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Macrofinancial Effects of the Output Floor in Euro Area Banking System

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Abstract

Output floor has emerged as a possibly important tool to ensure financial stability within the banking system. This paper proposes to assess the quantitative potential of output floor to ensure financial stability through the lens of a general equilibrium model for the Euro Area. We get three main results. First, implementation of output floor entails macrofinancial stabilization benefits for Euro Area activities in the long run, which confirms results found by financial European regulators. Second, along financial and economic cycles, output floor activation reduces volatility of banks capital to risk-weighted-asset ratio and the dispersion of this ratio between core and periphery banks, consistently with the desired outcome defined by financial regulators. Third, moderate banking openness in Euro Area limits cross-border credit flows spillovers, which does not affect output floor efficiency. However, full banking openness (i.e. banking union) produces high spillovers and erodes this efficiency.

Keywords: Output Floor, Credit Risk, Banking System, Euro Area, DSGE
JEL classification: G21, F36, F41, E44.

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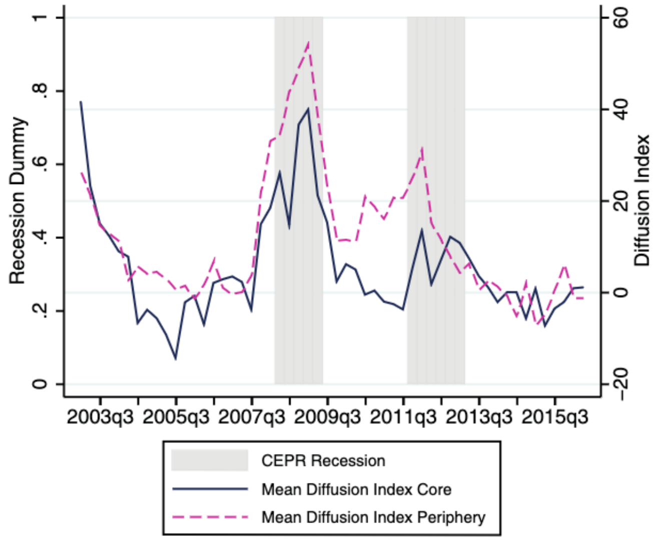
1 Introduction

The Global Financial Crisis (GFC) in 2007 and its consequences on the European Debt crisis in 2010 reinforced the economic and financial dichotomy among Euro Area countries. Basically, this dichotomy led to the definition of core economies in this area taht actively participate in the funding of periphery economies (Schmitz and Von Hagen, 2011). While this dichotomy is not new (already mentioned in Bayoumi and Eichengreen, 1993), it reflects financial heterogeneity and incomplete financial integration process (Poutineau and Vermandel, 2015). Thus, this issue is at the opposite objective of the financial integration promoted by European regulators and come to fuel work on structural heterogeneities in the Economic and Monetary Union (EUM). Both crises contributed to this financial heterogeneity by reducing cross-banking flows in the Euro Area (Poutineau and Vermandel, 2015 ; Emter et al., 2019 ; Hoffmann et al., 2022), which exacerbates the economic cycle asymmetry between core and periphery economies (Belke et al., 2017). Moreover, as shown in Figure 1, regarding the evolution of credit access conditions in Euro Area, both crises also have increased heterogeneity in the financial cycle between core (solid blue line in the figure) and peripheral economies (purple dashed line). Note that before the 2007 GFC, the figure highlights a lower restriction in credit access. Part of this lower tightening credit condition could be fueled by stronger incentives of banks to underestimate the credit risk used in the computation of Risk-Weighted-Asset (RWA).

Before the 2007 GFC, these incentives were more pronounced for banks using the Internal Rating Based (IRB) approach in the estimation of credit risk (Behn et al., 2016). Underestimation of credit risk comes from the essentially biased definition of default probability and Loss-Given-Default (henceforth LGD) made by banks and used in IRB approach[1]. Moreover, these incentives contribute to an unjustified variability in the bank capital to RWA ratio over time (i.e. volatility of the ratio) and among banks (variability). This ratio is a key indicator for assessing the financial robustness of financial institutions. Hence, the unjustified variability of this ratio erodes its comparability between banks and reduces its reliability for investors

[1]Basel Committee allows two IRB approaches in credit risk estimation. The first one is the Foundation IRB (F-IRB) approach where banks provide only estimation of borrowers default probability and LGD is fixed at 40%. The second one is the Advanced-IRB (A-IRB) approach where banks provide estimation of default probability and LGD.

Figure 1: Evolution of credit conditions between core and periphery banks in the Euro Area between 2003 and 2015.



