (29)$$

The aggregate price level is given by:

$$P_{UKt} = \left[\theta P_{UKt-1}^\varepsilon + (1 - \theta) (P_{UKt}^{OPT})^{1-\varepsilon} \right]^{1/(1-\varepsilon)}. \quad (30)$$

Using (29) and (30), and log-linearizing, we can obtain the standard forward-looking Phillips Curve.¹⁶

The firm problem is analogous in Country EU.

¹⁴This Cobb-Douglas production function implies that labor inputs of the two groups are not perfect substitutes. This assumption can be justified by the fact that savers are the managers of the firms and their wage is not the same as that of the borrowers. The Cobb-Douglas specification is analytically tractable and allows for closed form solutions for the steady state of the model.

¹⁵Symmetry across firms allows to avoid the index z .

¹⁶This Phillips curve is consistent with other two-country models with financial accelerator. See for instance Gilchrist et al (2002) or Iacoviello and Smets (2006).

2.3 Aggregate Variables and Market Clearing

Given α_{UK} , the fraction of variable-rate borrowers in Country UK, we can define aggregates across constrained consumers as the sum of variable-rate consumers aggregates and fixed-rate consumers aggregates, so that $C_t^c \equiv \alpha_{UK}C_t^{cv} + (1 - \alpha_{UK})C_t^{cf}$, $L_t^c \equiv \alpha_{UK}L_t^{cv} + (1 - \alpha_{UK})L_t^{cf}$, $H_t^c \equiv \alpha_{UK}H_t^{cv} + (1 - \alpha_{UK})H_t^{cf}$ and $b_t^c \equiv \alpha_{UK}b_t^{cv} + (1 - \alpha_{UK})b_t^{cf}$.

Therefore, economy-wide aggregates in Country UK are $C_t \equiv C_t^u + C_t^c$, $L_t \equiv L_t^u + L_t^c$ and aggregate supply of housing is fixed, so that market clearing requires $H_t \equiv H_t^u + H_t^c = H$.

The market-clearing condition for the final good in Country UK is $nY_{UKt} = nC_{UKt} + (1 - n)C_{UKt}^* + n\frac{\psi}{2}d_t^2$. Domestic financial markets clear as follows: $b_t^c = b_t^u$. The world bond market-clearing condition is $nd_t + (1 - n)\frac{P_{EUt}}{P_{UKt}}d_t^* = 0$, where d_t denotes the foreign bonds in real terms. The net foreign asset position follows $d_t = \frac{R_{EUt-1}}{(1-\psi)d_t}\pi_{UKt}d_{t-1} + Y_{UKt} - C_{UKt} - \frac{P_{EUt}}{P_{UKt}}C_{EUt}$. Everything is similar in the EU.

2.4 Monetary Policy

The model is closed with a Taylor Rule with interest-rate smoothing for interest-rate setting by each country's central bank. In Country UK,

$$R_{UKt} = (R_{UKt-1})^\rho \left(\pi_{UKt}^{(1+\phi_\pi)} R_{UK} \right)^{1-\rho} \varepsilon_{UKR,t}, \quad (31)$$

$0 \leq \rho \leq 1$ is the parameter associated with interest-rate inertia. $(1 + \phi_\pi)$ measures the sensitivity of interest rates to current inflation. $\varepsilon_{UKR,t}$ is a white noise shock process with zero mean and variance σ_ε^2 . In Country EU, R_{EUt} is set similarly.¹⁷

2.5 Parameter Values

We can use the model to explore how shocks are transmitted across countries. To do so, I calibrate the model to realistically reflect the characteristic of both countries, the UK and the EU. The discount factor parameters correspond to the standard values in Iacoviello-type models. The discount factor for savers, β , is set to 0.99 so that the annual interest rate is 4% in steady state. The discount factor for borrowers, $\tilde{\beta}$, is set to 0.98.¹⁸ The steady-state weight of housing in the utility function, j , is set to 0.1

¹⁷I assume that country EU is in a monetary union and the interest rate is set by a single central bank, i.e. the ECB. The Taylor Rule is consistent with the primary objective of the ECB being price stability. This type of rule is also used in other monetary union models. See Iacoviello and Smets (2007) or Aspachs and Rabanal (2008).

