

# Macroprudential Regulation in the Post-Crisis Era: Has the Pendulum Swung Too Far?<sup>1</sup>

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## Abstract

This paper presents an institutional model to investigate the cooperation between a government and a central bank. The former selects the monetary policy and then delegates the organization of macroprudential policy to the latter. Their policy stances are the result of sequential constrained utility maximization. Using indirect inference, we find a set of coefficients that can capture the UK policy stances for 1993-2016. This suggests post-crisis regulation has been overly intrusive. Finally, we show that this regulatory dilemma can be avoided by committing to a highly stabilizing monetary regime that uses QE extensively.

**Keywords:** Bank regulation; Financial stability; Monetary policy; Public choice theory

**JEL:** E52; E58; G28

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## 1. Introduction

The 07/08 financial crisis has reinvigorated economists' interest in studying macro-prudential policy and its impacts on macroeconomic stability. The reason is that, in the decades before the crash, macroeconomic management revolved around price stability and it was believed that inflation targeting alone was able to ensure overall stability. The UK adopted inflation targeting in 1992Q4 after its exit from the European Exchange Rate Mechanism (ERM). The resulting strategy for stabilizing both the real economy and the financial system was vindicated by the muted volatility observed in the "Great Moderation" from 1993 to 2007 throughout which the UK experienced 60 consecutive quarters of GDP growth. Nevertheless, the Global Financial Crisis (GFC) has amply demonstrated that the inflation-targeting regime alone does not guarantee stability, as financial imbalances can keep building up in such a regime even while the inflation is kept close to the target. With some hindsight, the actions of policymakers who acted as firefighters were necessary but too little and too late. Having realized that risks originating in the financial sectors can be contagious and endanger the real economy in the presence of low and stable inflation, central banks worldwide including, the Bank of England (BoE), have initiated a series of regulatory reforms under Basel III such as strengthening of

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the capital and liquidity requirements, and the introduction of a leverage cap and a countercyclical capital buffer. Compared with monetary policy tools which are blunt against financial imbalances, macroprudential tools can be more direct and effective for fostering financial stability as they target the source of systemic risk by discouraging unsustainable lending (Bernanke, 2010; Fischer, 2017). Notwithstanding their separate goals - monetary policy targets price stability while macroprudential regulation is geared towards financial stability, both tools are supposed to regulate the banking sector. Interaction between the two is thus inevitable and this raises the question of what “side effects” the conduct of one will have on the objective of the other. Ideally, these two measures should complement each other. However, in some situations, the two goals might clash.<sup>2</sup> Moreover, since in practice the conduct of both policies would face political constraints, it appears necessary to understand the institutional design in studying policy coordination. This is the focus of our paper.

The institutional framework we present here closely follows that of Le et al. (2018) and consists of the voters (principals) and two types of policymakers (agents): an elected government (politicians) and a non-elected central bank (bureaucrats). Our premiss is that the government is held accountable by voters at election time, whereas the central bank gets appointed by the government who defines the central bank’s budget based on the quantity of services (regulation) it supplies. These distinct mechanisms result in their different utility functions (incentive schemes): the government strives to maximize the voter’s utility as it is voted in by the public and wants to signal its competence for re-election purposes. The central bank, on the other hand, pursues an oversized budget (relative to what the government would want), besides fulfilling their job. We posit a policy constraint that resembles the well-known Laffer curve so that two levels of regulation can deliver the same stability. When the government first chooses the monetary policy subject to the policy constraint, it stays on the *left* side of the Laffer curve. Then, the central bank implements the mandated monetary rule but is allowed to set macroprudential policy freely. With private interests in mind, it chooses to do so at the point where regulatory power is large (greater bureaucracy size and budget). In effect, it proceeds to the *right* side of the Laffer curve to deliver the same stability. This results in a bloated and inefficient bureaucracy at a cost to taxpayers.

We apply the principal-agent model of public choice in Le et al. (2018) to the UK in studying the interplay of its monetary and macroprudential policies for 1993-2016. The data starts in 1993, as this was the point when the Bank of England was officially given its key role in the inflation-targeting framework. As in Le et al. (2018), we consult a DSGE model set up for the UK that extends the monetary model in Le et al. (2016) to a small open economy setting. This open economy DSGE model integrates financial frictions as in Bernanke et al. (1999) (BGG), zero lower bound (ZLB) constraint, and unconventional monetary policy -

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<sup>2</sup>For example, during the crisis, central banks tended to boost the demand by maintaining an accommodative monetary policy (“loose money” stance) at the ZLB, whereas from the regulatory viewpoint, a tightening of macroprudential policy could be needed to curb credit growth (“tight credit” stance).

Quantitative Easing (QE) in a well-known reference model of Smets and Wouters (2007) (SW(07)). Using indirect inference testing and estimation, we have found a set of coefficients that can generate the simulated data close enough to the UK observed data for 1993-2016. It is through this combination of the Institutional Model and its underlying DSGE model that we analyze the UK policy environment. We aim to shed light on the GFC and the recovery afterwards.

The rest of the paper is organized as follows. Section 2 reviews the literature and justifies the model assumptions. Section 3 lays out the model. Section 4 demonstrates how, when combined with a Macro-DSGE model, the Institutional Model is able to conform qualitatively with the UK data. Section 5 offers a solution to the regulatory dilemma. Finally, Section 6 concludes.

## **2. Literature Review**

By reviewing the relevant prior literature, we aim to provide the theoretical background and motivation for the model described in Section 3.

### *2.1. What motivates regulation?*

In advanced democracies, it is common practice for the governments (politicians) to delegate key policy areas such as macroprudential regulation to some independent bureaucrats such as central bankers who are believed to make policy decisions with little political bias (Alesina and Tabellini, 2008). Traditionally, if we followed the public interest theory, we would believe that regulation emerges as a way to rein in market failures, as is typically assumed in welfare economics. In the case of banking regulation, regulatory authorities require commercial banks to keep some of the money they take from depositors as reserves, so as to protect the public (savers and borrowers) from bank failures. Through adjusting the standard on minimum percentage of deposits that banks have to keep in their possession, authorities are supposed to regulate the supply of loans and promote stability.

However, previous works on regulatory economics, such as Stigler (1971), Niskanen (1975), Peltzman (1976), and Buchanan (1984) provide the alternative view of regulation we pursue in this paper. These public choice economists dislodge the idealistic view that regulation arises solely to advance the public interest, and argue that instead regulation is motivated mainly by regulators' self-interest. By applying the same principles used to analyze people's actions in the marketplace to collective decision making, these researchers maintain that the dominant motive in regulators' actions is a concern for themselves, rather than for others. Stigler (1971) employs an empirical model of regulation and shows that when faced with special interest pressure from large firms and electoral pressure from consumers, regulators (as self-interested actors) always pass regulatory rules to benefit the large firms due to their more persuasive power (e.g., bribes, campaign contributions and future employment opportunities). So we see regulation on control of entry such as occupational licensing and protective tariffs that bend to dominant firms' demands but generate

costs to consumers. Peltzman (1976) updates Stigler's theory by associating regulators with legislators who have electoral accountability. He demonstrated theoretically that regulators (legislators) would seek to balance interest group support from producers and voter support from consumers. Since winning election takes both money and votes, regulators would deliver regulation at equilibrium points to maximize their re-election odds. Buchanan (1984) points out one cannot be self-interested in one area, while being wholly altruistic in another. Politicians and bureaucrats are just normal people who will act to advance their own interests in the process of policymaking. Niskanen (1975) applies public choice literature on the bureaucracy and proposes a budget-maximizing model wherein self-interested bureaucrats pursue oversized budgets and expansion of power. Here we follow Niskanen's approach and model the central bank as made up of technocrats who, besides pursuing the public interest of stabilizing the economy, act to benefit themselves. We treat the central bank as a monopoly (the sole supplier in the market) that produces services (regulation) which will then be supplied by the government to the public. Due to the nature of the central bankers' job as civil servants, the price of their services is more or less fixed. Hence, in order to justify a huge budget from the government, bureaucrats will only resort to maximizing the quantity of services, subject to a stability break-even constraint. This results in a expansion of power and public spending, possibly at the cost of efficiency.

## *2.2. Does more regulation imply more stability?*

Regarding the efficacy of regulation, there has been considerable controversy over the years, as some regulatory controls have proved effective in reducing both the likelihood and the magnitude of bank failures while others are deemed costly and counterproductive. There is ample literature on both sides.

Furlong and Keeley (1989) theoretically assess the effect of bank capital regulation on bank default risk and the risk exposure of the deposit insurance system, concluding that raising capital standards would reduce the incentives for a value-maximizing bank to increase asset risk. See also Brunnermeier and Sannikov (2016) for theoretical evidence in favor of regulation. Empirically, Gropp and Vesala (2004) study a sample of EU banks during the 1990s and find that deposit insurance would reduce the risk-taking among smaller banks with low charter values or/and high shares of non-insured liabilities. Andries et al. (2017) analyze an international sample from 21 advanced economies in 2008-2014 and show that tightening the capital requirements, in general, would contain banks' risk-taking. Altunbas et al. (2018) investigate the effects of macroprudential tools on bank risk through a sample from 61 developed and emerging economies, suggesting that these tools are effective in mitigating bank risk, although the individual response of banks might differ depending on the sizes of their balance sheets.

Conversely, Berger et al. (1995) stress the practical difficulties in defining, measuring, and monitoring capital, concluding that capital requirement is too blunt a tool for protecting the system. Moreover, failure to set the requirement at its optimal level would create price distortion and allocative inefficiency. Besanko and Kanatas (1996) show empirically that higher capital standards result in asset-substitution moral hazard. Blum

(1999) employs a theoretical dynamic model with incentives for asset substitution and finds that imposing higher capital adequacy would reduce banks' profits and thus their incentives to avoid default. Based on evidence from 61 countries for 1980-1997, Demirgüç-Kunt and Detragiache (2002) emphasize that deposit insurance schemes might encourage risk-taking and increase the likelihood of crises. Ezer (2019) employs bank-level data from 30 European countries for 2000-2014, documenting that risk-taking tends to increase following a macroprudential tightening through capital-based tools.

Calem and Rob (1999) reconcile the above conflicting views by identifying a U-shaped relationship between bank capital and risk-taking. Using data from the US banking industry for 1984-1993, they find that risk-taking first decreases then increases with the capital position. When banks are severely undercapitalized and take the maximum risk, a rising capital ratio enhances stability. However, as capital continues to increase, well-capitalized banks begin to take on more risk again by increasing the portfolio share of risky assets. Clerc et al. (2014) examine the role of capital regulation in a DSGE model with three layers of default, verifying the existence of an optimal level of capital requirement ratio at around 10%. When the regulation is loose enough (low capital requirement), the positive effect of a higher capital requirement dominates as it lowers the average default rate. Then, when the regulation becomes sufficiently tight with a virtually zero default rate, the negative effect of the loan reduction dominates. Overall, the welfare gains first increase then decrease with the increasing capital requirement. More recently, Huang (2018) employs the macro-finance framework proposed by Brunnermeier and Sannikov (2014) and stresses again the U-shaped relationship between banking regulation and financial instability in a theoretical model where regular banks circumvent regulation via sponsoring shadow banking activities. The paper models shadow banking as the regular banks' off-balance-sheet financing, showing that with or without shadow banking, tightening regulation via raising the tax on regular banks' debt eventually undermines stability, despite their different underlying mechanisms.

We follow the evidence from the third approach and generalize it to the broader concept of regulation. The assumption we make in what follows is that stability first improves then deteriorates as regulation gets progressively tighter. The relationship between the two can be represented by a hump-shaped function resembling the well-known Laffer curve. Given that the UK has long stood as the world's leading fintech center, it seems particularly necessary to walk a tightrope between preventing financial excesses and imposing overly strict regulation that risks hampering financial innovation and undermining industrial competitiveness.

### **3. Model Setup**

In this section, we briefly introduce the model. Section 3.1 sets up the policy constraint formalizing how monetary and regulatory policies jointly contribute to stability. Sections 3.2 and 3.3 then detail the cost-benefit analyses of policymakers and their resulting policy choices.

### 3.1. Policy constraint

We study a simple policy environment with two tasks: the monetary policy and macroprudential (regulatory) policies. Despite their different primary objectives, they share the ultimate goal of smoothing macroeconomic cycles. Unlike monetary policy, for which there has long existed widely agreed indices and inflation target to meet (e.g. the current 2% annual CPI inflation in the UK), knowledge of regulatory policy's target - financial stability is incomplete. There is still no consensus on the exact definition of financial stability, nor do we have any well-defined metric for the financial risk in a system as a whole (systemic risk). In practice, outsiders can only evaluate the conduct of regulation based on the observable output stability. Given that policymakers seek to stabilize the economy via their joint use of both policies, we set up the policy constraint as follows:

$$S = a + bM + cP - 0.5dP^2 - \sigma_E^2 \quad (1)$$

where  $a > 0$ ,  $b > 0$ , and  $c > d > 0$ . Eq. (1) states that stability ( $S$ ) is jointly determined by the policymakers' monetary stance ( $M$ ), regulatory stance ( $P$ ), and some ambient noise ( $\sigma_E^2$ ) that varies with the size of shocks to the economy. The posited Laffer curve effect from  $P$  to  $S$  implies that  $S$  is quadratic in  $P$  - moderate regulation improves stability whereas excessive regulation undermines stability. Policy constraint (1) represents all possible combinations of monetary and regulatory stances that policymakers may choose to deliver the intended stability; it plays a similar role to the consumer's budget constraint.

### 3.2. Choice of the government

Having established how monetary and regulatory policies are supposed to jointly contribute to stability, we move on to look at how these policy decisions are chosen in the first place. We focus our analysis on the groups of individuals at the top - party leaders in charge of the government or high-level bureaucrats like central bank governors. We contrast political and bureaucratic accountability by assuming that politicians are held accountable by voters at election time, while bureaucrats are accountable to the public at large for how well they have fulfilled the goal assigned to their bureaucratic organization. We analyze a model wherein two types of policymakers with different incentive schemes maximize their corresponding objective functions subject to the institutional arrangement. Their policy stances are interpreted as some sequential constrained utility maximization. The timing of events is as follows. First, the government (politicians) chooses monetary policy. Armed with the premiss that political incumbents seek to please the voters by acting in the interests of society, we introduce the government's preference as:

$$U_G = S^\mu - M^\nu - lP \quad (2)$$

where  $S$ ,  $M$  and  $P > 0$ . For the parameters that govern the preference, we have  $0 < \mu < 1$ ,  $\nu > 1$  and  $l > 0$ . For the government, the measure of its performance is voters' utility.  $S$  enters positively as economic stability is closely and positively linked with social stability.  $M$  enters negatively as the more stabilizing the

monetary stance (greater  $M$ ), the more resource it costs the society to adjust it to some more interventionist levels. For example, during the GFC the binding ZLB on the nominal interest rate forced the central bank to deploy QE, which required extra stabilizing effort.  $P$  also enters negatively as the government (public) considers regulation as the resource cost that it wishes to reduce wherever possible. Quite often, we see from the government propaganda the expression “cutting of red tape” when it attempts to circumvent bureaucratic obstacles deemed to have obstructed enterprise. In effect, the government maximizes utility function (2) subject to the constraint (1).