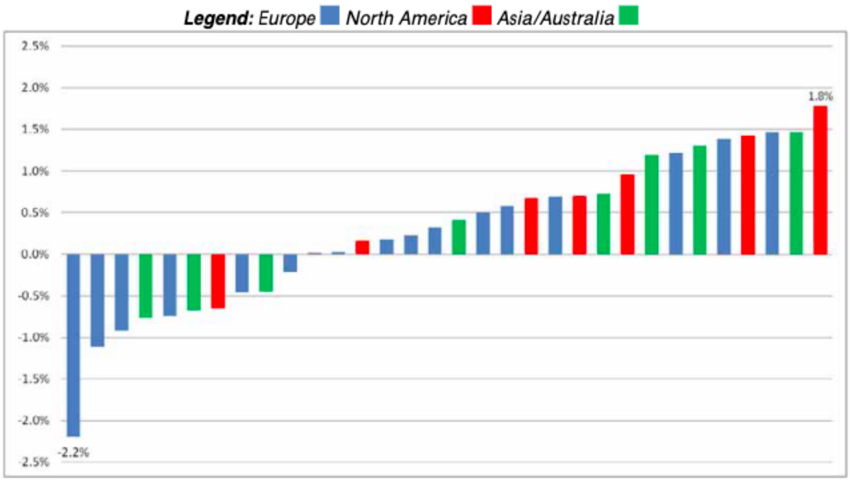
Sources : Dräger and Proaño (2020), *ECB bank lending survey*

(Avramova and Le Leslé, 2012).

The Hypothetical Portfolio Exercise (henceforth HPE) led by the Basel Committee in 2013 is a concrete proof of this variability issue (BCBS, 2013). The HPE was a bottom-up approach that asked 32 international banking groups to estimate the RWA from an identical and fictive credits portfolio. The results of the HPE pointed out a non-negligible dispersion of default probabilities and LGD among banks. This dispersion significantly contributes to the high RWA variability among these financial institutions. Based on a capital requirement ratio of 10%, figure 2 shows that RWA estimations in the HPE generated a deviation of this ratio between roughly minus 2 and 1.8 percentage points. This high variability confirms the results obtained in a 2012 FMI report that analyzed the potential reasons for capital requirements heterogeneity between banks (Avramova and Le Leslé, 2012).

The HPE results also contribute to the creation of Basel Committee recommendations regarding the harmonization of credit risk estimation and prudential policies to improve IRB credibility for financial actors. Among these recommendations, the Committee suggested setting a minimum value for banks' capital and / or estimated parameters in the IRB approach (BCBS, 2013). This suggestion led to the elaboration of an Output Floor (OF) in the Basel 3

Figure 2: Variability of capital adequacy ratio between international banking group participating at the HPE in 2013.



Change from 10% capital ratio if individual bank risk weights from the HPE are adjusted to the median from the sample. Each bar represents one bank. The chart is based on the assumption that variations observed at each bank for the hypothetical portfolios are representative for the entire sovereign, bank, and corporate portfolios of the bank and are adjusted accordingly. No other adjustments are made to RWA or capital.

Source : BCBS (2013)

finalization document (BCBS, 2017a). The OF imposes a minimum level of RWA estimated using the IRB approach. This minimum level corresponds to 72.5% of the RWA estimated using the standardized approach. As mentioned by the Basel Committee, the objective of the Output Floor is to limit RWA volatility (temporal dimension) and reduce capital to RWA variability between banks (cross-sectional dimension) (BCBS, 2017a). The cross-sectional dimension of the OF objective could play an important role in Euro Area prudential regulation as Figure 2 points out the high variability of the capital to RWA ratio between European banks.

While OF is applicable since January 2023, it has not yet been implemented in the Euro Area countries, and European financial regulators have recently confirmed an operational OF in two years, that is, on January 2025[2]. In the current financial and economic context, studies on the effect of the Output Floor in the Euro Area financial and real activities are important to obtain first intuitions about the potential benefits and costs of this instrument (Budnik et al., 2021). These studies are even more than necessary because the literature on the impact of the Output Floor is still in its infancy.

While the ongoing procedure for OF implementation in the Euro Area limits empirical

[2]See the speech of the European Central Bank (ECB) Vice-President made in June 2023. URL link to the speech:
https://www.ecb.europa.eu/press/key/date/2023/html/ecb.sp230609~c9ef904931.en.html

studies, some econometric and statistical papers provides insights about the potential effects of the prudential instrument. For instance, Pop and Pop (2022) conducted a counter-factual study on the OF by constituting a bank portfolio composed of credits to small and medium French companies. The authors' results indicate a reduction in the spread between RWA estimated using standardized and IRB approaches. This reduction limits OF efficiency. Other works, such as the one of Neisen and Schulte-Mattler (2021), concludes that OF implementation leads to a decrease in banking profitability, while Binder and Lehner (2020) indicate that OF obliges banks to increase their capital. This result corroborates the conclusions of the European Banking Authority report published in 2018 (EBA, 2018). Moreover, Stewart (2021) explains that OF reduces banks' incentives to use the IRB approach, and *in fine* erodes optimal allocation in banking capital. However, the work of Pfeifer and Hodula (2021) indicates that OF improves banks' resilience using the IRB approach. Furthermore, based on Norwegian banks, Andersen and Johnsen (2023) show that the Output Floor contributes to more equal and comparable capital requirements between Norwegian and foreign banks. This result confirms the cross-sectional objective of the OF defined by financial regulators.