¹⁸Lawrance (1991) estimates discount factors for poor consumers between 0.95 and 0.98 at quarterly frequency.

in order for the ratio of housing wealth to GDP in steady state to be approximately 1.40.¹⁹ I assign $\eta = 2$, implying a value of the labor supply elasticity of 1.²⁰ I set the LTV parameters in accordance to the data found in the European Mortgage Federation (EMF). LTVs in the UK are around 72%. For the EU, I take the value corresponding to Germany, the largest country, that is, 78%. The labor income share of unconstrained consumers, γ , is set to 0.7. This parameter was originally estimated by Iacoviello (2005) and has become standard in collateral constraint models of this type.²¹ I pick a value of 6 for ε , the elasticity of substitution between intermediate goods. This value implies a steady-state markup of 1.2, common value in the new Keynesian literature. The probability of not changing prices, θ , is set to 0.75, implying that prices change on average every four quarters, a realistically acceptable frequency. For the Taylor rule parameters, I use $\rho = 0.8$, $\phi_\pi = 0.5$. The first value reflects a realistic degree of interest-rate smoothing.²² ϕ_π is consistent with the original parameters proposed by Taylor in 1993. In terms of market structure for different mortgage interest rates, the EU is highly fragmented. Some countries almost exclusively have variable rate mortgages, whereas others rely more on long-term fixed rates, or on a mix. Taking into consideration the countries for which we have information in the EU area, according to the EMF, around 28% of gross new issuance were variable interest rate loans, while 54% in the UK. According to Eurostat, the United Kingdom represents 16% of EU's GDP. I set country sizes following this number.

A technology shock will be a one percent positive technology with 0.9 persistence²³. Housing demand shocks have a 0.95 persistence.²⁴ We set the size of the shock to the housing-demand parameter at 24.89%, consistent with Iacoviello (2005).

Tables 1 and 2 present a summary of the parameter values:

¹⁹This value corresponds to the US. I assume here that the ratio is similar across most industrialized countries, given the lack of housing wealth data for European countries. See Aspachs and Rabanal (2008).

²⁰Microeconomic estimates usually suggest values in the range of 0 and 0.5 (for males). Domeij and Flodén (2006) show that in the presence of borrowing constraints this estimates could have a downward bias of 50%.

²¹This value is in the range of the estimates of Iacoviello (2005), Iacoviello and Neri (2008) and Campbell and Mankiw (1991) for the US, Canada, France and Sweden.

²²See McCallum (2001).

²³This high persistence value for technology shocks is consistent with what is commonly used in the literature. Smets and Wouters (2002) estimate a value of 0.822 for this parameter in Europe, Iacoviello and Neri (2008) estimate is 0.93 for the US.

²⁴The persistence of the housing demand shock is consistent with the estimates in Iacoviello and Neri (2010).

Table 1: Common Parameter Values		
β	.99	Discount Factor for Savers
$\tilde{\beta}$.98	Discount Factor for Borrowers
j	.1	Weight of Housing in Utility Function
η	2	Parameter associated with labor elasticity
γ	.7	Labor share for Savers
X	1.2	Steady-state markup
θ	.75	Probability of not changing prices
ρ	.8	Interest-Rate-Smoothing Parameter in Taylor Rule
ϕ_π	.5	Inflation Parameter in Taylor Rule
ψ	.0001	Adjustment Cost Net Foreign Assets

Table 2: Country-Specific Parameter Values			
	UK	EU	
k	0.72	0.78	Average LTV
α	0.54	0.28	Proportion of variable rates
n	0.16	0.84	Country size

3 Dynamics

This section presents impulse responses of the above model, calibrated for the UK and for the EU. In this way, we can compare the different cross-country dynamics that the model displays. As Table 2 shows, there are several key differences in calibration across countries that should have an effect on how shocks are transmitted. For instance, the financial accelerator should be more powerful in the EU than in the UK, given that the LTV in the former economy is higher. Variable-rate mortgages in the UK, as opposed to mostly fixed rates in the large countries of the EU, should also make a difference because the monetary policy pass-through should be stronger in the UK. On the other hand, the UK is a relatively small economy as compared to the EU.

Figure 1 shows impulse responses to a productivity shock that happens in both countries at the same time, that is, a symmetric shock. This is a clear way to see how differences in calibration produce asymmetric responses across countries. We can observe that the same productivity shock impacts housing markets more strongly in the EU than in the UK. A technology shock, increases output and decreases