The situation is illustrated in Fig. 1 where the government chooses the monetary stance  $M_0$  and targets regulatory power  $P$  and stability  $S$  - what it thinks  $P$  and  $S$  should be according to the policy constraint ( $\hat{P}$  and  $\hat{S}$ ). Maximizing the Lagrangian  $\mathcal{L}_1 = U_G - \Lambda_1 S$  with respect to  $S$ ,  $M$ , and  $P$  leads to the following first-order conditions:

$$\frac{\partial \mathcal{L}_1}{\partial S} = \mu S^{\mu-1} - \Lambda_1 = 0, \quad \frac{\partial \mathcal{L}_1}{\partial M} = -\nu M^{\nu-1} + \Lambda_1 b = 0, \quad \frac{\partial \mathcal{L}_1}{\partial P} = -l + \Lambda_1(c - dP) = 0 \quad (3)$$

The solutions for  $M$  and  $P$  are:

$$M = \left( \frac{\mu b}{\nu} \right)^{\frac{1}{\nu-1}} S^{-\left(\frac{1-\mu}{\nu-1}\right)}, \quad P = \frac{c}{d} - \frac{l}{\mu d} S^{(1-\mu)} \quad (4)$$

It follows that:

$$\frac{dM}{dS} = -\left( \frac{1-\mu}{\nu-1} \right) \left( \frac{\mu b}{\nu} \right)^{\frac{1}{\nu-1}} S^{\left(\frac{\mu-\nu}{\nu-1}\right)} < 0 \quad (5)$$

Therefore, as  $S$  rises (more stability),  $M$  falls (the less interventionist monetary regime is needed). Note that only  $M$  is determined by this stage.

### 3.3. Choice of the central bank

In the second step, the government delegates the organization of the macroprudential policy to the central bankers (bureaucrats) who must implement the chosen monetary rule but are free to select their power. We assume that the government can pass a law to ensure the central bank will enforce this chosen  $M$ . Following Fischer (2017), we argue that the BoE only has instrument independence but not goal independence - the MPC of the BoE was given an explicit inflation target set by the government, then it implements interest rate policies or deploys QE accordingly to achieve price stability and an implied stabilization goal for real economic activity. This means the government can monitor the central bank's implementation of monetary rules so that in bureaucrats' determination of  $P$  they must take  $M$  as given. Assuming that non-elected central bankers act in their self-interest, notably the amount of power or bureaucracy size, we introduce their preference as:

$$U_{CB} = S^\varepsilon + \varpi P \quad (6)$$

where  $\varepsilon > 1$  and  $\varpi > 0$ .  $S$  enters positively as central bankers have to fulfill the task of delivering stability;  $P$  enters positively because of our private interest assumption. We take the stand that the central bank's budget is defined by the government (legislature) according to the quantity of services (regulation) the bank produces. Given the fixed unit cost of regulation, the more services the bank supplies, the greater will its budget be. Hence, in order to justify a huge budget, the self-interested bureaucrats will seek to expand their services wherever possible. Maximizing the associated Lagrangian  $\mathcal{L}_2 = U_{CB} - \Lambda_2 S$  yields:

$$\frac{\partial \mathcal{L}_2}{\partial S} = \varepsilon S^{\varepsilon-1} - \Lambda_2 = 0, \quad \frac{\partial \mathcal{L}_2}{\partial P} = \varpi + \Lambda_2(c - dP) = 0 \quad (7)$$

The solution for  $P$  is:

$$P = \frac{c}{d} + \frac{\varpi}{\varepsilon d} S^{-(\varepsilon-1)} \quad (8)$$

It then follows that:

$$\frac{dP}{dS} = -\frac{\varpi}{\varepsilon d}(\varepsilon - 1)S^{-\varepsilon} < 0 \quad (9)$$

This suggests that the less stabilized the economy is, the more regulatory power it requires. Moreover, the marginal utility generated from more power outweighs the marginal disutility from instability. Noticeably, the quadratic form of the policy constraint implies that two levels of regulation can deliver the same stability, though with different social costs. We assume imperfect monitoring so that politicians can only observe the regulatory outcome in terms of stability. This leaves open the possibility of grabbing more power and applying more regulation than necessary. With self-interest in mind, the central bank goes over the maximum point onto the *right* side of the Laffer curve where it achieves the same stability but with more power (bigger size of bureaucracy and larger budget). As a result, the common good is sacrificed for the bureaucrats' political self-interest.

Fig. 2 illustrates this situation where out of this model first comes a choice of  $M(\overline{M}_0)$  by the government, then the subsequent choices of  $P_0$  and  $S_0$  by the central bank given this  $\overline{M}_0$ . The justification for the delegation arises from the assumption that the government cannot carry out the necessary regulatory activities without delegating them to central bankers (technocrats). We appeal here to the politics of delegation with information asymmetry. The central bank can always convince the government that it is impossible to obtain the same stability with less power. The government does not know which side of the Laffer curve the central bank is on and hence cannot gauge its efficiency or prove in the public domain that the same stability can be obtained with smaller budgets. Being unable to monitor the central bank's use of power, the government finds it difficult to keep the central bankers within the budget or force them to be as efficient as possible.

Therefore, the government has no better way to limit the size of the budget than choosing the best  $M$ , because a good  $M$  that shifts the policy constraint upwards can limit the central bank's use of  $P$ . The better the monetary policy alone can stabilize the economy, the less need there is to resort to regulatory intervention,



and the less chance for the central bankers to exploit the situation for a huge budget. Note that  $P$  is only determined after the central bank's maximization. Substituting the solution for  $P$  into the policy constraint yields the following total differential (evaluated at  $S = P = 1$ ):

$$dS = - \frac{1}{1 + b \left( \frac{\mu b}{\nu} \right)^{\frac{1}{\nu-1}} \frac{1-\mu}{\nu-1} + (c-d) \frac{\varpi}{\varepsilon d} (\varepsilon - 1)} d\sigma_E^2 \quad (10)$$

So that  $dS/d\sigma_E^2 < 0$ , which is then combined with  $dM/dS < 0$  and  $dP/dS < 0$  to yield the following first-order derivatives:

$$\frac{dM}{d\sigma_E^2} > 0, \quad \frac{dP}{d\sigma_E^2} > 0 \quad \text{and} \quad \frac{dS}{d\sigma_E^2} < 0 \quad (11)$$

What this suggests is that a rise in the environmental volatility  $\sigma_E^2$  would raise  $M$  and  $P$  but reduce  $S$ . In Section 4 where we conduct model testing and estimation, these functions will form the auxiliary model to be observed in data moments. The signs of these derivatives would be checked for the robustness tests.

#### 4. Model testing and estimation

We employ indirect inference for model testing and estimation. This simulation-based method was first proposed in Smith Jr (1993) and developed later in Minford et al. (2009) and Le et al. (2011), who applied Monte Carlo experiments to evaluate the method. By “indirect”, it means choosing an auxiliary model such as VAR coefficients, IRFs or data moments as a lens to produce descriptions of the data. Here we check whether the moments from the model-generated data are similar to the moments from the actual data - a process analogous to using Simulated Method of Moments (SMM) for estimation. In effect, we calculate where in the distributions of joint correlations across simulated data subsamples their counterpart joint correlations across actual data subsamples lie. Fig. 3 summarizes the procedure of constructing the simulated and the actual data.

We consider the data sample 1993Q1-2016Q4 for the UK. The data is divided into three subsamples: 1993-1999, 2000-2007, and 2008-2016 depending on the shifts in policy regimes. Subsample 1 (the 1990s) was the period when the adoption of inflation-targeting made monetary policy more predictable and rule-like. Policymakers' monetary and regulatory stances were moderate throughout this period. Subsample 2 (the early 2000s) was known as the “irrational exuberance” phase where overly loose monetary and regulatory stances led to the pre-crisis credit and housing boom. Subsample 3 (post-crisis era), on the contrary, was characterized by aggressive monetary and regulatory policy shifts; it observed frequent unruly policy interventions such as unconventional monetary policy and increasingly intrusive banking regulation.

#### 4.1. Actual data

For the construction of actual data correlations between three variables  $S$ ,  $M$ , and  $P$  across subsamples, we gather the following facts for each episode. Stability ( $S$ ) is calculated as the inverse of HP-filtered output variance. The results are plotted in Fig. 4.

The monetary regimes ( $M$ ) for each episode are identified after Taylor (2016). Although Taylor's original speech was about the US, the UK economy bears certain resemblances to its US counterpart - the policy tendencies observed in the US before and after the crisis apply to the UK, to a large extent. This view was backed up by the former Deputy Governor of the BoE, Charles Bean, who attributed the pre-crisis housing price bubble in the UK partly to the policy rate enforced by the BoE which was below the level suggested by the rule (Bean et al., 2010; Taylor, 2016). The downward deviation from the rule had reduced market risk aversion and encouraged reckless lending under lower credit standards; this is consistent with the pre-crisis observation that the relatively loose monetary stance was accompanied by a housing boom and higher stock market volatility in the UK (e.g. Luo et al. 2011; Altunbas et al. 2018; Rubio and Yao 2020). So, if we rate Subsample 1 (93-99) as the standard Taylor rule period ( $M = 1$ ) for which the BoE stuck to the moderately stabilizing monetary regime, then Subsample 2 (00-07) refers to the poor Taylor rule period ( $M = 0.5$ ) when the BoE adopted an overly accommodating monetary regime that responded little to inflation and output and created a credit boom. Subsample 3 (post-2008 era), on the other hand, was the episode when the BoE deployed both conventional and unconventional monetary tools to combat the Great Recession by reacting aggressively to the low liquidity; we thus rank  $M = 1.5$  for it.

When serving as civil servants, regulators are unlikely to pass laws to raise their own income. Instead, they can only pursue non-pecuniary goals, e.g. prestige, feelings of control, greater financial budgets, and the expansion of power and authority, most of which are related to the total bureaucracy size, represented by the bureaucratic organization's employee number. Following Taylor (2016), we use the number of BoE employees as an indicator of regulatory intensity. The idea is that the BoE's staff number (excluding printing staff) moves in line with its financial stability responsibility which has been subject to considerable institutional changes over the past two decades.

Fig. 5 shows that before the crisis, the BoE had been shrinking in size between the mid 1990s and early 2000s. The drop in staff numbers had become particularly sharp since 1998 - the point when the BoE was granted operational independence under the Bank of England Act 1998 and handed most of its regulatory power to an institution outside the BoE - the Financial Stability Authority (FSA). The newly created FSA, together with the BoE and HM Treasury, formed the tripartite authorities that supervised microeconomic behaviour while exercising a light touch on macroeconomic effects in the early 2000s (Subsample 2). The common belief back then was that financial markets were able to police themselves, and should be free from

regulatory fetters (Yellen, 2011).<sup>3</sup> Nevertheless, the GFC was seen as proving the failure of the tripartite system for anticipating and preventing the crisis, demonstrating the need for an enhanced BoE overseeing of the financial system. The ensuing institutional reforms have led to an explosion in regulatory/supervisory power, swinging the pendulum sharply to the opposite side, to a regulatory state. For example, the FSA was split into two separate bodies in 2013, one of which - the Prudential Regulation Authority (PRA) became a subsidiary of the BoE and responsible for microprudential regulation. In the same year, the Financial Policy Committee (FPC) was established within the BoE as part of the macroprudential regulation system brought in after the crisis. The FPC was supposed to work jointly with the PRA to enhance the resilience of the system. Through these institutional reforms, regulatory power was largely returned to the BoE; this is consistent with the evidence from Fig. 5 - the bank underwent its most rapid expansion in size for decades from 2013 to 2016 as it restored the regulatory power that had been ceded to the FSA a decade ago.<sup>4</sup>

For the measure of regulation power ( $P$ ), we divide the number of BoE employees at the end of each episode by 10000. The point is that we are trying to rank each period by the intensity of regulation and also what we know of policy, using the data of BoE employees. Subsample 2 (pre-crisis episode) is the one where regulation was the lowest in line with the deregulation agenda. Before that, it was moving towards it in the late 1990s, but the regulation level was still higher for Subsample 1 (1990s). After the crisis in 2008 regulation went up in line with the new philosophy. So we use the endpoints to best capture this joint information as regulative burden takes time to show up in employment. This would give us 0.2833 for 93-99, 0.1789 for 00-07, and 0.3983 for 08-16.

Having gathered the observable data moments, we construct a number of correlations across subsamples in Fig. 6. There are essentially 3 data points for each variable.  $S$  is negatively correlated with both  $M$  and  $P$ , while the latter two move in sync with each other. We now proceed to find out if this data behavior can be generated from our Institutional Model.

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<sup>3</sup>Yellen (2011) mentions “Looking back, I believe the regulatory community was lulled into complacency by a combination of a Panglossian worldview and benign experience. The notion that financial markets should be as free as possible from regulatory fetters had evolved into the conviction that those markets could, to a very considerable extent, police themselves. Meanwhile, things went along so well for so long that the common belief came to be that nothing could go disastrously wrong” (p. 4), and “as with all forms of regulation, we must find the right balance between overly strict supervision and laissez faire...before the crisis, we had veered disastrously too far in the direction of laissez faire, with consequences we know too well” (p. 9).

<sup>4</sup>For a discussion of explosion of regulatory and supervisory powers in the UK since the GFC, see Willem Buiter’s speech “Central Bank Independence: Mirage and Mythos” at the “Bank of England independence: 20 years on conference”, available at <https://www.bankofengland.co.uk/events/2017/september/20-years-on> (slide 12 “Growing scope and scale of central bank activities, powers and responsibilities”).

## 4.2. Simulated data

### 4.2.1. Can the underlying DSGE model yield the posited shape for the policy constraint?

To generate the posited Laffer curve effect from regulatory strength to stability, we consult the underlying DSGE model set up for the UK which extends the US model in Le et al. (2016) to a small open economy setting (see Appendix B for the full model list). The model features nominal rigidities (Calvo price and wage setting and indexation to past inflation and wages) and financial frictions as in BGG, thus enabling both monetary and macroprudential policies to play a role.

In order to run simulations under different levels of regulation, we start by reviewing the premium equation (12) in Le et al. (2016).<sup>5</sup> The risk premium (lending-deposit spread)  $pm_t$ , calculated as the wedge between the expected real risky return (expected real lending rate)  $\mathbb{E}_t cy_{t+1}$  and the real risk-free return (real deposit rate)  $r_t - \mathbb{E}_t \pi_{t+1}$  (nominal deposit rate  $r_t$  minus the expected inflation  $\mathbb{E}_t \pi_{t+1}$ ), serves as an indicator that gauges distress in the credit market. Parameter  $\chi > 0$  measures the degree of financial frictions.  $pm_t$  increases with leverage ratio  $pk_t * k_t/n_t$  (price of capital \* amount of capital purchased by entrepreneurs / entrepreneurs' net worth or equity) as for entrepreneurs more heavily reliant on external funds for capital acquisitions, their default risks rise; this causes a widening of the lending-deposit spread that reflects banks' growing unwillingness to lend. QE is modeled as the government's injection of liquidity ( $m_0$ ) via gilt purchase which lowers  $pm_t$  for given leverage. Parameter  $\vartheta > 0$  captures the credit easing effect of  $m_0$  on the loan supply (i.e. QE's role in boosting lending).<sup>6</sup> In a similar vein, a macroprudential instrument  $\xi_t$  is injected into (12) to model regulators' intervention in the credit supply. Regardless of the specific type of instrument, macroprudential regulation is always aimed at constraining the supply of loans (risky lending). A tightening of regulation via additional capital surcharges, higher liquidity ratio limits or higher reserve requirements is approximated by a rise in  $\xi_t$  that raises  $pm_t$  and increases the cost of debt financing  $cy_t$ .

$$p\hat{m}_t = \mathbb{E}_t \hat{cy}_{t+1} - (\hat{r}_t - \mathbb{E}_t \hat{\pi}_{t+1}) = \chi(\hat{p}k_t + \hat{k}_t - \hat{n}_t) - \vartheta\hat{m}_t^0 + \hat{\xi}_t + \hat{\epsilon}_t^{pm} \quad (12)$$

To let the regulators have control over the regulatory strength via altering the risk premium, we re-express the regulatory impact on the risk premium as:

$$\hat{\xi}_t = \kappa[\zeta \cdot p\hat{m}_t + \hat{\eta}_t] \quad (13)$$

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<sup>5</sup>Le et al. (2016) embed the BGG financial accelerator in the SW(07) model by modifying the latter's setup and assuming that intermediate goods producers (entrepreneurs) must take loans from commercial banks for their capital purchases. Entrepreneurs' production is subject to an idiosyncratic shock which is only known to themselves. The asymmetric information between entrepreneurs (borrowers) and the banks (lenders) results in costly monitoring in case of default, which in turn motivates financial frictions.