Regarding the theoretical literature, to the best of my knowledge, only the work of Acosta-Smith et al.(2021) has evaluated the macrofinancial and macroeconomic impact of the Output Floor in a modeling approach. The authors used the Dynamic Stochastic General Equilibrium (DSGE) model of Gambacorta and Karmakar (2018) (an extended version of the DSGE model of Gerali et al., 2010) to analyze OF impacts in United Kingdom economy. the results of Acosta-Smith et al.(2021) indicate that OF incites banks to compose their portfolio with credits whose risk-weight is close to the OF threshold, that is, corporate credits in their model. Despite an asymmetrical effect between credit sectors, the authors show that the use of the Output Floor improves financial stability. Nevertheless, the DSGE model of Gambacorta and Karmakar (2018) does not integrate the default probabilities of borrowers. This issue constrains Acosta-Smith et al.(2021) to define an alternative IRB approach taht differs from the one imposed by the Basel Committee. Contrary to these authors, one of the contributions of this paper is the consideration of endogenous borrowers default probability, determined via a financial accelerator. This probability is consistent with the empirical IRB approach and provides a more realistic Output Floor analysis.

To do so, this paper modifies and extends the core-periphery DSGE model of Poutineau and Vermandel (2017) in order to bring three main contributions in the literature : 1) evaluate potential OF benefits and costs for the Euro Area activity in different time horizons ; 2) verify whether OF would reach its objectives, that is, reduce volatility and variability of capital to RWA ratio between Euro Area banks and 3) analyze its compatibility with banking integration promoted by European financial regulators.

The main results of the paper suggest that OF implementation produces macrofinancial and macroeconomic benefits for Euro Area activities in the long run which confirms guesses made by financial European regulators. However, these potential benefits comes at a lower welfare for households because higher production leads to the generation of more hours of work (negatively linked to households utility) than consumption (positively linked to it).

The paper shows that, in comparison with immediate and full Output Floor implementation, progressive OF implementation in time (i.e. phase-in process) limits macrofinancial and macroeconomic costs of Euro Area activities in the short run (i.e. during the process) but not in the medium run (i.e. after the process ends). Moreover, process transition costs is smoother for core banks than for periphery banks. This result underlines the potential asymmetry for European banks to adapt their activities to a new prudential instrument.

Furthermore, the results show that during financial and economic cycles, OF activation reduces the volatility of bank capital to RWA ratio and the dispersion of this ratio between core and peripheral banks. This means that OF can reach its goals of limiting banking solvency risk and improving financial investors' confidence in using the ratio to compare solvency risk between banks hail from different economic regions in the Euro Area.

Finally, the paper indicates that, up to a certain threshold, banking openness in the Euro Area has no significant impact on OF efficiency. However, full banking openness (i.e. banking union) is detrimental to it. This last result calls for the design of a national OF instead of a federal one to preserve OF and banking integration objectives in the Euro Area simultaneously.

The rest of the paper is organized as follows. Section 2 describes the key parts of the DSGE model for OF analysis. Section 3, evaluates the long-run impact of the Output Floor on banking and real sectors in the Euro Area. This section also discusses the choice of progressive implementation of the instrument, as suggested by Basel Committee (i.e. OF phase-in process). Section 4 studies the role of the Output Floor in banking solvency risk along the financial and economic cycles. Section 5 studies the influence of banking integration on Output Floor efficiency. Section 6 concludes.