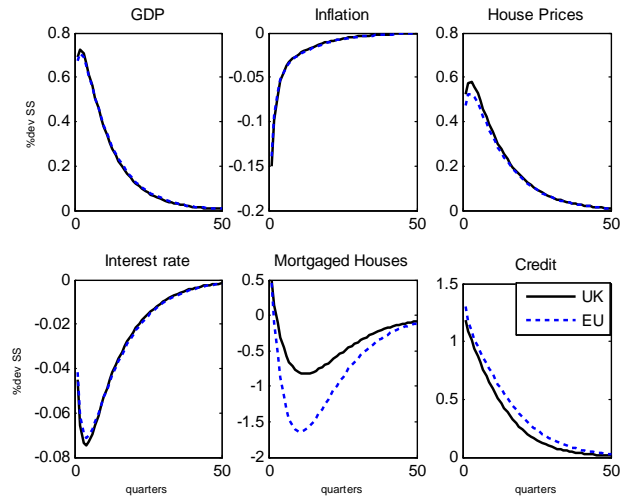


Figure 1: Impulse Responses to a Symmetric Productivity Shock. UK vs. EU

inflation, by definition, in both countries, because it implies a way to produce more but less costly. We can see from the graph that, although the effect on inflation and output is similar in both countries, there are differences in financial markets. This is due to the fact that in the EU, which is much larger in population as well, the financial accelerator effects are stronger, given that the LTV is higher. We see that, for housing variables, it has a negative effect on mortgaged houses. Overall, housing prices are increasing. However, the effects on houses purchased by borrowers are stronger in the EU, for the same reason as we have already pointed out. The fact that the LTV is larger in this region makes both borrowers and savers react more in terms of housing purchases. Since the economy is expanding, credit is also increasing in both countries. Differences do not come from monetary policy because the interest rate response is almost identical in both countries. Inflation is behaving similarly in both countries and thus the interest rate reaction is accordingly similar.

These results are important because they may definitely have implications for the conduct of financial policies. We see that, even though the shock is symmetric, the effects on financial markets are not symmetric. This may advocate for macroprudential policies that are set independently, according to country-specific needs. Before Brexit, the UK is restricted to the supervision of the ESRB. After Brexit, however, the UK has the chance to implement a macroprudential policy in favor of its own developments, avoiding coordination with the EU and not taking into account overall welfare.

Figure 2 displays impulse responses when there is an asymmetric productivity shock, hitting just the UK. We see that most of the increase in GDP happens in the UK, the country that was hit from the shock. However, there is some international transmission because the two countries are trading and also

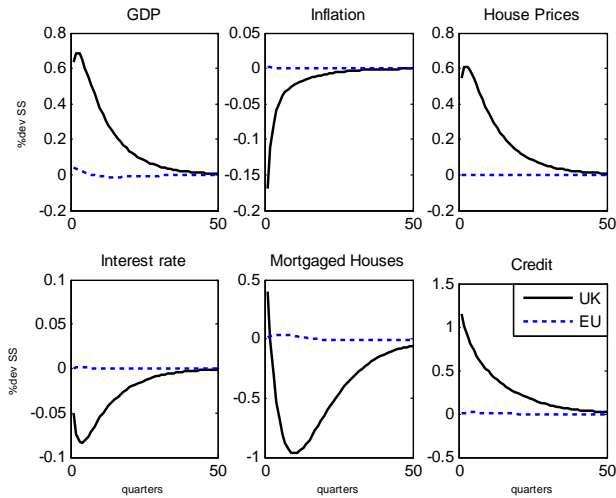


Figure 2: Impulse Responses to a Productivity Shock in the UK. UK vs. EU

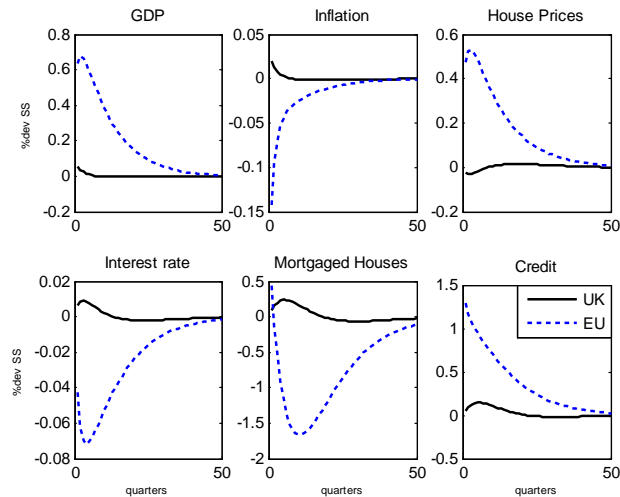


Figure 3: Impulse Responses to a Productivity Shock in the EU. UK vs. EU

the EU is benefiting from the real shock, even taking into account the small size of the UK relative to the EU. There is almost no transmission in financial and housing markets, though. Housing variables are only affected in the country where the shock happens. Monetary policy does not respond in the EU but there is a decrease in the interest rate in the UK, following the fall in inflation. This pushes credit further up since the cost of borrowing is decreasing.

As Figure 3 shows, if the shock happens in the EU, there is some real transmission to the other country. There is also some financial transmission. Monetary policy mostly responds in the country where the shock happens, and this further boosts the effects of the shock. Interest rates go down and this makes credit and house prices to increase in that region.