<sup>6</sup>Le et al. (2016) supplement the BGG contract with the collateral requirement that induces a liquidation cost  $\delta$  when entrepreneurs default. They allow M0 (cash) injection via QE to have effects on the credit market by assuming the newly issued M0 is used as the cheapest collateral for loan agreements. M0 thus finds its way into the BGG financial accelerator via acting as the credit agent that eliminates this  $\delta$  and reduces the real cost of credit. See Le et al. (2016) and the appendices therein for the mathematical proof.

where  $\kappa$  measures the strength of financial regulation ( $0 \leq \kappa < 1$ ),  $\zeta$  the response size of regulatory policy to the premium and is set at unity, and  $\eta_t$  the regulatory errors with certain variances  $\sigma_\eta^2$ . Substituting (13) into (12) yields:

$$\hat{p}m_t = \chi(\hat{p}k_t + \hat{k}_t - \hat{n}_t) - \vartheta \hat{m}_t^0 + \kappa \zeta \cdot \hat{p}m_t + \kappa \cdot \hat{\eta}_t + \hat{\epsilon}_t^{pm} \quad (14)$$

We further relate these regulatory errors to the existing noise of premium equation by assuming that:  $\kappa \cdot \eta_t = g(\kappa) \cdot \epsilon_t^{pm}$ , where  $g(k)$  is a function of  $\kappa$  whose shape will be chosen to yield the assumed relationship between regulation and stability. This way the regulatory errors (hidden social costs induced by imposing regulation) are transformed into the extra noise in the premium equation. All together (14) becomes:

$$\hat{p}m_t = \underbrace{\left( \frac{1}{1 - \kappa \zeta} \right) \left[ \chi(\hat{p}k_t + \hat{k}_t - \hat{n}_t) - \vartheta \hat{m}_t^0 \right]}_{\text{direct effects}} + \underbrace{\left( \frac{1}{1 - \kappa \zeta} \right) [g(\kappa) + 1] \cdot \hat{\epsilon}_t^{pm}}_{\text{indirect effects}} \quad (15)$$

Eq. (15) decomposes the total effects of regulation on the credit market into two parts. The first part captures the direct (indented) effect that regulation has on the premium, while the second part captures the side-effect on the financial environment. We assume that changes in regulation that do not directly affect the premium size would cause extra noise and instability in the financial market. Noise here can be associated with: i) social costs due to red tape e.g. having multiple committees approve the decision, obtaining licenses, and filling out paperwork which not only slow decision-making but create costs and even possibly corruption; ii) political backlash from borrowers in response to overly stringent regulatory measures. For example, too high a loan-to-value (LTV) ratio can make taking out mortgage loans extremely expensive; the resulting onerous loan burden on borrowers can become politically intolerable, which risks undermining social stability.

We assume that macroprudential authorities can scale up regulation by raising  $\kappa$  from 0 to 1. This increases the size of the premium via  $\frac{1}{1 - \kappa \zeta}$  but also that of noise via  $\left( \frac{1}{1 - \kappa \zeta} \right) [g(\kappa) + 1]$ . The functional form we have chosen for  $g(\kappa)$  must satisfy that: i)  $g(0) = 0$  - when regulation is at the minimum ( $\kappa = 0$ ), there is no extra noise induced by regulation; ii) the  $g$  function should be able to generate the presumed Laffer curve effect from regulation to stability. Through simulation experimenting, we have chosen  $g(\kappa)$  to be  $\kappa^2 + 10\kappa$ . Results are obtained through 1000 simulations.

Table 1 shows that, at the minimum level of regulation ( $\kappa = 0$ ), the premium and its error variances remain at their original levels. Once regulation deviates from this minimum, both the premium and the ambient noise get scaled up. For instance, raising  $\kappa$  from 0 to 0.2 amplifies the premium 1.25 times, the error variances 3.8 times. Overall, the stabilizing effort of  $\frac{1}{1 - \kappa \zeta}$  outweighs the destabilizing effect of  $\left( \frac{1}{1 - \kappa \zeta} \right) [g(\kappa) + 1]$ , improving the stability to 0.9421 - the maximum level achieved in our simulations. However, more regulation beyond this level ( $\kappa > 0.2$ ) does not bring more stability. As we keep strengthening the regulation, stability deteriorates progressively as the exponential blow-up of the noise dominates the stabilizing effect from

tighter credit.

With this experiment in mind, it can be seen that this DSGE model for the UK can generate the quadratic policy constraint that is included in the Institutional Model. As Fig. 7 indicates, stability increases with a peak at  $\kappa = 0.2$ . More stringent regulation entails more costs than benefits and destabilizes the economy. Note that  $\kappa$  (regulatory intensity) of the DSGE model corresponds to  $P$  (regulatory power) of the Institutional Model.

#### 4.2.2. Generating the simulated data

To generate the simulated data, we start by bootstrapping the DSGE model for each subsample to find the distribution of  $S_{sim}$ . The underlying DSGE model was already tested for its fit to the UK data. The log-linearized model list and the coefficient values are reported in the Appendices. Now we need to create a corresponding version for each subsample. As with most DSGE models with a banking sector and financial frictions, we assume that monetary policy works via the nominal interest rate channel  $r_t$ , and macroprudential policy via the risk premium channel  $pm_t$ . It is through adjusting these equations that we model the shifts in policy regime across subsamples.

The number of BoE employees has gradually declined to 2833 in 1999, so we assign  $\kappa = 0.2$  for Subsample 1, indicating some moderate banking regulation. The number hit the bottom at 1789 in 2007 just before the crisis and we thus rate Subsample 2 as having very light regulation ( $\kappa = 0$ ); it was also the period with most risky projects undertaken by financial institutions in the background of a benign macroeconomic prospect. Subsample 3 has seen a sharp increase in BoE's staff number; we see this as a signal of the drastically tightened regulation and assign  $\kappa = 0.4$  for it.

For the modeling of monetary policy, we stick to the standard Taylor rule for the period 93-99 where the BoE responded appropriately to developments in output and inflation. For the early 2000s, we halve the Taylor rule responses for output ( $r_y$ ) and for inflation ( $r_p$ ) to accommodate the fact that the BoE did not react as much as it should to curb the excessive lending that fuelled asset-price bubbles; we discuss the evidence for this in the second paragraph of Section 4.1 - especially Bean et al. (2010) who suggest that the policy followed was about twice as loose as the rule suggested, creating a housing and stockmarket boom; see also Taylor (2016) that mentions "Here I want to refer to some work that the former Deputy Governor of the Bank of England, Charles Bean, performed back in 2010. He found that the interest rate at the Bank of England was also too low in the years before the crisis, or below the level suggested by policy rules. He also found, and, to be sure, it is just one study and just an example, that 46 percent of the housing boom price bubble observed in the UK was due to this policy" (p. 16). It is those prolonged periods of low rates that induced fragility in the financial system. For the post-2008 era, we supplement the standard Taylor rule with a powerful QE rule. The idea is that besides adhering to the standard rule coefficients, the BoE was doing extra stabilizing action via the QE response. The way we model the monetary policy with the DSGE model is consistent with how we assign  $M$  for the actual data.

### 4.3. Indirect Inference estimation

To compare the actual data with the model-generated simulated data, we proceed as follows. First, we obtain 1000 sets of simulated  $S(S_{sim})$  in each of the 3 episodes by bootstrapping the innovations 1000 times. This generates for each subsample the distribution of  $S_{sim}$  because we want to “animate” the Institutional Model as realistically as possible with sufficient exogenous noise.

The histogram (left panel) in Fig. 8 shows that the Subsample 3 experiences the most volatility in output with most simulations out of 1000 falling into the low stability bins (left side of the horizontal axis). The scatter plot (right panel) presents the same results in a different way, showing that compared with Subsamples 1 and 2, more simulations from Subsample 3 (green dots) end up in the bottom (low stability range). From combining these  $S_{sim}$  randomly we create 1000 pseudo histories for 3 episodes that could have occurred. The Institutional Model’s reliance on the DSGE model is limited to finding the distribution of  $S_{sim}$ .

Then, we inject 1000  $S_{sim}$  into the parameterized Institutional Model to derive the corresponding 1000 sets of  $M_{sim}$  and  $P_{sim}$  according to the solutions:  $M_{sim} = \left(\frac{\mu b}{v}\right)^{\frac{1}{v-1}} S_{sim}^{-\left(\frac{1-\mu}{v-1}\right)}$ ,  $P_{sim} = \frac{c}{d} + \frac{\varpi}{\varepsilon d} S_{sim}^{-(\varepsilon-1)}$ , and also the implied  $\sigma_E^2$  which is not directly observable but implied by the constraint (1). The general environmental volatility  $\sigma_E^2$  is produced by different shocks in the underlying macroeconomic model which cannot be directly aggregated into a single measure of volatility. We have up to this point accumulated 1000 sets of three  $S_{sim}$ ,  $M_{sim}$ ,  $P_{sim}$  and  $\sigma_E^2$ , one for each episode. This in turn generates 1000 sets of  $corr(S_{sim}, M_{sim})$ ,  $corr(S_{sim}, P_{sim})$  and  $corr(M_{sim}, P_{sim})$ .

Finally, we compute from these correlations their joint distribution, which is to be compared with the moments we constructed from the actual data. From calculating where in the distribution of the simulated correlations the actual data correlations lie we can obtain the Wald-percentile which is further transformed into the p-value. A p-value greater than 0.05 suggests that the Institutional Model could be the data-generating one. For any p-value equal to or smaller than 0.05, we carry out the simulated annealing algorithm across the calibrated parameter space and keep substituting different sets of parameters into the model until we find the one that maximizes the p-value ( $p > 0.05$ ). The greater this p-value, the better the model fits the data. Table 2 reports the coefficient set that delivers a p-value of 0.741 ( $> 0.05$ ), which indicates the model easily passes the test. Note that parameters  $a$  (constant in the policy constraint) and  $l$  (the government’s preference for power) do not enter the solutions for  $M$  or  $P$ , and hence cannot be identified from our estimation. From Table 3 we find just as expected, the actual correlations lie within the lower and upper 25th percentiles of the simulated correlations.

Fig. 9 plots the simulated distribution of  $M$  and  $P$  across subsamples conditional on the model estimates. We see that Subsample 3 observes the highest frequency of large  $M$  and  $P$  (strong efforts in monetary and regulatory stabilizing), which is followed by Subsamples 1 and 2. This suggests the estimated model is capable of accommodating the fact that monetary and regulative stances were moderate in the late 1990s, relaxed before the crisis, and aggressive since 2008. Fig. 10 plots five correlations from randomly combining

simulated data points across subsamples. We see that  $S$  is negatively correlated with both  $M$  and  $P$ , while  $M$  and  $P$  move together across subsamples; this is consistent with the evidence from the actual data in Fig. 6.

#### 4.4. Robustness checks

##### 4.4.1. How powerful is our test?

The first robustness check is concerned with the power of our estimation. To this end, we perform a Monte Carlo experiment to examine the test power. To begin with, we take the estimated model as the true one and create a series of false models by altering each estimated parameter by  $+ \text{ or } - x\%$  randomly. Note that  $x$  is set to comply with the bound restrictions we put on parameters, such that the model is always correctly identified.

Table 4 summarizes how raising the degree of falseness (top row) leads to the increasing frequency of rejection (bottom row). The rejection rate rises slowly until the falseness reaches 65% which gives us a 29.7% rejection, then it jumps to 57.7% with 68% falseness. When the falsified model is seriously misspecified and gets really close to the parameter bounds (e.g. 70%), we see a 99.9% rejection. Our Monte Carlo evaluation of the power of our test of the Institutional Model here reveals that it is less than on the DSGE models examined in prior studies (e.g. Le et al. 2016; Minford and Meenagh 2019) that reject the falsified parameters when 10% or less are deviated from the correct setting. This lower power is forced on us unfortunately by the limited data we have for use in the test - just three moments. We feel there is still sufficient power to provide reasonable information on the truth of the model; what it means is that the range of quantitative uncertainty around the model parameters is quite large - roughly speaking they could possibly be out by 70%. Nevertheless, this does not diminish the main policy insight provided by the model - namely that the central bank will over-regulate because this applies even if the model is this far wrong, as the central bank still would be operating on the wrong side of the regulation Laffer Curve.

Another check is concerned with the private interest assumption upon which the model is built, as we want to find out if a model wherein the central bank does not enjoy power would be rejected at all times as we would hope given that it is entirely mis-specified according to our proposed model. In doing so, we set the parameter  $\varpi$  - which governs the central bank's preference for regulatory power to negative values. So, the central bank would dislike  $P$  and aim to reduce the size of bureaucracy wherever possible; its choice of power will not proceed over the maximum point of the Laffer curve but stay on the *left* side. Our test results show that regardless of the absolute size of this negative  $\varpi$ , we end up with a 99.9% rejection rate. This gives us reasonable confidence that our private interest assumption can be validated from the data, since were this key public choice mis-specification to be correct, our model would have been definitely rejected; as our model has passed the test, we know this cannot be so.



#### 4.4.2. Does the estimated model fit into related theories?

Fig. 11 depicts the optimal choices made by the government and the central bank conditional on the model estimates.<sup>7</sup> We see that the choices (utility-maximizing points given policy constraints) of the government always lie on the *left* side of the Laffer curve, while those of the central bank always end up on the *right* side. The quadratic form of the policy constraint, along with information asymmetry, enables the central bank to pursue more power than necessary besides delivering the required stability. Raising  $M$  by selecting a more stabilizing monetary regime shifts the Laffer curve upwards, which in effect limits the central bank's use of power.