2 The Model

To study the macro effects of the Output Floor (henceforth OF), this paper modifies and extends the core-periphery DSGE model of Poutineau and Vermandel (2017) in three ways. First, contrary to these authors, our analysis does not consider the inter-bank market in the model because banks do not have the possibility of default. This implies the absence of a default probability, which makes the IRB approach (and thus OF analysis) of banks' credit risk less realistic. Second, instead of using the Pareto distribution to compute a firm's default risk, as in Poutineau and Vermandel (2015) and Poutineau and Vermandel (2017), our model follows Bernanke, Gertler and Gilchrist (BGG, 1999) by adopting a log-normal distribution. This choice in DSGE models provides a dynamic of IRB risk-weighted-assets closer to the one provided by the Basel regulation (Mendicino et al., 2018 and Darracq-Paries et al., 2019). Third, the model integrates the OF mechanism into the bank capital constraint as in Acosta-Smith et al.(2021). Similar to Gerali et al.(2010), the bank capital constraint corresponds to a quadratic cost in a bank's profit. The rest of the model is close to that of Poutineau and Vermandel (2017) and can be summarized as follows. The model is based on a monetary union similar to the Euro Area, that is, it incorporates two economies (core and periphery) that have a common monetary policy directed by a central bank. In each economy $i \in \{c, p\}$ (core and periphery economies respectively), there is a continuum of identical households that consume, save and work in intermediate firms. Household work is remunerated via a salary that is determined by labor unions and subjected to nominal friction *à la* Calvo (1983).

In the production sector of each economy i, competitive intermediate firms use capital and labor (realized by households) to produce and sell heterogeneous intermediate goods to monopolistic final firms. Prices of intermediate goods are also subject to nominal friction *à la* Calvo (1983), while final firms can generate a mark-up on the prices of their final goods. There are also entrepreneurs who finance intermediate firms' capital rental through investment projects. Entrepreneurs use their own net worth and banking loans to finance such projects. For an entrepreneur in economy i, banking loans come from banks implemented in both economies. Entrepreneurs can make default when projects return is not profitable enough to reimburse bank loans. Moreover, entrepreneurs have a biased view of the expected return of their projects, which influences the banking lending condition and generates a financial accelerator. Capital producers buy depreciated capital from intermediate firms and invest in the production of the necessary capital in entrepreneurs' projects. Investment decisions of capital producers imply the definition of an optimal capital price subject to a quadratic adjustment cost of investments. In each economy i, banks provide loans to core and peripheral entrepreneurs. Loans finance banks' capital and deposits made by domestic households. Banks have two financial constraints : balance-sheet and prudential capital constraints. The latter corresponds to a quadratic cost in the bank profit function, which increases when the capital-to-risk-weighted-asset ratio deviates from the level expected by the financial authority.

There is a government and financial authority in each economy i. Government finances public spending by charging lump-sum taxes to local households. The amount of taxes permits the full financing of public spending, which means that the government does not contract public debt to guarantee the balance of the public budget. Financial authority implements prudential policy on banks' capital to maintain financial stability. Finally, a central bank sets a common Taylor-shaped monetary policy in both economies.

In the rest of this section, we focus on the modified and extended parts of the model for the OF analysis, that is, the entrepreneurs and banking blocks. The other parts of the model are similar to those of Poutineau and Vermandel (2017).

2.1 Entrepreneurs

2.1.1 Projects' financing

Each entrepreneur e provides the amount $K_{i,t}(e)$ of capital to finance the projects of intermediate firms. In period t, an entrepreneur manages a large number of heterogeneous projects with a total value of $q_{i,t}K_{i,t}(e)$ (where $q_{i,t} = Q_{i,t}/P^C_{i,t}$ is the implicit real price of capital, i.e. the ratio between nominal capital price $Q_{i,t}$ and the aggregated price level $P^C_{i,t}$). Entrepreneur finance these projects with their own net worth $N_{i,t}(e)$ and a real amount of banking loans $L^H_{i,t}(e)$. The balance of the representative entrepreneur is given by :

$$q_{i,t}K_{i,t}(e) = N_{i,t}(e) + L^H_{i,t}(e) \tag{1}$$

Moreover, loan demands are subject to external habits such as $L^H_{i,t}(e) = L^d_{i,t}(e) - h^L_i \left(L^d_{i,t-1} - \overline{L}^d_i\right)$ where $h^L_i \in [0, 1]$ denotes the habit degree, $L^d_{i,t-1}$ reflects the aggregate average of loan demand in the previous period and $\overline{L}^d_i$ is the long run level of loans' demand. As mentioned by Poutineau and Vermandel (2017), the integration of this habit allows the capture of the high autocorrelation of loans observed empirically. Entrepreneurs borrow from domestic banks (indexed by h) and foreign banks (indexed by f) to meet their balance sheet. Similar to Brzoza-Brzezina et al.(2017), the total amount of loans borrowed by the representative entrepreneur is expressed by the following CES function :

$$L^d_{i,t}(e) = \left[\left(1 - \alpha^L_i\right)^{1/v} \left(L^d_{h,i,t}(e)\right)^{(v-1)/v} + \left(\alpha^L_i\right)^{1/v} \left(L^d_{f,i,t}(e)\right)^{(v-1)/v}\right]^{v/(v-1)} \tag{2}$$

where $\alpha^L_i \in [0, 1/2]$ corresponds to the share of entrepreneurial loans financed by foreign banks. This parameter also indicates the degree of banking openness inside the monetary union ($\alpha^L_i = 0$ for banking autarky and $\alpha^L_i = 0.5$ for banking union). Parameter $v \geq 0$ denotes the elasticity of substitution between domestic and foreign banking loans while $L^d_{h,i,t}(e)$ (respectively $L^d_{f,i,t}(e)$) stands for the amount of domestic (foreign) loan demands of entrepreneur e in economy i.