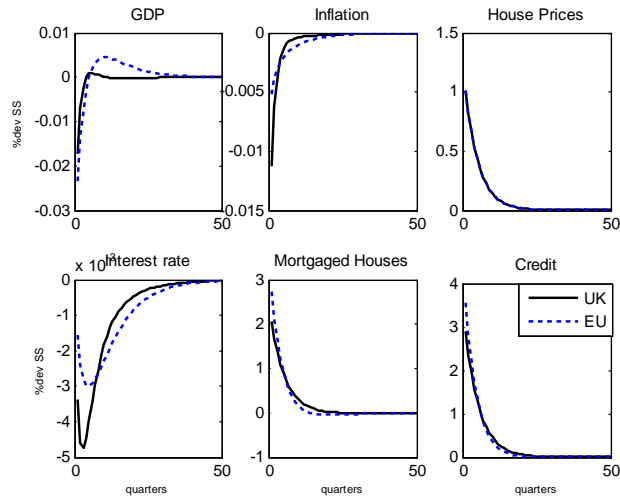


Figure 4: Impulse Responses to a Symmetric House Price Shock. UK vs. EU

Asymmetric technology shocks, either in the UK or the EU, leave it also evident that financial market dynamics can differ much from country to country, depending on which country is hit. Analyzing these shocks is important because it would be expected that asymmetric shocks happen more often after Brexit. In terms of macroprudential policies, after Brexit, in the presence of asymmetric shocks, the UK will implement unsupervised measures. In light of the cross-country asymmetries in impulse responses, it is expected that post-Brexit UK macroprudential policy will differ from the pre-Brexit one, supervised by the ESRB.

A second shock that is being considered is a house price shock. Figure 4 presents impulse responses coming from a symmetric house price shock. As we see, house prices are increasing in both countries, given the symmetry of the shock. The financial side of the graph is showing a similar pattern across countries. However, wealth effects should be stronger in the region with a higher LTV, that is, the EU. In effect, although GDP is initially decreasing, GDP is increasing more strongly in the long run in the EU. Inflation is slightly decreasing in both countries but further in the UK. That makes monetary policy also react a little, following the decrease in inflation. Accordingly, monetary policy's reaction in the UK is stronger than in the EU. Interest rates are decreasing by more in the UK.

In figure 5 the house price shock is just happening in the UK. While financial and housing variables are only affected in the UK, there is some transmission in GDP to the EU. Trade with the UK makes that output in the EU goes down, because in the UK, there is a substitution to housing instead of consumption goods. Inflation is dropping mainly in the UK and thus, interest rates fall in that country, which contributes to the increase in credit that is already happening because of the house price shock.

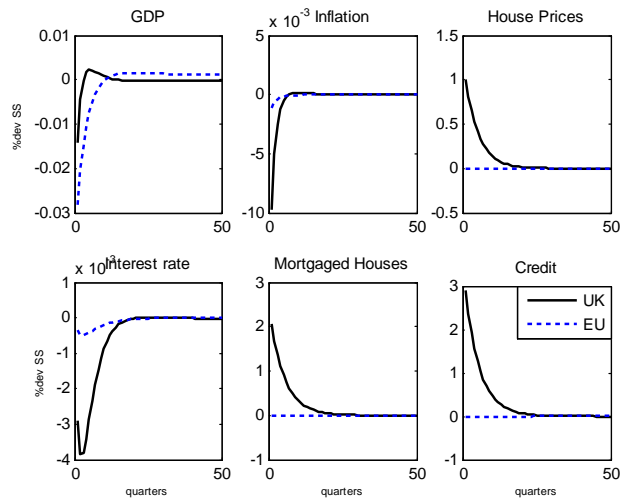


Figure 5: Impulse Responses to a House Price Shock in the UK. UK vs. EU

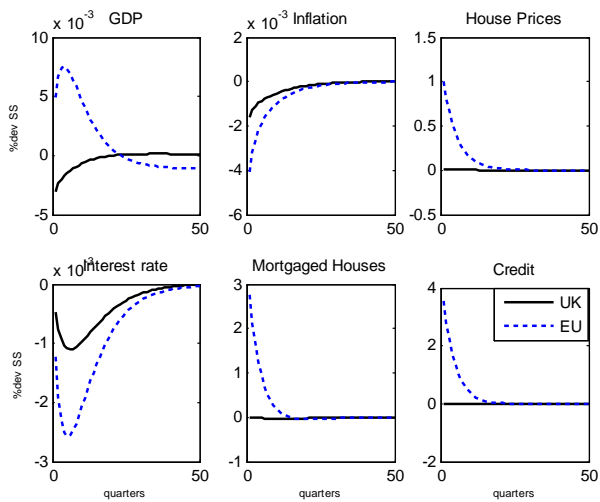


Figure 6: Impulse Responses to a House Price Shock in the EU. UK vs. EU

On the contrary, in figure 6 the house price shock is just happening in the EU. In this case, there is also some transmission of the shock to the other country. However, financial markets in the UK remain virtually unaffected. There is a slight reduction of inflation in the UK and monetary policy in that country responds to that. Interest rates in the EU also drop, as in the UK.