Finally, the last check is concerned with the effect of environmental volatility  $\sigma_E^2$  on  $S$ ,  $M$  and  $P$ . As shown in Fig. 12,  $S$  decreases with  $\sigma_E^2$  and drops to zero when the latter rises above 18; this is straightforward as general volatility contributes to stability negatively on top of monetary and regulatory stances. Turning to its effect on  $M$ , we see that raising  $\sigma_E^2$  causes a steady and slow rise in  $M$ . The idea is that, on the one hand, a greater  $M$  adds to  $S$  as suggested by the policy constraint - this is desired by the government. On the other hand, this greater  $M$  also generates more administrative costs and thus disutility from the government's utility function. Overall, the government weighs up costs and benefits and it is clear that the gains from stability outweigh the costs. As a result, government selects progressively more stabilizing monetary regimes in reaction to higher environmental volatility. The response of  $P$  to  $\sigma_E^2$  remains positive but quite muted before  $\sigma_E^2$  reaches about 10, then it increases much more sharply while  $S$  approaches 0; this is because for the central bank, the gains from raising  $P$  (power grab) will no longer be offset by the loss in utility from smaller  $S$  (instability due to excessive regulation), as  $S$  cannot fall below zero. At this point, we have verified from our estimated model that:  $dS/d\sigma_E^2 < 0$ ,  $dM/d\sigma_E^2 > 0$  and  $dP/d\sigma_E^2 > 0$ . Given the limitations in our model - its estimation involves only the correlation between three variables and with three data points, it is only when the estimated model survives a series of robustness checks that we can be confident about its policy implications.

### 5. Reformed monetary regimes: a way out of this impasse?

So far, we have built and estimated an Institutional Model for the UK wherein macroprudential regulation has brought more pain than gain in the post-crisis era. Now we move on to explore if there are better alternatives to burdening the economy with cumbersome regulation. Recall that besides macroprudential policy, monetary policy in the form of Taylor-type feedback rules has been employed commonly in advanced economies for output stabilization. Admittedly, the painful experience from the recent crisis reveals the inability of the standard Taylor rule (i.e. adjusting the nominal interest rate in reaction to inflation and output only) to prevent financial turmoil. This came about because the rule does not respond much to the credit

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<sup>7</sup>Parameter  $l$  (the government's preference for power) is calibrated at 0.4; parameter  $a$  (constant in the policy constraint) is calibrated at 0.5. The other parameters are set as in estimation.

condition. Permitted by the inflation targeting regime, credit growth in the UK was strongly elevated in the periods leading up to the crisis.

Previously in our subsample simulations, an occasionally binding ZLB constraint divides the DSGE model into two states - a normal (non-ZLB) state where the BoE sets  $r_t$  according to the unconstrained Taylor rule as in SW(07), and a crisis (ZLB) state where it deploys QE as  $r_t$  solves below the threshold (0.025% quarterly) and gets fixed at the ZLB. These are summarized in equation sets (16a) and (16b) which we refer to jointly as the baseline regime (BR):

$$\text{BR} = \begin{cases} \text{For } r_t > 0.025 \\ \text{(Normal state)} \end{cases} \begin{cases} \hat{r}_t = \rho \hat{r}_{t-1} + (1 - \rho)(r_p \hat{\pi}_t + r_y \hat{y}_t) + r_{\Delta y}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\epsilon}_t^r \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{m_2}^{(normal)} (\hat{m}_t^2 - \hat{m}_{t-1}^2) + \hat{\epsilon}_t^{m_0} \\ \hat{m}_t^2 = (1 - \frac{M0}{M2} + \frac{N}{M2}) \hat{k}_t + \frac{M0}{M2} \hat{m}_t^0 - \frac{N}{M2} \hat{n}_t \end{cases} \quad (16a)$$

$$\begin{cases} \text{For } r_t \leq 0.025 \\ \text{(Crisis state)} \end{cases} \begin{cases} \hat{r}_t = 0.025 \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{pm}^{(crisis)} (\hat{pm}_t - pm^*) + \hat{\epsilon}_t^{m_0} \end{cases} \quad (16b)$$

where  $\rho$  measures the degree of interest rate smoothing.  $r_p$ ,  $r_y$ , and  $r_{\Delta y}$  denote Taylor rule's responses to inflation, output, and changes in output, respectively.  $M0/M2$  and  $N/M2$  are steady-state ratios.  $pm^*$  is the steady state value of the risk premium.  $r_t$ ,  $\pi_t$ ,  $y_t$ ,  $m_t^0$ ,  $m_t^2$ ,  $k_t$ ,  $n_t$ , and  $pm_t$  are nominal interest rate (deposit rate), inflation, output, monetary base supply, broad money supply, capital, net worth, and risk premium, respectively. This setup is intended to capture the facts before and after the GFC. In the pre-crisis boom (16a), the financial system was believed to be self-correcting, and monetary policy had focused on stabilizing inflation; the supply of  $m_0$  was set to accommodate that of  $m_2$  determined by entrepreneurs' balance sheets.<sup>8</sup> During the crisis (16b), as the binding ZLB made the conventional rate cuts unavailable, the government resorted to unconventional monetary policy of QE. As in Gertler and Gilchrist (2018), we describe a crisis state as a situation where the risk premium (credit spread) rises (widens) drastically. The feedback rule from  $pm_t$  to  $m_0$  captures the monetary authorities' effort to stabilize credit supply at the ZLB by targeting  $pm_t$  around its steady state  $pm^*$  using gilt purchases.

### 5.1. Premium-augmented regime ( $AR_{pm}$ )

One lesson we draw from the crisis is that the monetary authorities have a duty to intervene in the credit market not only when the economy is struggling, but also when it is booming. Ideally, monetary policy is supposed to prevent the build-up of financial imbalances and pre-empt the next crisis. This opens the discussion on whether reacting to credit conditions in normal times (non-ZLB situations) could help tame the credit cycle. To this end, we specify three alternative monetary regimes. First, we follow the previous

<sup>8</sup>  $m_2 = m_0 + \text{household deposits} = m_0 + \text{loans to entrepreneurs} = m_0 + \text{externally financed part of capital purchase } (k_t - n_t)$ .

attempts (e.g. Taylor et al. 2008 and Curdia and Woodford 2010) in considering a premium-augmented regime ( $AR_{pm}$ ) which incorporates into the Taylor rule (normal state) of the BR a response to the premium variable  $pm_t$ :<sup>9</sup>

$$AR_{pm} = \begin{cases} \text{For } r_t > 0.025 \\ \text{(Normal state)} \end{cases} \begin{cases} \hat{r}_t = \rho \hat{r}_{t-1} + (1 - \rho)(r_p \hat{\pi}_t + r_y \hat{y}_t - r_{pm} \hat{pm}_t) + r_{\Delta y}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\epsilon}_t^r \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{m_2}^{(normal)} (\hat{m}_t^2 - \hat{m}_{t-1}^2) + \hat{\epsilon}_t^{m_0} \\ \hat{m}_t^2 = (1 - \frac{M_0}{M_2} + \frac{N}{M_2}) \hat{k}_t + \frac{M_0}{M_2} \hat{m}_t^0 - \frac{N}{M_2} \hat{n}_t \end{cases} \quad (17a)$$

$$\begin{cases} \text{For } r_t \leq 0.025 \\ \text{(Crisis state)} \end{cases} \begin{cases} \hat{r}_t = 0.025 \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{pm}^{(crisis)} (\hat{pm}_t - pm^*) + \hat{\epsilon}_t^{m_0} \end{cases} \quad (17b)$$

where  $0 < r_{pm} < 1$  is the parameter governing the strength of spread adjustment. The negative sign before  $r_{pm}$  implies that the policy rate should be lowered (raised) relative to what the baseline rule would prescribe when the risk premium is higher (lower) than normal. For instance, in an environment of a widening lending-deposit spread that suggests the growing unease in the credit market,  $r_t$  would be reduced (compared to the level implied by the baseline rule) to counteract the dampening effect on economic activities due to tighter credit. Allowing a response in the Taylor rule to the variation in the financial market ensures that the credit supply is monitored and regulated in the normal state (non-ZLB situation). We argue that this complements the conduct of monetary policy in the booms and helps prevent financial excesses before they lead to crises. The specification for the crisis state under the  $AR_{pm}$  remains unchanged as for the BR.

Fig. 13 shows IRFs to a risk premium shock in normal states under the BR (blue solid) and  $AR_{pm}$  (red dashed). It is clear that the dampening effects arising from tighter credit due to financial disturbances (approximated by a positive premium shock) on output, consumption, labor and inflation are partially offset under the  $AR_{pm}$ . On the other hand, the responses of the risk premium, real lending rate and investment are unaffected.

## 5.2. Premium shock-augmented regime ( $AR_{epm}$ )

Gilchrist and Zakrajšek (2012) show that due to the endogenous response of asset prices in the financial accelerator mechanism, a positive financial (premium) shock can lead to a rise in the premium variable that exceeds the size of the shock itself. This raises the question of whether responding directly to the exogenous component of the premium - the underlying disruption in the credit intermediation process - could lead to a superior stabilizing outcome. So we consider the following premium shock-augmented regime ( $AR_{epm}$ ) which replaces the premium variable  $pm_t$  of  $AR_{pm}$  with the premium shock  $\epsilon_t^{pm}$  for the normal state:

<sup>9</sup>Taylor et al. (2008) propose a modified rule that allows the interest rate to respond to the LIBOR-OIS spread. Curdia and Woodford (2010) examine both spread-adjusted and credit volume-adjusted rules and show that either type of adjustment, if of a suitable magnitude, can damp the negative impact of financial disturbances, although the volume-adjusted rule is less beneficial for welfare gains and less robust to alternative assumptions.

$$AR_{\epsilon pm} = \begin{cases} \text{For } r_t > 0.025 \\ \text{(Normal state)} \end{cases} \begin{cases} \hat{r}_t = \rho \hat{r}_{t-1} + (1 - \rho)(r_p \hat{\pi}_t + r_y \hat{y}_t - r_{\epsilon pm} \hat{\epsilon}_t^{pm}) + r_{\Delta y}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\epsilon}_t^r \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{m_2}^{(normal)} (\hat{m}_t^2 - \hat{m}_{t-1}^2) + \hat{\epsilon}_t^{m_0} \\ \hat{m}_t^2 = (1 - \frac{M_0}{M_2} + \frac{N}{M_2}) \hat{k}_t + \frac{M_0}{M_2} \hat{m}_t^0 - \frac{N}{M_2} \hat{n}_t \end{cases} \quad (18a)$$

$$\begin{cases} \text{For } r_t \leq 0.025 \\ \text{(Crisis state)} \end{cases} \begin{cases} \hat{r}_t = 0.025 \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{pm}^{(crisis)} (p \hat{m}_t - pm^*) + \hat{\epsilon}_t^{m_0} \end{cases} \quad (18b)$$

The specification for the crisis state of the  $AR_{\epsilon pm}$  is the same as for the BR and  $AR_{pm}$ . Fig. 14 shows IRFs to a risk premium shock in normal states under the BR (blue solid) and the  $AR_{\epsilon pm}$  (red dotted). The responses under the  $AR_{\epsilon pm}$  are not dissimilar to those under the  $AR_{pm}$  - both stabilize consumption, inflation and output but not investment.

### 5.3. Dual rule regime (DRR)

On the other hand, some argue that relying merely on a single instrument to achieve both price and financial stability would violate the Tinbergen rule. This rule of thumb applies here because under the  $AR_{pm}$  and  $AR_{\epsilon pm}$ , the credit conditions-augmented Taylor rules (R rule) are made to react to developments in both inflation and risk premium. As noted by Badarau and Popescu (2014) and Carrillo et al. (2017), trade-offs might appear if one instrument is employed for multiple goals, as the achievement of one target might precludes the achievement of the other. The successful conduct of monetary and financial policies thus requires each to have its own instrument, for example, using a separate rule to tackle financial instability, while keeping the Taylor rule focused on price stability. Therefore we specify a dual rule regime (DRR) by complementing the normal state of the BR with a powerful M0 rule similar to the one at the ZLB:

$$DRR = \begin{cases} \text{For } r_t > 0.025 \\ \text{(Normal state)} \end{cases} \begin{cases} \hat{r}_t = \rho \hat{r}_{t-1} + (1 - \rho)(r_p \hat{\pi}_t + r_y \hat{y}_t) + r_{\Delta y}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\epsilon}_t^r \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{pm}^{(normal)} (p \hat{m}_t - pm^*) \end{cases} \quad (19a)$$

$$\begin{cases} \text{For } r_t \leq 0.025 \\ \text{(Crisis state)} \end{cases} \begin{cases} \hat{r}_t = 0.025 \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{pm}^{(crisis)} (p \hat{m}_t - pm^*) + \hat{\epsilon}_t^{m_0} \end{cases} \quad (19b)$$

In effect, there are two instruments (rules) under the DRR operating in the normal times with each pursuing its own objective - the standard Taylor rule targets price stability while M0 rule pursues financial stability. By extending credit intervention to the non-ZLB situation, using bond purchases to stabilize the credit market is activated at all times to stabilize the risk premium and so loan provision. Previous works in this direction include: Ellison and Tischbirek (2014), who embed a stylized financial sector and central bank asset purchase in a New-Keynesian DSGE model and find that bond purchases should be kept in

place even after the interest rates normalize; Quint and Rabanal (2017), who use an estimated non-linear DSGE model to show that asset purchases of government and corporate bonds should be used in conjunction with conventional monetary policy, whatever the state of the economy and not just in crises when the ZLB binds. QE is dubbed “unconventional” as it is only resorted to when the conventional interest rate policy becomes unavailable. Through evaluating the DRR’s stabilizing property, we aim to shed light on whether the unconventional monetary policy should become conventional.

Fig. 15 compares the IRFs in normal states under the BR (blue solid) and the DRR (red dash-dotted). We can see that the counteractive M0 rule stabilizes not only output but the risk premium and investment. The cushioning effect under the DRR also appears to be long lasting; there is increasing differentiation in the variable responses over a 7-year horizon (30 quarters).

#### 5.4. Comparison across monetary regimes

To find a clear ranking of monetary regimes in terms of output stabilization, we conduct 1000 simulations for each of them with increasing regulatory intensity. The coefficients for the alternative monetary regimes are obtained through the grid search.<sup>10</sup> We assume monetary authorities can act optimally in the sense that they choose policy elasticities that maximize output stability (measured as the inverse of HP-filtered output variance). Simulation results are summarized in Table 5 and plotted in Fig. 16.

From the right panel figure, we find that there is a Laffer curve effect from  $\kappa$  to  $S$  for all regimes. When there is moderate regulation, say  $\kappa = 0.2$ , stability improves compared to the minimum regulation case ( $\kappa = 0$ ). Nonetheless, raising  $\kappa$  beyond this optimal level delivers more volatility (instability). The DRR that employs a separate M0 rule to stabilize the risk premium (credit supply) in both states achieves the most stability under any regulatory strengths. It is followed by the  $AR_{pm}$  and then the  $AR_{\epsilon pm}$  which also improve stability relative to the BR, but by smaller margins. All but one regime (DRR), fail to converge with extreme regulation ( $\kappa = 0.8$ ). However, before that, all regimes are destabilized already for  $\kappa \geq 0.4$ . Some moderate regulation ( $\kappa = 0.2$ ) does contribute to stability for poorly stabilizing monetary regimes such as the BR, but for highly stabilizing ones like the DRR, regulation adds little to no stability. In general, the more stabilizing the monetary regime, the less space left for stability improvement via regulation, the more difficult it is for regulators to exploit the situation and justify a huge budget. Note that virtually the same stability is obtained under the BR when  $\kappa = 0.2$  and the  $AR_{pm}$  when  $\kappa = 0$ . What this suggests is that stability crucially depends on the choice of the monetary regime. Raising  $M$  by adopting a more stabilizing monetary regime shifts the Laffer curve upwards systematically. While the UK government has little if any

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<sup>10</sup>For the  $AR_{pm}$  ( $AR_{\epsilon pm}$ ), we perform a three-dimensional grid search over  $r_p$ ,  $r_y$  and  $r_{pm}$  ( $r_{\epsilon pm}$ ), and keep the remaining parameters fixed on the basis of mathematical restrictions. The search involves creating a grid for all the parameters to be varied and evaluating the welfare costs for each possible combination. The search algorithm randomly goes through points (combinations) that may or may not improve our objectives. For the DRR, we search  $\theta_{pm}^{(normal)}$  within the chosen space. The parameter values are summarized in Appendix A.

power over the regulatory procedures used by the BoE as the delegated authority, the government can and should still use the power it undoubtedly has to set the monetary policy regime that the BoE must implement. Hence, the best way for the government to mitigate instability (e.g., frequency, length, and severity of crises) is to select a good monetary regime that systematically enhances the system's resilience to adverse financial shocks. This should be preferable to distorting the economy with regulation which proves not only inefficient but can even undermine stability if posed at levels more than necessary.