The CES function of aggregate loan demand implies that the global cost of loan $P^L_{i,t}(e)$ for the entrepreneur aggregates domestic and foreign loan interest rates (respectively $R^L_{h,t}(e)$ and

$R^L_{f,t}(e)$) as follows :

$$1 + P^L_{i,t}(e) = \left[\left(1 - \alpha^L_i\right)\left(1 + R^L_{h,t}\right)^{1-v} + \alpha^L_i\left(1 + R^L_{f,t}\right)^{1-v}\right]^{1/(1-v)} \tag{3}$$

Furthermore, loan demands for banks in both economies depend on the relative level of their local interest rate such as :

$$L^d_{h,i,t}(e) = (1 - \alpha^L_i)\left[\frac{1 + R^L_{h,t}}{1 + P^L_{i,t}(e)}\right]^{-v} L^d_{i,t}(e)$$
$$L^d_{f,i,t}(e) = \alpha^L_i\left[\frac{1 + R^L_{f,t}}{1 + P^L_{i,t}(e)}\right]^{-v} L^d_{i,t}(e)$$

2.1.2 Financial accelerator and projects' return

Similar to Bernanke, Gertler and Gilchrist (BGG, 1999), it is assumed that entrepreneurs' projects are risky and obtain an individual return equal to $\omega_{i,t}(1 + R^k_{i,t})$. Component $\omega_{i,t}$ represents the idiosyncratic risk of the project's return whereas $R^k_{i,t}$ reflects its aggregate return. Contrary to Poutineau and Vermandel (2017), it is supposed that the idiosyncratic risk $\omega_{i,t}$ follows a log-normal distribution with a mean $\mu_{ln(\omega_{i,t})}$ and a stochastic standard deviation $\sigma_{ln(\omega_{i,t})} = e^{\varepsilon^\sigma_t}\overline{\sigma_{ln(\omega_i)}}$ as in Mendicino et al.(2018) and Darracq-Paries et al.(2019). The stochastic process of the standard deviation $e^{\varepsilon^\sigma_t}$ corresponds to a random exogenous shock on default risk to capture exogenous changes in banks risk estimation.

The variable $\omega_{i,t}$ is i.i.d with a cumulative distribution function $F(\omega_{i,t})$ which follows standard regularity properties[3]. The mean of idiosyncratic risk ω is equal to $\mu_{ln(\omega_{i,t+1})} = -0.5\sigma^2_{ln(\omega_{i,t+1})}$ in order to guarantee that $\mathbb{E}_{i,t}(\omega_{i,t+1}) = 1$ in each period.

Each project is profitable when its return is above a threshold $\omega^C_{i,t}$ such that the value of the profitable project is equal to $\overline{\omega}_{i,t}(e) = E\left(\omega_{i,t}|\omega_{i,t} \geq \omega^C_{i,t}(e)\right)$. After aggregating all projects, profit function of the entrepreneur e can be expressed as follows :

$$\Pi^E_{i,t}(e) = \mathbb{E}_t\left\{\overline{\omega}_{i,t}(e)(1 + R^k_{i,t+1})q_{i,t}K_{i,t}(e) - (1 + P^L_{i,t})L^H_{i,t}(e)\right\} \tag{4}$$

To obtain a loan, entrepreneurs engage in financial contracts before the realization of risk

[3] The cumulative distribution function is continuous, first order differentiable and satisfies the following condition : $\frac{\partial \omega f(\omega)}{\partial \omega} > 0$, where $f(\omega)$ is the hazard rate.

ω which can generate unexpected losses for banks and entrepreneurs. After the realization of ω, entrepreneurs observe the *ex-post* value of $\omega_{i,t}^C$ and are able to distinguish profitable projects (i.e. $\omega > \omega_{i,t}^C$) from non-profitable ones ($\omega < \omega_{i,t}^C$). Assuming null profit in equation (4), the *ex post* value of $\omega_{i,t}^C$ must respect the condition below :

$$\omega_{i,t}^C(1 + R_{i,t}^k)q_{i,t-1}K_{i,t-1}(e) = (1 + P_{i,t-1}^L)L_{i,t-1}^H(e) \tag{5}$$

Contrary to Bernanke, Gertler and Gilchrist (BGG, 1999), this condition implies that entrepreneurs do not know the *ex-ante* value of $\overline{\omega}_{i,t}(e)$ (i.e. before the realization of ω).