In light of asymmetric house price shocks, it would also be expected that a post-Brexit unsupervised policy in the UK would lead to a different macroprudential policy making than the one in favor of the majority.

In summary, both symmetric and asymmetric shocks produce difference cross-country dynamics both for the real economy and financial markets. This should have implications for the conduct of macroprudential policies. The next section studies this issue.

4 Macroprudential Policy

Some macroprudential measures, including changes in LTVs are set at a national level in the EU. However, they are supervised and coordinated by supranational authorities, namely the ESRB and the ECB. As part of the EU, the UK was under the supervisory umbrella of the ESRB. However, after Brexit, this is no longer the case and no official coordination is taking place.

In this section, I provide a theoretical framework to study the welfare implications of this change of regime after Brexit. In particular, I consider two regions setting macroprudential policy independently. In the pre-Brexit scenario, both regions coordinate when implementing their policies, in the sense that they simultaneously choose optimal policies by maximizing social welfare. Post-Brexit, each region maximizes their own welfare. I compare the two scenarios in terms of optimality of policies, welfare, and macroeconomic and financial stability.

4.1 Macroprudential Policy Rule

As an approximation for a realistic macroprudential policy, I consider a Taylor-type rule for the LTV.²⁵ In standard models, the LTV ratio is a fixed parameter, which is not affected by economic conditions. However, we can think of regulations of LTV ratios as a way to moderate credit booms. When the LTV ratio is high, the collateral constraint is less tight. And, since the constraint is binding, borrowers will borrow as much as they are allowed to. Lowering the LTV tightens the constraint and therefore restricts

²⁵I call it "Taylor type" because its structure reminds that of the traditional Taylor rule.

the loans that borrowers can obtain. Research on macroprudential policies has typically proposed Taylor-type rules for the LTV ratio so that it reacts inversely to variables such as GDP, credit, the credit-to-GDP ratio or house prices. These rules can be a simple illustration of how a macroprudential policy could work in practice. Here, I assume that there exists a macroprudential Taylor-type rule for the LTV ratio, so that it responds to credit and output deviations from the steady state.²⁶

Macroprudential policy is national, that is, each country can implement its own rule:

$$k_{UKt} = k_{SSUK} \left(\frac{b_t}{b} \right)^{-\phi_{UK}^b} \left(\frac{Y_{UKt}}{Y_{UK}} \right)^{-\phi_{UK}^y}, \quad (32)$$

$$k_{EUt} = k_{SSEU} \left(\frac{b_t^*}{b^*} \right)^{-\phi_{EU}^b} \left(\frac{Y_{EUt}}{Y_{EU}} \right)^{-\phi_{EU}^y}, \quad (33)$$

where $\phi_{UK}^b, \phi_{UK}^y, \phi_{EU}^b$ and ϕ_{EU}^y are the reaction parameters to credit and output for the UK and the EU, respectively. k_{SSUK} and k_{SSEU} are steady-state values of the LTV.

4.2 Welfare Measure

In order to optimally evaluate macroprudential policies, we need to provide a measure for welfare. As discussed in Benigno and Woodford (2012), the two approaches that have traditionally been used for welfare analysis in DSGE models include either characterizing the optimal Ramsey policy, or solving the model using a second-order approximation to the structural equations for given policy, and then evaluating welfare using this solution. As in Mendicino and Pescatori (2007), I take this latter approach to be able to evaluate the welfare of the three types of agents separately.²⁷ The individual welfare for savers and borrowers in UK is defined, respectively, as follows:

$$V_{u,t} \equiv E_t \sum_{m=0}^{\infty} \beta^m \left(\ln C_{t+m}^u + j \ln H_{t+m}^u - \frac{(L_{t+m}^u)^\eta}{\eta} \right), \quad (34)$$

$$V_{cv,t} \equiv E_t \sum_{m=0}^{\infty} \tilde{\beta}^m \left(\ln C_{t+m}^{cv} + j \ln H_{t+m}^{cv} - \frac{(L_{t+m}^{cv})^\eta}{\eta} \right), \quad (35)$$

²⁶ Although macroeconomic variables are not an explicit target of macroprudential policies, research shows that these variables are meaningful, especially at those instances in which monetary policy is restricted (See for instance Rubio and Yao, 2020).

²⁷ I used the software Dynare to obtain a solution for the equilibrium implied by a given policy by solving a second-order approximation to the constraints, then evaluating welfare under the policy using this approximate solution, as in Schmitt-Grohe and Uribe (2004). See Monacelli (2006) for an example of the Ramsey approach in a model with heterogeneous consumers.