Finally, it is worth noting that although both the reformed monetary regimes and financial regulation are modeled here via the risk premium channel, their working mechanisms are notably different. The reformed regimes stabilize the risk premium through some integral control mechanisms, i.e. they all react to some certain measures of financial distress (e.g.  $pm_t$  or  $\epsilon_t^{pm}$ ) and adjust  $m_0$  or  $r_t$  to bring the current state closer to the target; this stands in contrast to the way regulation distorts the economy by artificially blowing up the premium and its associated error variances.

## 6. Conclusion

This study examines the re-emergence of an emboldened concept of macroprudential regulation since 2008 and takes issue with it on several fronts. First, departing from the idealized perspective that regulators have the public interest in mind when designing regulatory rules, we argue that it is their private interests that prevail in the regulatory process; as non-elected technocrats, regulators act in their own interests and pursue maximum regulatory power. Second, regulation is assumed to only promote stability up to a certain point, beyond which it undermines stability as the distortions it creates outweigh the stabilizing effect of tighter credit. Finally, at the current juncture, analyses of the effectiveness of macroprudential instruments and how they interface with monetary policy tools are still rather limited.

We resort to an estimated DSGE model for the UK and build on top of it an Institutional Model whereby we study task allocation between the government and the central bank with two policy tasks. The government officials (politicians) face re-election and choose monetary policy first. Next, they delegate the management of macroprudential policy to self-interested central bankers (technocrats) who utilize the hump-shaped policy constraint and deliver the required stability on the wrong side of the Laffer curve. The resulting abuse of power and redundant regulatory rules lead to systematic deviations from optimality. Using indirect inference testing and estimation, we find a set of coefficients that can generate the observed moments for the UK economy over 1993-2016. Simulations for different monetary regimes under varying regulatory intensity show that in the presence of a well-conducted monetary policy, macroprudential regulation at best contributes little, at worst destabilizes the economy. More importantly, we show that by committing to an extra stabilizing monetary regime which supplements the standard Taylor rule with an additional QE rule to keep the credit condition in check in both states, the monetary authorities can stabilize the economy without resorting to excessive regulation.

We attribute the post-crisis sluggish recovery partially to the faulty institutional arrangement and its associated intrusive regulation that prevented the necessary credit growth for recovery. By highlighting the drawbacks intrinsic to the delegation framework, we hope that the findings of our study may offer new insights into bureaucratic delegation and management.

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Table 1: Effect of raising regulation on stability. Cell with “—” indicates non-converging case.

$\kappa$	Raise the premium	Raise the error variances	Stability
value	$\times \frac{1}{1 - \kappa\zeta}$	$\times \left( \frac{1}{1 - \kappa\zeta} \right) (\kappa^2 + 10\kappa + 1)$	$\frac{1}{\text{var}[\text{HP-filtered}(\text{simulated output})]}$
0	1	1	0.6132
0.2	1.25	3.80	0.9421
0.4	1.67	8.60	0.4834
0.6	2.5	18.4	0.1742
0.8	5	48.2	—

Table 2: Estimated coefficients

Coefficients	$\varepsilon$	$\varpi$	$\mu$	$\nu$	$b$	$c$	$d$
Starting calibration	1.5	0.5	0.5	1.5	0.5	0.5	0.5
Estimation	1.5634	8.1662	0.6674	3.1481	5.9214	4.7975	4.6804

Table 3: Correlations in the actual data vs. Correlations in the simulated data

	Corr(S, M)	Corr(S, P)	Corr(M, P)
Actual data correlation	-0.9386	-0.9478	0.9996
Mean simulation	-0.9498	-0.9604	0.9993
Lower 25% percentile	-0.9940	-0.9954	0.9990
Upper 25% percentile	-0.9296	-0.9464	0.9999

Table 4: Power of estimation

Degree of Falseness in %	5	10	20	30	40	50	60	65	68	70
Rejection rate in %	7.5	9.7	14.7	18.1	21.8	24.6	27.4	29.7	57.7	99.9

Table 5: Stability across regimes

$\kappa$	BR	$\text{AR}_{\text{epm}}$	$\text{AR}_{\text{pm}}$	DRR
0	0.6132	0.84545	0.9097	0.9945
0.2	0.9421	0.8961	1.0018	1.0371
0.4	0.4834	0.5728	0.5634	0.6771
0.6	0.1742	0.2760	0.4478	0.4412
0.8	—	—	—	0.0311

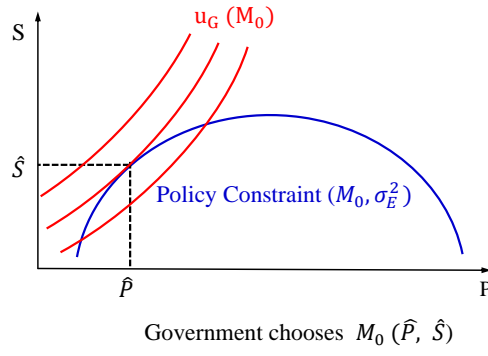


Figure 1: Choice of the government

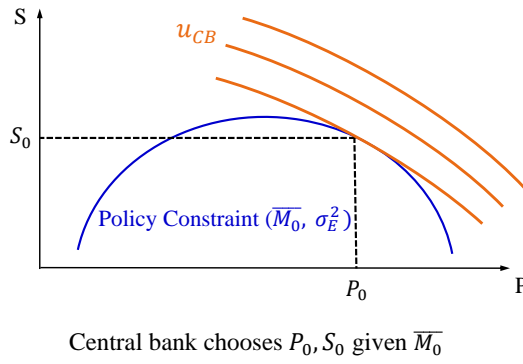


Figure 2: Choice of the central bank

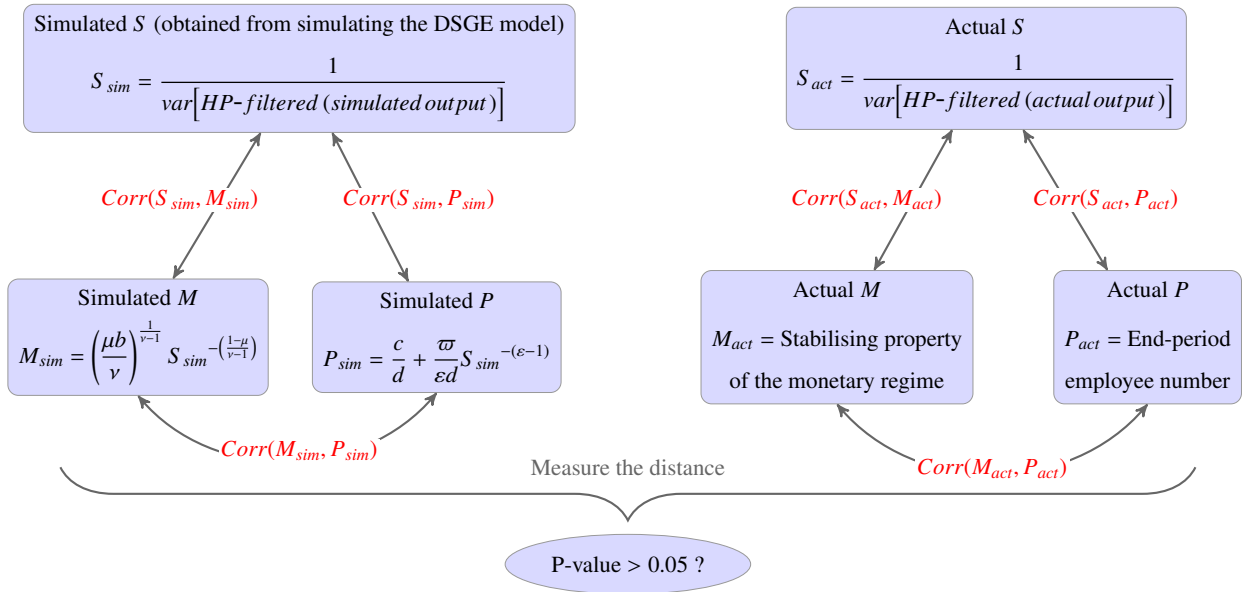


Figure 3: Construction of the simulated and actual data for indirect inference testing and estimation

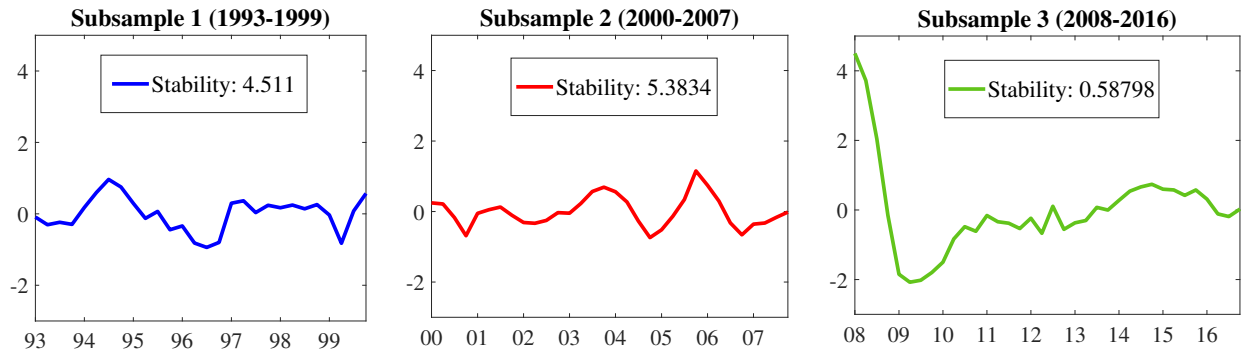


Figure 4: Output stability in subsamples

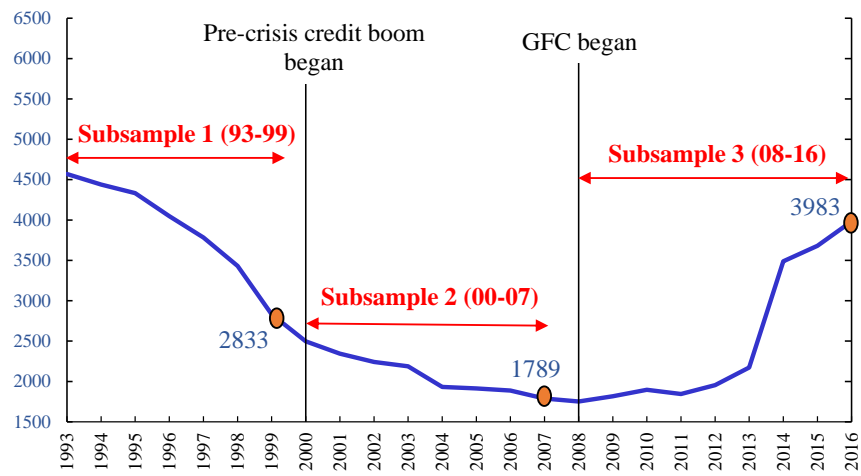


Figure 5: Bank of England employee numbers excluding printing staff (BoE annual reports)