Moreover, unlike these authors, the financial accelerator introduced in the model comes from a biased view of the entrepreneur on the expected return of projects and not from a moral hazard issue. This bias view concept is similar that of De Grauwe (2010) and allows for the introduction of an alternative financial accelerator in the model. This bias generates a distortion in the *ex-ante* entrepreneur's perception of the profitable project $\overline{\omega}_{i,t}(e)$ which is defined by the following CES function :

$$g\left(\overline{\omega}_{i,t+1}(e)\right) = \overline{\omega}_i(e)^{1/(1-\varkappa_i)}\left(\overline{\omega}_{i,t+1}(e)\right)^{\varkappa_i/(\varkappa_i-1)} \tag{6}$$

where $\varkappa_i \in [0, 1[$ denotes the bias intensity and $\overline{\omega}_i(e)$ corresponds to the long run value of $\overline{\omega}_{i,t}(e)$. Therefore, the financial accelerator mechanism can be summarized as follows. During economic and financial upturns, projects' aggregate returns increase above their steady state values ($\overline{\omega}_{i,t+1}(e) > \overline{\omega}_i(e)$). Entrepreneurs' forecasts regarding aggregate profitability are optimistic ($g\left(\overline{\omega}_{i,t+1}(e)\right) > \overline{\omega}_{i,t+1}(e)$) and send a stronger confidence signal to banks' beliefs about projects quality. Banks further reduce financial restrictions for entrepreneurs, and the latter can invest in more profitable projects, increasing aggregate return. During downturn episodes, this relationship between banking and real the sector exacerbates the economic and financial recession.

Furthermore, in the long run, it is assumed that entrepreneurs are not exposed to a biased view of aggregate returns, such as $g(\overline{\omega}_i(e)) = \overline{\omega}_i(e)$. Note that the force of the financial accelerator depends on the degree of bias, that is, this accelerator is stronger when $\varkappa_i$ converges to 1.

Once entrepreneur e forecasts the projects' aggregate returns before the realization of ω, it can to select profitable projects (i.e. $\geq \omega_{i,t}^{C}$) and choose the amount of capital $K_{i,t}(e)$ to maximize its *ex ante* profit function :

$$\Pi_{i,t}^{E}(e) = \mathbb{E}_t \left\{ \eta_{i,t+1}^{E} \left[g(\overline{\omega}_{i,t+1}(e))(1 + R_{i,t+1}^{k}) q_{i,t} K_{i,t}(e) - (1 + P_{i,t}^{L}) L_{i,t}^{H}(e) \right] \right\} \tag{7}$$

where $\eta_{i,t+1}^{E}$ reflects the proportion of profitable projects. From the banks' perspective, this share represents the entrepreneur's non-default probability.

Using the condition of equation (5), the maximization of this profit function generates an external finance premium that depends on the *ex-ante* aggregate profitability forecasts of entrepreneurs :

$$\frac{1 + R_{i,t+1}^{k}}{1 + P_{i,t}^{L}} = \frac{1}{g(\overline{\omega}_{i,t+1}(e))} = \overline{\omega}_i(e)^{-1/(1-\varkappa_i)} \left(\overline{\omega}_{i,t+1}(e)\right)^{-\varkappa_i/(\varkappa_i-1)} \tag{8}$$

The equation above highlights the negative relationship between entrepreneurs' forecasts and their credit access restrictions : the more optimistic entrepreneurs are the lower the external finance premium.

Finally, the law of motion of entrepreneurs net wealth is given by the profit obtained at the end of period $t-1$:

$$N_{i,t}(e) = (1 - \delta^{E}) \Pi_{i,t-1}^{E}(e) e^{\varepsilon_{i,t}^{N}} \tag{9}$$

where $\delta^{E} \in [0, 1[$ describes the tax rate on entrepreneurs' profit and $\varepsilon_{i,t}^{N}$ corresponds to a random exogenous shock on net wealth to capture exogenous changes in stock prices and demand for loans.

2.2 Banking sector

Monopolistic banks provide different types of loan and deposit services. Banks also set an interest rate subject to friction *à la* Calvo (1983). Banks' heterogeneous loan and deposit services are provided to financial intermediaries, who aggregate them to produce homogeneous loan and deposit services (such as a CES packer).