Following Mendicino and Pescatori (2007), I define social welfare in Country UK as a weighted sum of the individual welfare for the different types of households:

$$V_t = (1 - \beta) V_{u,t} + (1 - \tilde{\beta}) [\alpha_{UK} V_{cv,t} + (1 - \alpha_{UK}) V_{cf,t}]. \quad (36)$$

Borrowers and savers' welfare are weighted by $(1 - \tilde{\beta})$ and $(1 - \beta)$, respectively, so that the two groups receive the same level of utility from a constant consumption stream. Everything is symmetrical for Country EU.

Total welfare is defined as a weighted sum of the welfare in the two countries:

$$W_t = nV_t + (1 - n) V_t^*. \quad (37)$$

4.3 Optimal Macprudential Policy

For the optimal macroprudential policy calculation, I study two cases; the first one considers a coordinated case in which both national policies are decided taking into account the welfare of the whole EU, including the UK. This is pre-Brexit, that is, national macroprudential policies supervised by the ESRB. The second one corresponds to two independent national policies, which are not coordinated and which do not take into account total welfare, just national welfare. This case would represent Brexit. Monetary policy is national, and taken as given in all cases.²⁸

When national macroprudential policies are designed independently and without taking into account total welfare, I consider a non-coordinated game between the two countries, in which the Nash equilibrium would determine the solution.²⁹ However, when they are supervised by the ESRB, national authorities are forced to simultaneously take into account total welfare when optimizing their policies.

In light of the cross-country asymmetries studied in the above sections, one might expect differences in the optimal macroprudential policies in each of the cases, especially for the UK. For instance, mortgage contracts are different across countries. The majority of borrowers in UK take mortgages at a variable interest rate, while borrowers the large countries of the EU do it at a fixed rate. As above-mentioned, with fixed-rate mortgages, monetary policy is less efficient to stabilize the macroeconomy. A macroprudential policy responding to macroeconomic changes may compensate the lack of effectiveness of monetary

²⁸I consider technology shocks for optimal policy.

²⁹Each country would find the optimal parameters in its policy rule, taking the macroprudential regulation of the other country as given. The intersection of these two best responses would give us the Nash equilibrium.

policy. Thus, it would be expected that the country in which the proportion of fixed-rate mortgages is larger, had a macroprudential policy responding more strongly to output. With respect to differences in LTVs, this creates cross-country asymmetric wealth effects. The LTV ratio dictates the strength of the financial accelerator, since it is directly related to the tightness of the collateral constraint. In a country in which the LTV is higher, the financial accelerator effects will be stronger. A stronger financial accelerator may make it optimal to respond more aggressively to output, so that the financial accelerator effects are not as strong and they balance out across countries.

Table 3: Optimal Macroprudential Policy				
	Coordinated (Pre-Brexit)		Brexit	
	ϕ^b	ϕ^y	ϕ^b	ϕ^y
UK	0.11	0.60	0.15	0
EU-27	0.92	1.95	0.92	1.95
EU-28	-	-	-	-

I present results from the optimization problem considering the two cases above-mentioned; independent versus supervised national macroprudential policies. I display the optimized parameters in the macroprudential rules for both cases (Table 3), and the volatilities of macroeconomic and financial variables, measured by the standard deviation of borrowing, output and inflation (Table 4). I also calculate the welfare gain (loss) derived from moving to the Brexit scenario (Table 5). I present the welfare gains (in consumption equivalents) resulting from implementing this optimal rule, in order to make the results more intuitive. That is, I find the constant fraction of steady-state consumption that would have to be transferred to the agent if a welfare loss occurred under the new scenario.³⁰ Here, a positive value for consumption units represents a welfare increase; i.e. it indicates how much the country would pay in units of consumption to be better off. A negative value means that welfare has decreased, i.e. it indicates by how much a country should be compensated in units of consumption for the welfare loss. As a benchmark, I take the pre-Brexit case and compare it with the Brexit scenario.

Optimal values for macroprudential policies in Table 3 confirm the intuition that in the country with fixed rates and higher LTVs, that is the EU, macroprudential policies respond more aggressively to output. Results also show that, both pre-Brexit and after Brexit, it is optimal for the UK to perform a less aggressive macroprudential policy than the one in the EU. As we see, the reaction parameters for

³⁰The consumption equivalent measure for the UK, as in Ascari and Ropele (2009), is given by $1 - \exp[(1 - \beta)(V_{new} - V_{old})]$, and analogously for the other country.

both borrowing and output are lower than the analogous ones in the EU, coming from the fact that the majority of mortgages in the UK are issued at a variable rate, as opposed to the large countries in the EU. Also, as we have already discussed, the LTV is lower in the UK, which would also advocate for a weaker macroprudential response to output. Pre-Brexit, although to a lower extent, the UK also responds more aggressively to output than to credit because it needs to take into account welfare of the whole EU and accommodate to its features. However, when we move to the Brexit case and the UK has no longer to take into account EU welfare for policy optimality, then it is not optimal for UK macroprudential policy to respond to output. Monetary policy alone should be enough to achieve macroeconomic stability, given the high degree of mortgage rate variability in the UK. Interestingly, Brexit does not affect the optimal policy-making in the EU, given the UK small comparative weight.