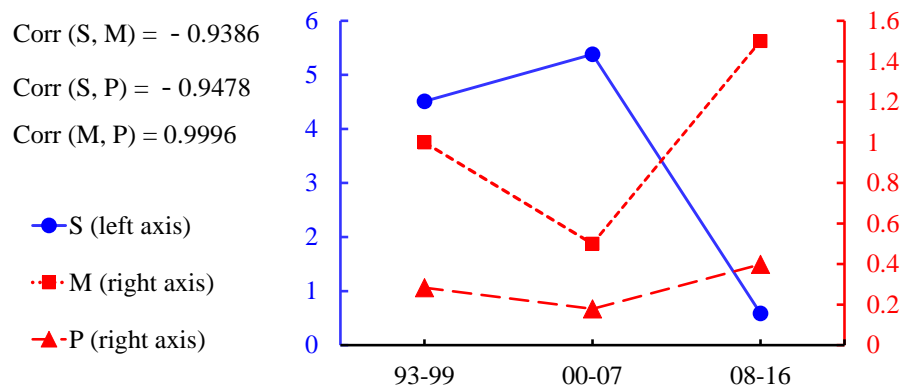


Figure 6: Subsample correlations in the actual data

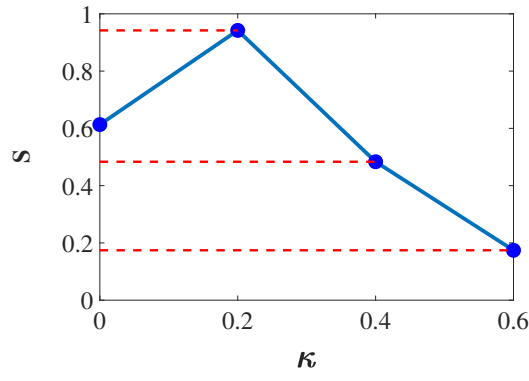


Figure 7: Laffer curve effect

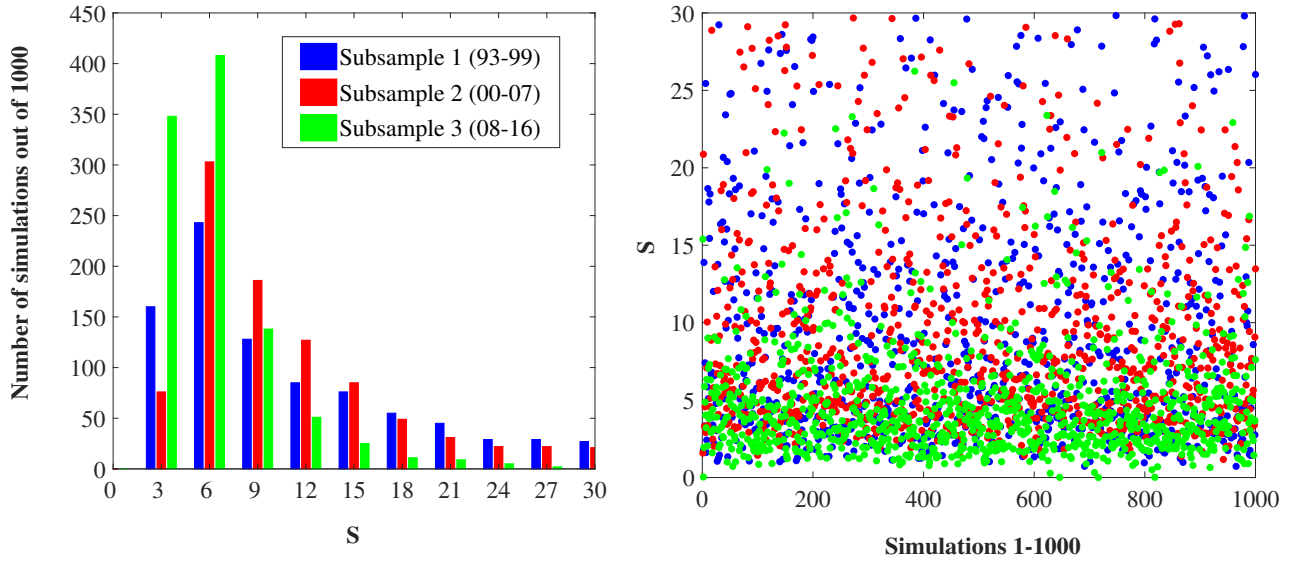


Figure 8: Distribution of  $S$  from subsample simulations

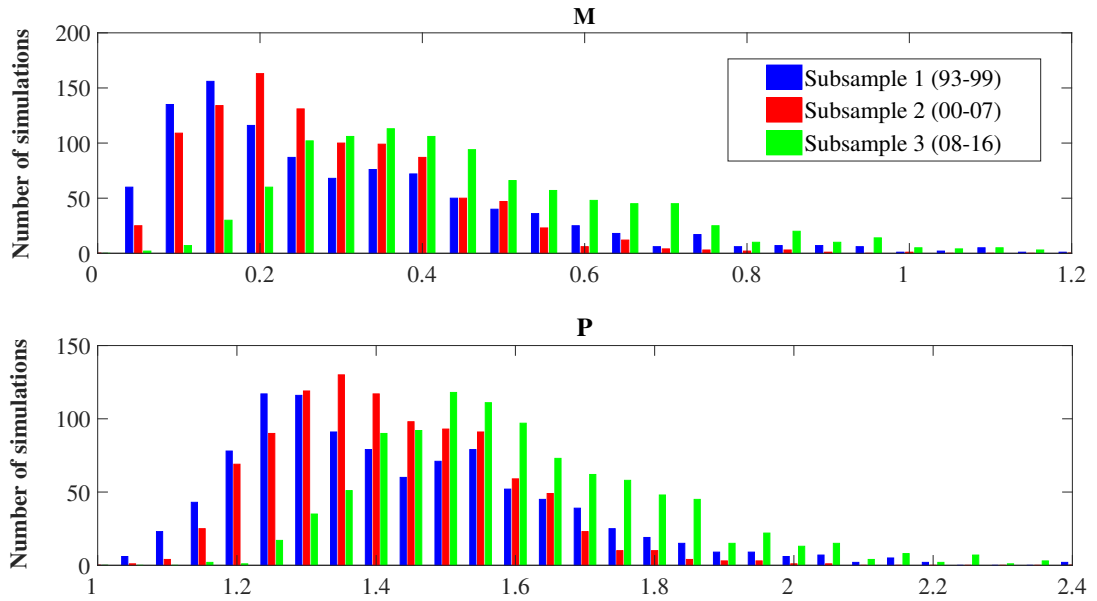


Figure 9: Distribution of  $M$  and  $P$  conditional on the estimated model

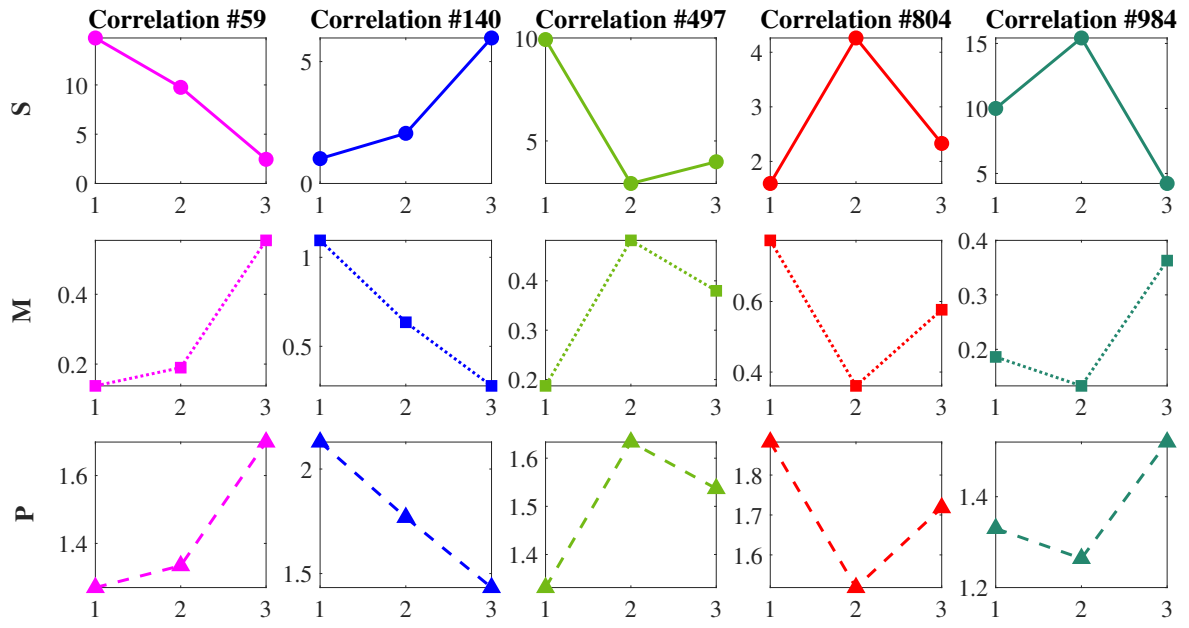


Figure 10: Examples of simulated correlations across subsamples conditional on the estimated model. Numbers on the horizontal axes represent subsample periods.

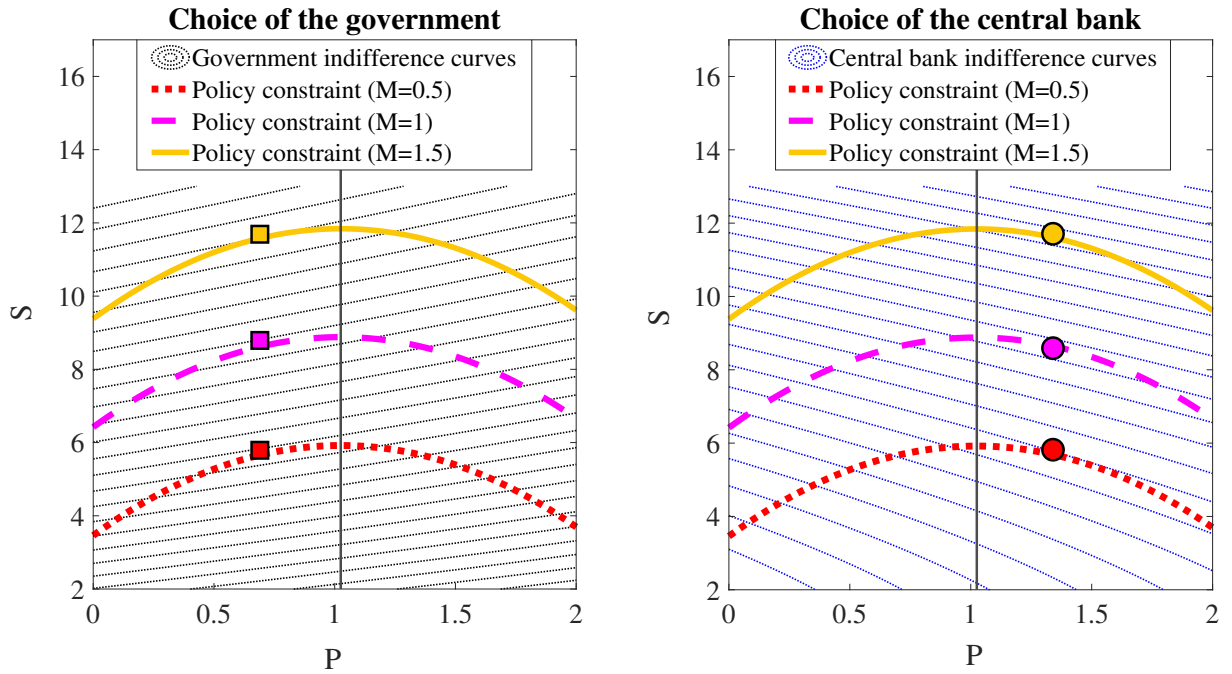


Figure 11: Choices of the government and the central bank

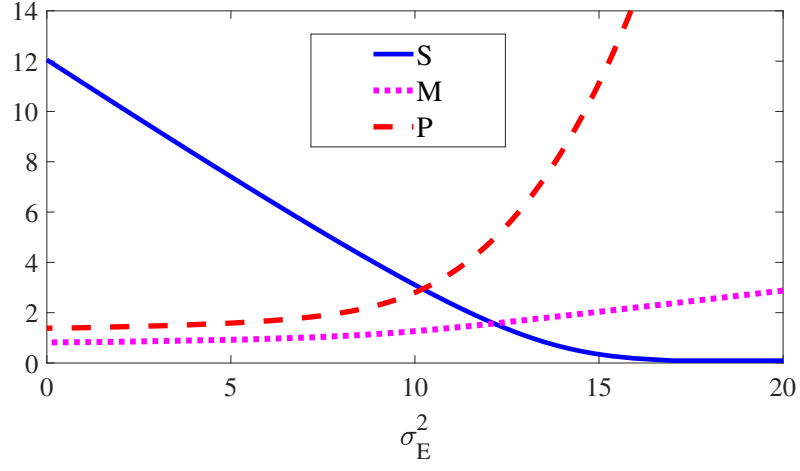


Figure 12: Responses of  $S$ ,  $M$  and  $P$  to environmental volatility  $\sigma_E^2$

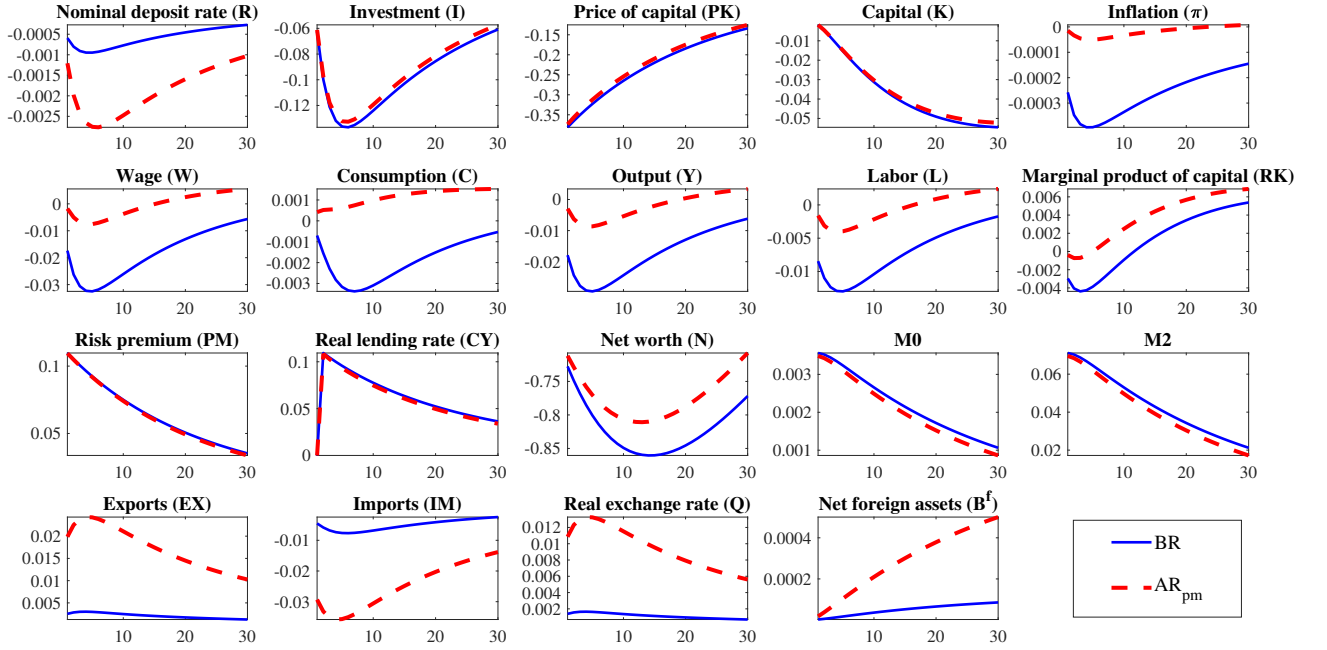


Figure 13: Baseline regime (BR) vs. Premium-augmented regime ( $AR_{pm}$ ) in response to a premium shock  $\epsilon_t^{pm}$

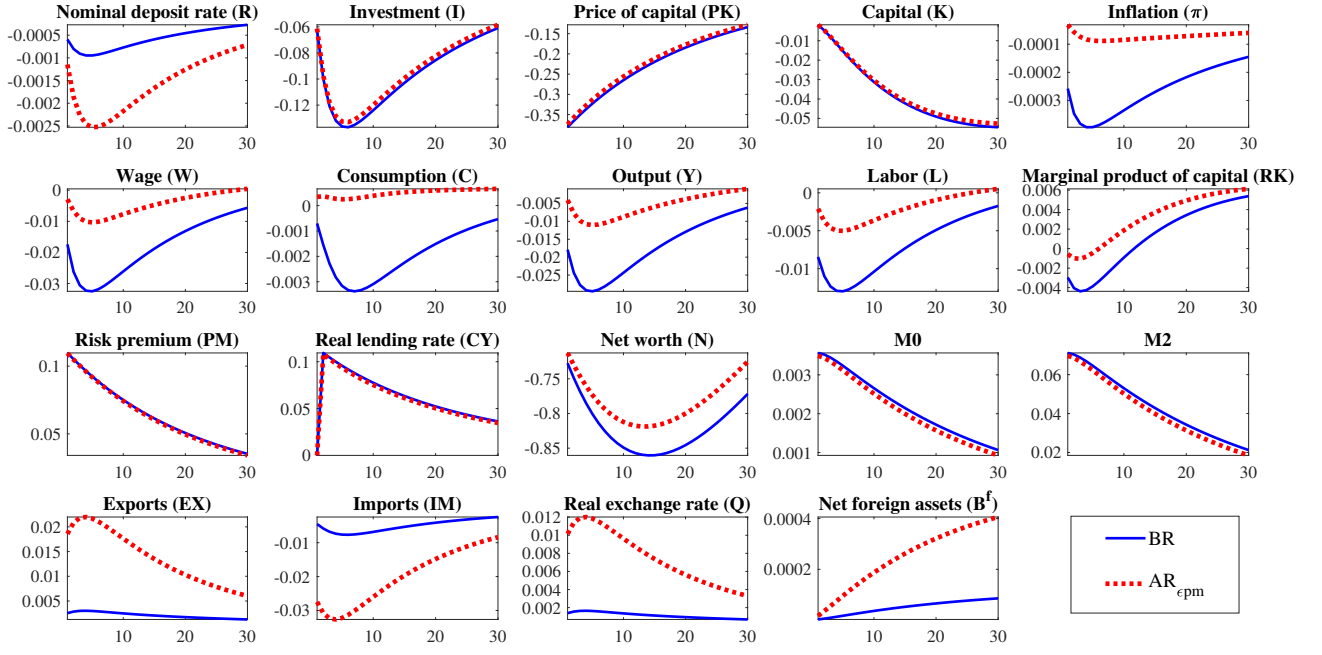


Figure 14: Baseline regime (BR) vs. Premium shock-augmented regime ( $AR_{\epsilon_{pm}}$ ) in response to a premium shock  $\epsilon_t^{pm}$