Each bank b in economy i finances its credit supply to domestic and foreign entrepreneur $L_{i,t}^{s}(b)$ with domestic households deposits $D_{i,t}(b)$, its own capital $BK_{i,t}(b)$ and liquidity furnished by central bank $L^{ECB}_{i,t}(b)$. In each period, banks must respect the following balance sheet constraint :

$$L^{s}_{i,t}(b) = D_{i,t}(b) + BK_{i,t}(b) + L^{ECB}_{i,t}(b) + liab_{i,t} \tag{10}$$

where $liab_{i,t} = exp(\varepsilon^{B}_{i,t})\overline{liab}_{i}$ represents an exogenous stochastic shock that captures aggregate changes in other liabilities in the banks' balance sheet that are not considered in the model. We assume that the cost of these liabilities is indexed to the intesrest rate of the central bank.

By considering the balance sheet constraint in equation (10), banks maximize the following profit function :

$$\begin{aligned}\Pi_{i,t} = &\left(1 - \mu^{B}\left(1 - \mathbb{E}_{t}\left\{\eta_{i,t+1}\right\}\right)\right)\left(1 + R^{L}_{i,t}\right)L^{s}_{i,t}(b) - \left(1 + R^{D}_{i,t}\right)D_{i,t}(b) \\ &- (1+R_{t})liab_{i,t} - (1+R_{t})L^{ECB}_{i,t} - \frac{\chi^{B}}{2}\left(\frac{BK_{i,t}(b)}{\text{RWA}_{i,t}(b)} - v^{B}_{i}\right)^{2} BK_{i,t}\end{aligned} \tag{11}$$

where $R^{L}_{i,t}$ and $R^{D}_{i,t}$ stand for loans and deposit interest rates respectively. R_{t} is the interest rate set by the central bank. The parameter $\mu^{B} \in [0,1]$ reflects the banking costs associated with the use of recovery agencies in the case of entrepreneurs' default. Variable $1 - \mathbb{E}_{t}\left\{\eta_{i,t+1}\right\}$ denotes the expected default probability of entrepreneurs. For each bank of economy i, this probability comes from an aggregation of domestic and foreign entrepreneurs' default rates such as :

$$\eta_{i,t} = \left[\left(\eta^{E}_{i,t}\right)^{1-\alpha^{L}_{i}}\left(\eta^{E}_{j,t}\right)^{\alpha^{L}_{j}}\right]^{1/(1-\alpha^{L}_{i}+\alpha^{L}_{j})} \quad \text{with} \quad i \neq j \tag{12}$$

Similar to Gerali et al.(2010), Garcia-Revelo and Levieuge (2022) and Badarau and Roussel (2022), banking activity is constrained by the capital requirements of a financial regulator. In the bank's profit function, the constraint is represented via a quadratic cost on any deviation of bank capital to risk-weighted-assets ratio (i.e. $BK_{i,t}(b)/\text{RWA}_{i,t}(b)$) from the value required by the financial regulator (i.e. $v^{B}_{i} = 10.5\%$). Parameter $\chi^{B} \geq 0$ describes the intensity of the capital requirements constraint on banking activity. As explained by Poutineau and Vermandel (2017), the representation of this constraint through a cost in the banks' profit function allows the production of a response of credit interest rates to prudential regulation that is closer to that observed empirically (Kashyap and Stein, 2004; Berrospide and Edge, 2019; Fraisse et al.2020 among others).

In the model, risk-weighted-assets are computed as the product of the credit supply to entrepreneurs $L^s_{i,t}(b)$ and the risk-weight assigned to these credits $rw_{i,t}(b)$ such as :

$$\text{RWA}_{i,t}(b) = rw_{i,t}(b) * L^s_{i,t}(b) \tag{13}$$

Moreover, as in Angelini et al.(2014), the bank capital accumulation process is determined by :

$$BK_{i,t} = (1 - \tau_i^B)\Pi_{i,t-1} \tag{14}$$

where $\tau_i^B \in [0, 1]$ reflects bank costs coming from resources used in managing bank capital.

By considering the banks' balance sheet constraint in equation (10) and capital requirements constraint, each bank b chooses the amount of credit supply $L^s_{i,t}(b)$ which maximizes its profit function. The first-order condition of this program defines the credit marginal cost $MC_{i,t}(b)$ as follows :

$$1 + MC_{i,t}(b) = \frac{1 + R_t - \chi^B \left(\frac{BK_{i,t}(b)}{\text{RWA}_{i,t}(b)} - v_i^B\right)\left(\frac{BK_{i,t}(b)}{\text{RWA}_{i,t}(b)}\right)^2 rw_{i,t}(b)}{1 - \mu^B \left(1 - \mathbb{E}_t \left\{\eta_{i,t+1}\right\}\right)} \tag{15}$$

The equation above indicates that, during financial upturns, banks are willing to provide more loans to increase their profits. However, this initiative can generate a decrease in bank capitalization with respect to capital requirements (i.e. $BK_{i,t}(b)/\text{RWA}_{i,t}(b) < v_i$) and leading to financial regulator sanction. This sanction implies an increase in bank marginal cost which tightens credits access to real economy and contains banking activity expansion (Van den Heuvel, 2014; Meh and Moran, 2010). The prudential sanction disappears when banks are able to meet their capital requirements.