Table 4: Volatilities						
	Coordinated (Pre-Brexit)			Brexit		
	σ_b	σ_y	σ_π	σ_b	σ_y	σ_π
UK	1.9488	0.5703	0.2543	1.4245	0.5662	0.2611
EU-27	10.2526	3.0181	0.2547	10.2389	2.9965	0.2608
EU-28	-	-	-	-	-	-

In terms of financial and macroeconomic stability, Table 4 shows the standard deviations associated with credit, output and inflation. Credit volatility would approximate financial stability, while output and inflation volatilities are a proxy for macroeconomic stability. We see that after Brexit, the UK enjoys a substantial improvement in financial stability, while macroeconomic stability is not highly compromised. This is due to the fact that now, UK macroprudential policy does not need to respond to output just to favor the EU. Given the high proportion of variable-rate mortgages in the UK, monetary policy does not need to be complemented by macroprudential policy. This is a clear example in which the Tinbergen principle applies and there can be a separation of objectives; macroprudential policies can take care of financial stability while monetary policy focuses on macroeconomic stability. It is clear from the table that a macroprudential rule, which strongly responds to output was not optimal for the UK and that may have delivered conflicting outcomes pre-Brexit. Separating objectives in the UK makes it enjoy much higher financial stability, only at the expense of a slight lower macroeconomic stability. The EU has comparable economic stability with respect to the Brexit situation. It has a slightly better financial stability, given that the UK has substantially improved. However, it is also slightly worse off

in terms of inflation variability, also given that the UK's macroprudential policy is not responding to output anymore.

Table 5: Welfare Gain		
	Coordinated (Pre-Brexit)	Brexit
		Welf Gain (CE)
UK	-	0.6510
EU-27	-	-0.0742
EU-28	-	-0.0018

In terms of welfare, we see in Table 5 that the UK obtains a welfare gain, in consumption equivalents, from not being restricted anymore by the supervision of the European regulator and being able to optimize its macroprudential policy taking into account its own welfare. The benefits of much higher financial stability totally outweigh the cost of a slight higher inflation variability. On the other hand, the EU is just slightly worse off with Brexit because inflation variability is slightly higher.

4.3.1 Impulse Responses

In this subsection, I present impulse responses to several shocks, as an illustration on how optimal macroprudential policy pre and after Brexit affects the dynamics of the economy in both regions. As interesting cases, I select a symmetric technology shock, and both a technology and a house price shock just happening in the UK. I present the responses both for the UK and the EU, pre and after Brexit. For that, I use the optimal parameter values found in Table 3 for the simulations.

Figure 7 displays impulse responses to a symmetric technology shock, that is, to the shock happening in both countries at the same time. We can see from the graph that the main difference of the change of policy happens in UK's financial markets. As we see, after Brexit, the LTV response is much weaker in the UK. This is a general equilibrium effect, originated by the expectations of macroprudential policies being tighter. Credit ends up moving less, and also the LTV. Notice also that, regardless the regime, although LTVs decrease in both regions, UK policy is always much softer than the one in the EU. As a consequence, pre-Brexit, a common technology shock would restrict credit in the UK. However, after Brexit, this is no longer the case and housing markets would be boosted. There are no visible consequences from the change in the macroprudential regime for the aggregate real economy, though.

Figure 8 illustrates the case of an asymmetric technology shock happening just in the UK. The shock

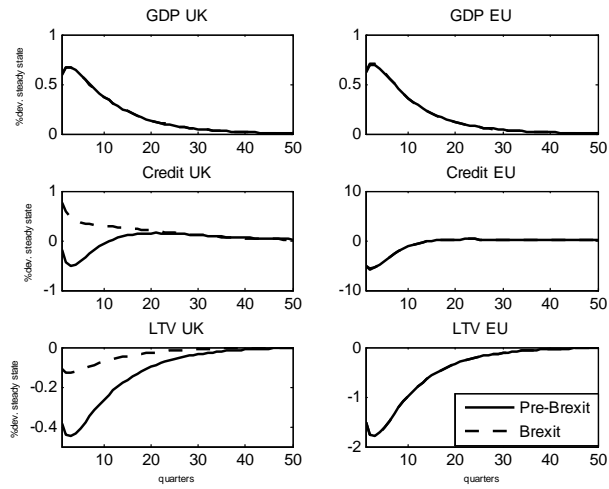


Figure 7: Impulse Responses to a Symmetric Technology Shock. Optimal Policy. UK and EU. Pre-Brexit vs. Brexit