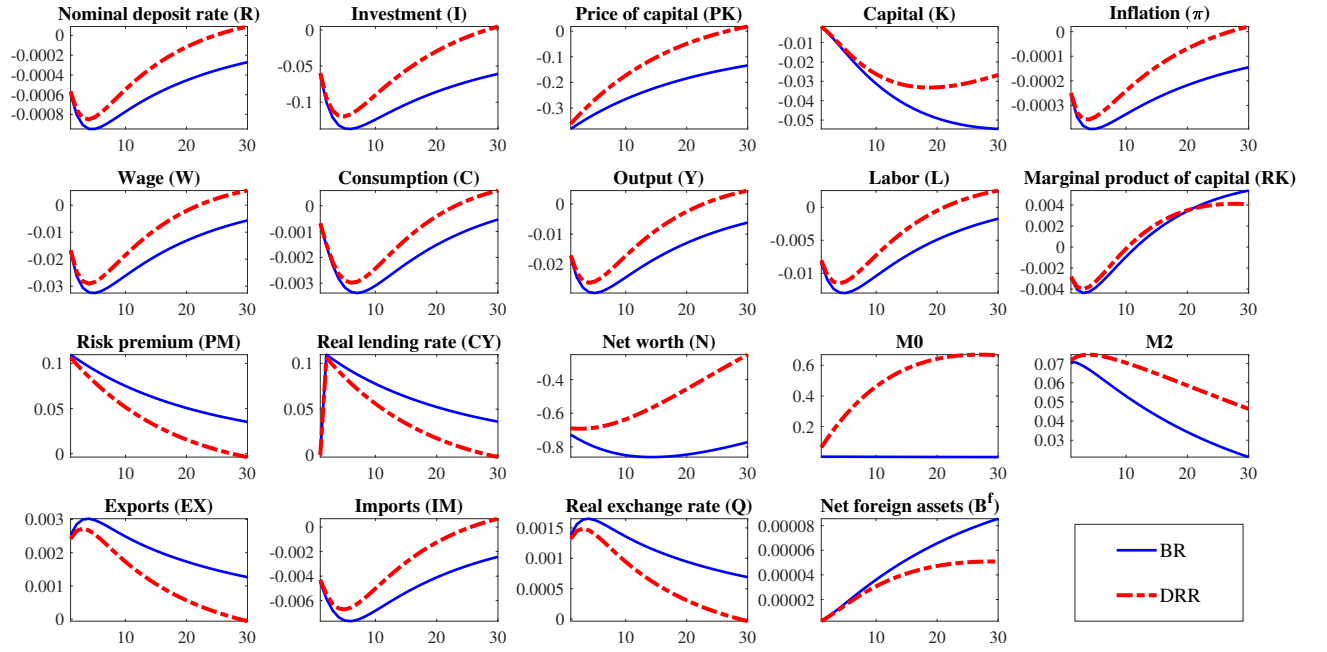


Figure 15: Baseline regime (BR) vs. Dual rule regime (DRR) in response to a premium shock  $\epsilon_t^{pm}$



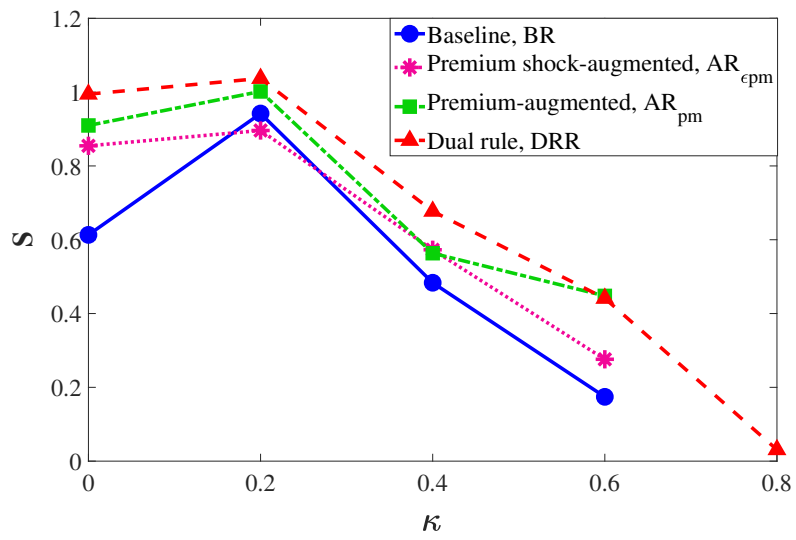


Figure 16: Comparison of stability across regimes

## Appendices

### A. DSGE model coefficients

Table A1: DSGE model coefficients used for simulation

Symbol	Description	Subsample simulations			Stability comparison across regimes			
Parameters obtained via indirect inference estimation or grid search		(93-99)	(00-07)	(08-16)	BR	AR <sub>pm</sub>	AR <sub>εpm</sub>	DRR
$r_p$	Taylor rule response to inflation	2.6459	1.3230	2.6459	2.6459	1.8371	3.0096	2.6459
$r_y$	Taylor rule response to output	0.0275	0.0138	0.0275	0.0275	0.0271	0.0364	0.0275
$r_{\Delta y}$	Taylor rule response to changes in output	0.0219	0.0219	0.0219	0.0219	0.0219	0.0219	0.0219
$\rho$	Interest rate smoothing	0.6588	0.6588	0.6588	0.6588	0.6588	0.6588	0.6588
$\xi_p$	Degree of Calvo price stickiness	0.9463	0.9463	0.9463	0.9463	0.9463	0.9463	0.9463
$\xi_w$	Degree of Calvo wage stickiness	0.5696	0.5696	0.5696	0.5696	0.5696	0.5696	0.5696
$\iota_p$	Degree of indexation to past inflation	0.1603	0.1603	0.1603	0.1603	0.1613	0.1603	0.1603
$\iota_w$	Degree of indexation to past wages	0.3687	0.3687	0.3687	0.3687	0.3687	0.3687	0.3687
$\omega_{NK}^p$	Proportion of sticky prices in hybrid price setting	0.0969	0.0969	0.0969	0.0969	0.0969	0.0969	0.0969
$\omega_{NK}^w$	Proportion of sticky wages in hybrid wage setting	0.4599	0.4599	0.4599	0.4599	0.4599	0.4599	0.4599
$\lambda$	Degree of external habit formation in consumption	0.7761	0.7761	0.7761	0.7761	0.7761	0.7761	0.7761
$\varphi$	Elasticity of investment adjustment costs	6.9538	6.9538	6.9538	6.9538	6.9538	6.9538	6.9538
$\psi$	Elasticity of capital utilization costs to capital inputs	0.1145	0.1145	0.1145	0.1145	0.1145	0.1145	0.1145
$\phi_p$	One plus the share of fixed costs in production	1.5876	1.5876	1.5876	1.5876	1.5876	1.5876	1.5876
$\sigma_c$	Inverse of the intertemporal elasticity of substitution for constant labor	1.6347	1.6347	1.6347	1.6347	1.6347	1.6347	1.6347
$\sigma_L$	Inverse of the elasticity of labor supply to real wage	2.4533	2.4533	2.4533	2.4533	2.4533	2.4533	2.4533
$\alpha$	Share of capital in production	0.1961	0.1961	0.1961	0.1961	0.1961	0.1961	0.1961
$\chi$	Elasticity of the risk premium to leverage ratio	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287
$\vartheta$	Elasticity of the risk premium to M0 via QE	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440
$\vartheta_{m2}^{(normal)}$	Elasticity of M0 to M2 (normal state)	0.0501	0.0501	—	0.0501	0.0501	0.0501	—
$\vartheta_{pm}^{(crisis)}$	Elasticity of M0 to the risk premium (crisis state)	0.0586	0.0586	0.0586	0.0586	0.0586	0.0586	0.0586
$r_{pm}$	Taylor rule response to the risk premium (normal state)	—	—	—	—	0.0414	—	—
$r_{\epsilon pm}$	Taylor rule response to the premium shock (normal state)	—	—	—	—	—	0.0514	—
$\vartheta_{pm}^{(normal)}$	Elasticity of M0 to the risk premium (normal state)	—	—	0.4857	—	—	—	0.4857
Parameters calibrated to values from previous studies (e.g. Smets and Wouters 38; Bernanke et al. 8; Dong et al. 19)								
$\beta$	Quarterly discount rate	0.99	0.99	0.99	0.99	0.99	0.99	0.99
$\delta$	Quarterly depreciation rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025
$\gamma$	Quarterly trend growth rate	1.004	1.004	1.004	1.004	1.004	1.004	1.004
$\theta$	Survival rate of entrepreneurs	0.97	0.97	0.97	0.97	0.97	0.97	0.97
$\epsilon_p$	Kimball aggregator curvature in the goods market	10	10	10	10	10	10	10
$\epsilon_w$	Kimball aggregator curvature in the labor market	10	10	10	10	10	10	10
$\sigma$	Elasticity of substitution between home and foreign produced goods	2.74	2.74	2.74	2.74	2.74	2.74	2.74
$\sigma^F$	Foreign equivalent of $\sigma$	1.83	1.83	1.83	1.83	1.83	1.83	1.83
$\omega$	Weight of home-produced goods in consumption bundle	0.5	0.5	0.5	0.5	0.5	0.5	0.5
$\omega^F$	Foreign equivalent of $\omega$	0.16	0.16	0.16	0.16	0.16	0.16	0.16

**B. DSGE model list (log-linearized)**

Consumption Euler equation:

$$\hat{c}_t = \left( \frac{\frac{\lambda}{\gamma}}{1 + \frac{\lambda}{\gamma}} \right) \hat{c}_{t-1} + \left( \frac{1}{1 + \frac{\lambda}{\gamma}} \right) \mathbb{E}_t \hat{c}_{t+1} + \left[ \frac{(\sigma_c - 1) \frac{W^h L_s}{C^*}}{\left( 1 + \frac{\lambda}{\gamma} \right) \sigma_c} \right] \left( \hat{l}_t - \mathbb{E}_t \hat{l}_{t+1} \right) - \left[ \frac{1 - \frac{\lambda}{\gamma}}{\left( 1 + \frac{\lambda}{\gamma} \right) \sigma_c} \right] \left( \hat{r}_t - \mathbb{E}_t \hat{\pi}_{t+1} + \hat{\epsilon}_t^p \right) \quad (\text{B1})$$

Investment Euler equation:

$$\hat{i}_t = \left( \frac{1}{1 + \beta \gamma^{(1-\sigma_c)}} \right) \hat{i}_{t-1} + \left( \frac{\beta \gamma^{(1-\sigma_c)}}{1 + \beta \gamma^{(1-\sigma_c)}} \right) \mathbb{E}_t \hat{i}_{t+1} + \left[ \frac{1}{\left( 1 + \beta \gamma^{(1-\sigma_c)} \right) \gamma^2 \varphi} \right] \hat{p}k_t + \hat{\epsilon}_t^i \quad (\text{B2})$$

Capital arbitrage condition:

$$\hat{p}k_t = \left( \frac{1 - \delta}{1 - \delta + R_*^k} \right) \mathbb{E}_t \hat{p}k_{t+1} + \left( \frac{R_*^k}{1 - \delta + R_*^k} \right) \mathbb{E}_t \hat{r}k_{t+1} - \mathbb{E}_t \hat{c}y_{t+1} \quad (\text{B3})$$

Capital stock evolves according to:

$$\hat{k}_t = \left( \frac{1 - \delta}{\gamma} \right) \hat{k}_{t-1} + \left( 1 - \frac{1 - \delta}{\gamma} \right) \hat{i}_t + \left[ \left( 1 - \frac{1 - \delta}{\gamma} \right) \left( 1 + \beta \gamma^{(1-\sigma_c)} \right) \right] \gamma^2 \varphi \hat{\epsilon}_t^i \quad (\text{B4})$$

Output is produced using capital and labor services:

$$\hat{y}_t = \phi_p \left[ \alpha \hat{k}_{t-1} + \alpha \left( \frac{1 - \psi}{\psi} \right) \hat{r}k_t + (1 - \alpha) \hat{l}_t + \hat{\epsilon}_t^a \right] \quad (\text{B5})$$

Cost minimization yields the demand for labor:

$$\hat{l}_t = \hat{r}k_t - \hat{w}_t + \hat{k}_t \quad (\text{B6})$$

Firms (entrepreneurs)' net worth evolves according to:

$$\hat{n}_t = \theta \hat{n}_{t-1} + \frac{K}{N} \hat{c}y_t - \left( \frac{K}{N} - 1 \right) \mathbb{E}_{t-1} \hat{c}y_t + \hat{\epsilon}_t^n \quad (\text{B7})$$

Firms (entrepreneurs)' consumption equals their net worth:

$$\hat{c}_t^c = \hat{n}_t \quad (\text{B8})$$

Hybrid price setting is a weighted average of the corresponding New Keynesian (NK) and New Classical (NC) equations:

$$\hat{r}k_t = \omega_{NK}^p \left\{ \frac{\left[ \frac{\iota_p}{1 + \beta \gamma^{(1-\sigma_c)} \iota_p} \right] \hat{\pi}_{t-1} + \left[ \frac{\beta \gamma^{(1-\sigma_c)}}{1 + \beta \gamma^{(1-\sigma_c)} \iota_p} \right] E_t \hat{\pi}_{t+1} - \hat{\pi}_t + \hat{\epsilon}_t^p}{- \alpha \left[ \frac{1}{1 + \beta \gamma^{(1-\sigma_c)} \iota_p} \right] \frac{[1 - \beta \gamma^{(1-\sigma_c)} \xi_p] (1 - \xi_p)}{\xi_p [(\phi_p - 1) \epsilon_p + 1]}} + \frac{\alpha - 1}{\alpha} \hat{w}_t - \frac{\hat{\epsilon}_t^a}{\alpha} \right\} + (1 - \omega_{NK}^p) \left\{ \frac{(\alpha - 1) \hat{w}_t + \hat{\epsilon}_t^a}{\alpha} \right\} \quad (\text{B9})$$