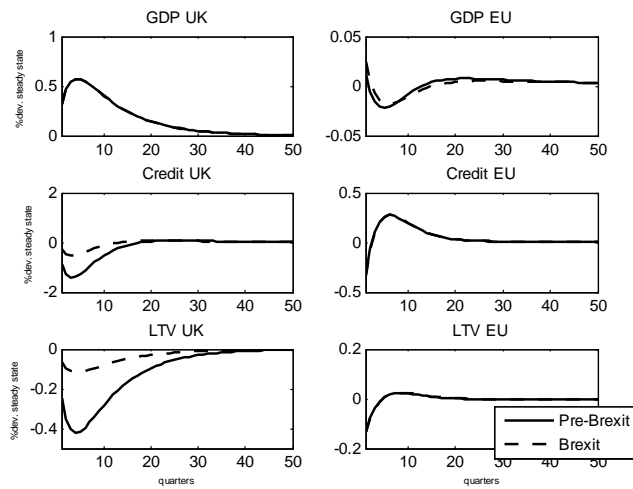


Figure 8: Impulse Responses to a Technology Shock in the UK. Optimal Policy. UK and EU. Pre-Brexit vs. Brexit

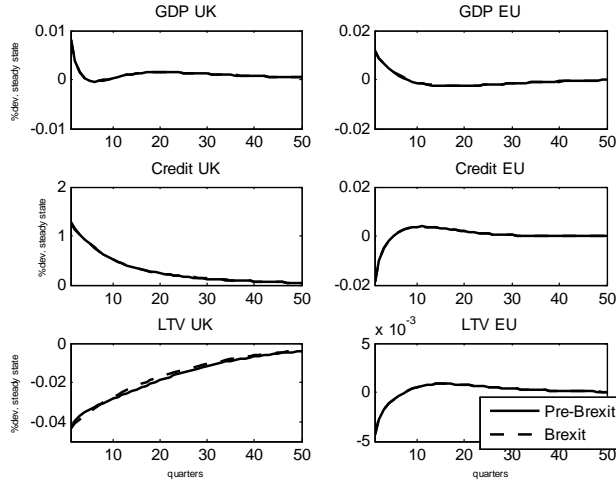


Figure 9: Impulse Responses to a House Price Shock in the UK. Optimal Policy. UK and EU. Pre-Brexit vs. Brexit

is slightly transmitted to the EU through trade linkages. The EU applies a restrictive LTV policy. The UK also cuts LTVs both pre and after Brexit. However, the response after Brexit, as expected, is much weaker than when the policy was supervised by the ESRB.

Figure 9 displays another interesting case in which there is an asymmetric house price shock just happening in the UK. As we see, when the shock comes from housing markets, there is no much difference in the policy response after Brexit. This is due to the fact that, the optimal macroprudential policy parameter with respect to credit has not changed much after Brexit and thus, macroprudential policy responds very similarly with respect to credit markets before and after Brexit.

In light of the previous impulse responses, it seems that the differences in optimal macroprudential policies after Brexit have an implication on UK financial markets, but mostly if the shock comes from the real side of the economy.

5 Concluding Remarks

This paper addresses the following research question: How do optimal macroprudential policy and financial stability change after Brexit, both for the UK and the EU? In order to answer this question I use a two-country DSGE model, which features a housing market. I calibrate the two countries to capture the UK and EU characteristics. Macroprudential policy is proxied by a rule on the LTV that responds to both credit and macroeconomic developments. The pre-Brexit macroprudential scenario, in which the UK is supervised by EU macroprudential authorities, is captured by a situation in which the

UK sets its optimal policy maximizing the whole EU welfare. On the contrary, in the Brexit situation, optimal macroprudential policy is set independently, taking into account only each country's own welfare.

I find that it is optimal for the UK to have a less aggressive macroprudential policy than the EU. I also find that, after Brexit, the UK is better off by setting its own macroprudential policy. When taking into account its own welfare, the UK optimal macroprudential policy advocates for a macroprudential policy in which the Tinbergen principle applies, focusing on credit developments and not taking into account output. This is mainly due to the fact that in the UK, the majority of consumers borrow at a variable rate and its LTV is lower than the EU counterpart.

When analyzing the dynamics under the optimal macroprudential policy pre and after Brexit, results show that differences in optimal macroprudential policies after Brexit have an implication on UK financial markets but mostly if the shock comes from the real side of the economy.

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