Similarly, hybrid wage setting is a weighted average of the corresponding NK and NC wage equations:

$$\begin{aligned} \hat{w}_t = & \omega_{NK}^w \left\{ \left[ \frac{1}{1 + \beta\gamma^{(1-\sigma_c)}} \right] \hat{w}_{t-1} + \left[ \frac{\beta\gamma^{(1-\sigma_c)}}{1 + \beta\gamma^{(1-\sigma_c)}} \right] \left( \mathbb{E}_t \hat{w}_{t+1} + \mathbb{E}_t \hat{\pi}_{t+1} \right) - \left[ \frac{1 + \beta\gamma^{(1-\sigma_c)}\iota_w}{1 + \beta\gamma^{(1-\sigma_c)}} \right] \hat{\pi}_t \right. \\ & + \left[ \frac{\iota_w}{1 + \beta\gamma^{(1-\sigma_c)}} \right] \hat{\pi}_{t-1} - \left[ \frac{1}{1 + \beta\gamma^{(1-\sigma_c)}} \right] \left[ \frac{(1 - \beta\gamma^{(1-\sigma_c)}\xi_w)(1 - \xi_w)}{\xi_w((\phi_w - 1)\varepsilon_w + 1)} \right] \left[ \hat{w}_t - \sigma_l \hat{l}_t - \frac{1}{1 - \frac{\lambda}{\gamma}} \left( \hat{c}_t - \frac{\lambda}{\gamma} \hat{c}_{t-1} \right) \right] + \hat{\epsilon}_t^{wnk} \Big\} \\ & + (1 - \omega_{NK}^w) \left\{ \sigma_l \hat{l}_t + \left( \frac{1}{1 - \frac{\lambda}{\gamma}} \right) \left( \hat{c}_t - \frac{\lambda}{\gamma} \hat{c}_{t-1} \right) - (\hat{\pi}_t - \mathbb{E}_{t-1} \hat{\pi}_t) + \hat{\epsilon}_t^{wls} \right\} \quad (B10) \end{aligned}$$

**Monetary policy** in the baseline and alternative regimes:

$$\text{BR} = \begin{cases} \text{For } r_t > 0.025 \\ \text{(Normal state)} \end{cases} \begin{cases} \hat{r}_t = \rho \hat{r}_{t-1} + (1 - \rho)(r_p \hat{\pi}_t + r_y \hat{y}_t) + r_{\Delta_y}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\epsilon}_t^r \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{m_2}^{(normal)} (\hat{m}_t^2 - \hat{m}_{t-1}^2) + \hat{\epsilon}_t^{m_0} \\ \hat{m}_t^2 = (1 - \frac{M0}{M2} + \frac{N}{M2}) \hat{k}_t + \frac{M0}{M2} \hat{m}_t^0 - \frac{N}{M2} \hat{n}_t \end{cases} \quad (B11a)$$

$$\begin{cases} \text{For } r_t \leq 0.025 \\ \text{(Crisis state)} \end{cases} \begin{cases} \hat{r}_t = 0.025 \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{pm}^{(crisis)} (\hat{p} \hat{m}_t - pm^*) + \hat{\epsilon}_t^{m_0} \end{cases} \quad (B11b)$$

$$\text{AR}_{pm} = \begin{cases} \text{For } r_t > 0.025 \\ \text{(Normal state)} \end{cases} \begin{cases} \hat{r}_t = \rho \hat{r}_{t-1} + (1 - \rho)(r_p \hat{\pi}_t + r_y \hat{y}_t - r_{pm} \hat{p} \hat{m}_t) + r_{\Delta_y}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\epsilon}_t^r \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{m_2}^{(normal)} (\hat{m}_t^2 - \hat{m}_{t-1}^2) + \hat{\epsilon}_t^{m_0} \\ \hat{m}_t^2 = (1 - \frac{M0}{M2} + \frac{N}{M2}) \hat{k}_t + \frac{M0}{M2} \hat{m}_t^0 - \frac{N}{M2} \hat{n}_t \end{cases} \quad (B12a)$$

$$\begin{cases} \text{For } r_t \leq 0.025 \\ \text{(Crisis state)} \end{cases} \begin{cases} \hat{r}_t = 0.025 \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{pm}^{(crisis)} (\hat{p} \hat{m}_t - pm^*) + \hat{\epsilon}_t^{m_0} \end{cases} \quad (B12b)$$

$$\text{AR}_{\epsilon pm} = \begin{cases} \text{For } r_t > 0.025 \\ \text{(Normal state)} \end{cases} \begin{cases} \hat{r}_t = \rho \hat{r}_{t-1} + (1 - \rho)(r_p \hat{\pi}_t + r_y \hat{y}_t - r_{\epsilon pm} \hat{\epsilon}_t^{pm}) + r_{\Delta_y}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\epsilon}_t^r \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{m_2}^{(normal)} (\hat{m}_t^2 - \hat{m}_{t-1}^2) + \hat{\epsilon}_t^{m_0} \\ \hat{m}_t^2 = (1 - \frac{M0}{M2} + \frac{N}{M2}) \hat{k}_t + \frac{M0}{M2} \hat{m}_t^0 - \frac{N}{M2} \hat{n}_t \end{cases} \quad (B13a)$$

$$\begin{cases} \text{For } r_t \leq 0.025 \\ \text{(Crisis state)} \end{cases} \begin{cases} \hat{r}_t = 0.025 \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{pm}^{(crisis)} (\hat{p} \hat{m}_t - pm^*) + \hat{\epsilon}_t^{m_0} \end{cases} \quad (B13b)$$

$$\text{DRR} = \begin{cases} \text{For } r_t > 0.025 \\ \text{(Normal state)} \end{cases} \begin{cases} \hat{r}_t = \rho \hat{r}_{t-1} + (1 - \rho)(r_p \hat{\pi}_t + r_y \hat{y}_t) + r_{\Delta_y}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\epsilon}_t^r \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{pm}^{(normal)} (\hat{p} \hat{m}_t - pm^*) \end{cases} \quad (B14a)$$

$$\begin{cases} \text{For } r_t \leq 0.025 \\ \text{(Crisis state)} \end{cases} \begin{cases} \hat{r}_t = 0.025 \\ \hat{m}_t^0 - \hat{m}_{t-1}^0 = \vartheta_{pm}^{(crisis)} (\hat{p} \hat{m}_t - pm^*) + \hat{\epsilon}_t^{m_0} \end{cases} \quad (B14b)$$

**Macroprudential policy:** financial regulation targets the risk premium with the strength of regulatory intensity governed by  $\kappa$ :

$$\hat{p}m_t = \left( \frac{1}{1 - \kappa\zeta} \right) \left[ \chi(\hat{p}k_t + \hat{k}_t - \hat{n}_t) - \vartheta \hat{m}_t^0 \right] + \left( \frac{1}{1 - \kappa\zeta} \right) [\kappa^2 + 10\kappa + 1] \cdot \hat{\epsilon}_t^{pm} \quad (B15)$$

**Foreign economy sectors:** we extend the model in Le et al. (28) to a small open economy setting by incorporating Eqs. (B16), (B17), (B18) and (B19) into the system. Aggregate resource constraint is modified as in (B20) to account for the UK's trade with the rest of world. Real exchange rate  $q_t$  is defined as the quantity of UK goods and services that can be exchanged for one unit of foreign goods and services, so that a rise in  $q_t$  corresponds to a sterling depreciation. Foreign real interest rate  $r_t^{f(real)}$  and foreign consumption  $c_t^f$  are treated as exogenous AR(1) processes. Variables in block capitals without time subscripts are steady states.

Export demand:

$$\hat{e}x_t = \sigma^F \log(1 - \omega^F) + \hat{c}_t^f + \sigma^F \hat{q}_t + \hat{\epsilon}_t^{ex} \quad (B16)$$

Import demand:

$$\hat{im}_t = \sigma \log(1 - \omega) + \hat{c}_t - \sigma \hat{q}_t + \hat{\epsilon}_t^{im} \quad (B17)$$

Movement in real exchange rate satisfies the uncovered interest rate parity (UIRP):

$$\mathbb{E}_t \hat{q}_{t+1} - \hat{q}_t = (\hat{r}_t - \mathbb{E}_t \hat{\pi}_{t+1}) - (\hat{r}_t^f - \mathbb{E}_t \hat{\pi}_{t+1}^f) = \hat{r}_t^{(real)} - \hat{r}_t^{f(real)} \quad (B18)$$

Evolution of foreign bonds satisfies the balance of payment (BoP) constraint:

$$\hat{b}_t^f = (1 + \hat{r}_t^f) \hat{b}_{t-1}^f + \frac{EX}{Y} (\hat{e}x_t - \hat{q}_t) - \frac{IM}{Y} \hat{im}_t \quad (B19)$$

Aggregate real resource constraint:

$$\hat{y}_t = \frac{C}{Y} \hat{c}_t + \frac{I}{Y} \hat{i}_t + \left( R^k k_y \frac{1 - \psi}{\psi} \right) \hat{r}k_t + \frac{C^e}{Y} \hat{c}_t^e + \frac{EX}{Y} \hat{e}x_t - \frac{IM}{Y} \hat{im}_t + \hat{\epsilon}_t^g \quad (B20)$$

**Exogenous processes:**

Government spending shock:  $\hat{\epsilon}_t^g = \rho_g \hat{\epsilon}_{t-1}^g + \eta_t^g + \rho_{ga} \eta_t^a$

Investment-specific shock:  $\hat{\epsilon}_t^i = \rho_i \hat{\epsilon}_{t-1}^i + \eta_t^i$

Productivity shock:  $\hat{\epsilon}_t^a = \hat{\epsilon}_{t-1}^a + \rho_a (\hat{\epsilon}_{t-1}^a - \hat{\epsilon}_{t-2}^a) + \eta_t^a$

New Keynesian wage mark-up shock:  $\hat{\epsilon}_t^{wnk} = \rho_{wnk} \hat{\epsilon}_{t-1}^{wnk} + \eta_t^{wnk}$

Risk premium shock:  $\hat{\epsilon}_t^{pm} = \rho_{pm} \hat{\epsilon}_{t-1}^{pm} + \eta_t^{pm}$

M0 shock:  $\hat{\epsilon}_t^{m0} = \rho_{m0} \hat{\epsilon}_{t-1}^{m0} + \eta_t^{m0}$

Import demand shock:  $\hat{\epsilon}_t^{im} = \rho_{im} \hat{\epsilon}_{t-1}^{im} + \eta_t^{im}$

Foreign real interest rate shock:  $\hat{r}_t^{f(real)} = \rho_{rf(real)} \hat{r}_{t-1}^{f(real)} + \eta_t^{rf(real)}$

Preference shock:  $\hat{\epsilon}_t^b = \rho_b \hat{\epsilon}_{t-1}^b + \eta_t^b$

Taylor rule shock:  $\hat{\epsilon}_t^r = \rho_r \hat{\epsilon}_{t-1}^r + \eta_t^r$

Price mark-up shock:  $\hat{\epsilon}_t^p = \rho_p \hat{\epsilon}_{t-1}^p + \eta_t^p$

Labor supply shock:  $\hat{\epsilon}_t^{wls} = \rho_{wls} \hat{\epsilon}_{t-1}^{wls} + \eta_t^{wls}$

Net worth shock:  $\hat{\epsilon}_t^n = \rho_n \hat{\epsilon}_{t-1}^n + \eta_t^n$

Export demand shock:  $\hat{\epsilon}_t^{ex} = \rho_{ex} \hat{\epsilon}_{t-1}^{ex} + \eta_t^{ex}$

Foreign consumption shock:  $\hat{\epsilon}_t^{cf} = \rho_{cf} \hat{\epsilon}_{t-1}^{cf} + \eta_t^{cf}$

### C. DSGE model variable construction and data sources

Table C1: Model variable construction and data sources

Symbol	Variable	Definition and description	Source
$R$	Nominal deposit rate	$\frac{\text{3-month Treasury Bills rate}}{4}$	BoE <sup>1</sup>
$I$	Investment	$\ln \left( \frac{\text{Total Gross fixed capital formation}}{\text{GDP deflator} * \text{Population index}} \right) * 100$ <sup>2</sup>	ONS
$PK$	Price of capital	Derived from capital arbitrage equation	Calculation
$K$	Capital stock	Derived from capital accumulation equation	Calculation
$\pi$	Inflation	$\left[ \ln(\text{GDP deflator}_t) - \ln(\text{GDP deflator}_{t-1}) \right] * 100$	FRED
$W$	Wage	$\ln \left( \frac{\text{Wage and salaries} + \text{Employers' social contributions} + \text{Income from self employment}}{\text{GDP deflator} * \text{Population index}} \right) * 100$	ONS
$C$	Consumption	$\ln \left( \frac{\text{Household final consumption expenditure}}{\text{GDP deflator} * \text{Population index}} \right) * 100$	ONS
$Y$	Output	$\ln \left( \frac{\text{Real gross domestic product}}{\text{Population index}} \right) * 100$	ONS
$L$	Labor	$\ln \left( \frac{\text{Total actual weekly hours worked} * \text{Employment index}}{100 * \text{Population index}} \right) * 100$ <sup>3</sup>	ONS
$RK$	Marginal product of capital	Derived from labor demand equation	Calculation
$PM$	Risk Premium	$\frac{\text{3-month LIBOR} - \text{3-month Treasury Bills rate}}{4}$	FRED, BoE
$CY$	Real Lending rate	$\frac{\text{3-month LIBOR}}{4} - \text{one-period ahead inflation}$	FRED
$N$	Net worth	$\ln \left( \frac{\text{FTSE 250 index}}{\text{GDP deflator} * \text{Population index}} \right) * 100$	Yahoo Finance
$M0$	Monetary base	$\ln \left( \frac{\text{M0 money stock}}{\text{GDP deflator} * \text{Population index}} \right) * 100$	FRED
$M2$	Broad supply of money	$\ln \left( \frac{\text{M2 money stock}}{\text{GDP deflator} * \text{Population index}} \right) * 100$	FRED
$EX$	Exports	$\ln \left( \frac{\text{Exports of goods and services in the UK}}{\text{GDP deflator} * \text{Population index}} \right) * 100$	FRED
$IM$	Imports	$\ln \left( \frac{\text{Imports of goods and services in the UK}}{\text{GDP deflator} * \text{Population index}} \right) * 100$	FRED
$Q$	Real exchange rate	$\ln \left( \frac{1}{\text{Sterling effective exchange rate}} * \frac{P^f}{P} \right)$ <sup>4</sup>	BoE, FRED
$B^f$	Net foreign assets position	$\frac{\text{Nominal net foreign assets (NFA)}}{\text{Nominal GDP}}$ <sup>5</sup>	ONS

<sup>1</sup> BoE, FRED, IMF, and ONS are short for the Bank of England, Federal Reserve Economic Data, International Monetary Fund, and Office for National Statistics, respectively.

<sup>2</sup> GDP deflator is constructed using “Implied GDP deflator at market prices” (ONS: QNA), normalized so that QNA(2010Q1)=100; population index is constructed using “Population aged 16+” (ONS: MGSL), normalized so that MGSL (2010Q1)=1.

<sup>3</sup> Data for weekly hours is normalized so that YBUS (2010Q1)=1; employ index is constructed using “Total employment by professional status” (FRED:LFESSEETTGBQ647S), normalized so that LFESSEETTGBQ647S (2010Q1)=100.

<sup>4</sup> Foreign price level  $P^f$  is calculated as the weighted average GDP deflator in Germany (0.62), US (0.23), and Japan (0.15) (FRED); domestic price level is UK GDP deflator; all GDP deflators are normalized so that the values in 2010Q1 are 100.

<sup>5</sup> Nominal NFA is accumulated current account surplus, taking the balance of payments international investment position (ONS: HBQC) in 1993Q1 as the starting point.

<sup>6</sup> Two foreign variables are treated as exogenous AR(1) processes: foreign real interest rate  $R^{f(real)}$  is the weighted average real interest rates in Germany (0.62), US (0.23), and Japan (0.15); foreign consumption demand  $C^f$  is the world imports of goods and services.