2.3 Credit risk and Output Floor

2.3.1 Definition of IRB approach

In the same vein as Mendicino et al.(2018) and Darracq-Paries et al.(2019), it is supposed that each bank b can use an IRB approach to estimate the risk-weight of entrepreneurs' credits, i.e.

$rw_{i,t}(b)$. To use this approach in the model, banks must determine their Exposure-At-Default (EAD) and the borrowers' Default Probability (PD). The estimation of EAD depends on the Loss-Given-Default (LGD) of borrowers. The determination of EAD, PD and LGD allows banks to define the risk-weighted-assets (RWA) needed to meet capital requirements :

$$\text{RWA}_{i,t}^{IRB}(b) = rw_{i,t}^{IRB}(b) L_{i,t}^{s}(b) = CR_{i,t}(b) * 12.5 * EAD_{i,t}(b) \tag{16}$$

where $CR_{i,t}$ represents the amount of capital required to cover credit losses and the value of 12.5 corresponds to the inverse of capital requirement without capital conservation buffers (i.e. 8%). In the IRB approach, the Basel Committee imposes banks to compute $CR_{i,t}$ as follows :

$$CR_{i,t}(b) = LGD{*}\mathcal{N}\left[\left(1-\tau_{i,t}(b)\right)^{-0.5}\mathcal{N}^{-1}\left(PD_{i,t}(b)\right) + \left(\frac{\tau_{i,t}(b)}{1-\tau_{i,t}(b)}\right)^{0.5}\mathcal{N}^{-1}\left(0.999\right)\right] - LGD{*}PD_{i,t}(b)$$

where $\mathcal{N}[.]$ denotes the cumulative distribution function for a standard normal random variable while $\mathcal{N}^{-1}(.)$ is the inverse of this function. In the model, default probability of entrepreneurs is equal to $PD_{i,t} = 1 - \mathbb{E}_t\left\{\eta_{i,t+1}\right\}$. Variable $\tau_{i,t}$ indicates the correlation coefficient for borrower exposure. The Basel Committee mandates the computation of this coefficient as :

$$\tau_{i,t}(b) = 0.12\left[\frac{\left(1-e^{-50*PD_{i,t}(b)}\right)}{\left(1-e^{-50}\right)}\right] + 0.24\left[1 - \frac{\left(1-e^{-50*PD_{i,t}(b)}\right)}{\left(1-e^{-50}\right)}\right]$$

Similar to Darracq-Paries et al.(2011), Angeloni and Faia (2013) and Mendicino et al.(2018), this model focuses on the foundation IRB (F-IRB) approach by assuming that the LGD of borrowers in both economies is fixed by financial regulator and is equal to $LGD = 0.45$[4]. Moreover, in line with Darracq-Paries et al.(2011) and Darracq-Paries et al.(2016), it is assumed that the EAD of credits corresponds to the amount of loans acquired by entrepreneurs, that is, $EAD_{i,t}(b) = L_{i,t}^{s}(b)$. Combining these two assumptions allows us to define the risk-weight of credits as :

[4]Modeling Advanced-IRB (A-IRB) approach is more complex because it implies to access private banking data.

$$rw^{IRB}_{i,t}(b) = \left(\mathcal{N}\left[(1-\tau_{i,t}(b))^{-0.5}\mathcal{N}^{-1}\left(PD_{i,t}(b)\right) + \left(\frac{\tau_{i,t}(b)}{1-\tau_{i,t}(b)}\right)^{0.5}\mathcal{N}^{-1}\left(0.999\right)\right] - PD_{i,t}(b)\right) * 0.45 * 12.5 \quad (17)$$

2.3.2 Output Floor setting

Basel 3 finalization imposes banks to integrate an Output Floor (OF) in the computation of their risk-weighted-assets (RWA) estimated using the IRB approach. OF defines a minimum level of the RWA obtained using the IRB approach. This minimum corresponds to 72.5% of the RWA estimated using standardized approach (BCBS, 2017a). As in the work of Acosta-Smith et al.(2021), the OF implementation introduces a non-linear constraint in the RWA estimated with the IRB approach :

$$\text{RWA}^{OF}_{i,t}(b) = max\left\{\text{RWA}^{IRB}_{i,t}(b)\ ;\ 0.725 * \text{RWA}^{SA}_{i,t}(b)\right\} \quad (18)$$

where RWA^{SA}_{t} reflects RWA using a standardized approach, that is, $\text{RWA}^{SA}_{i,t} = rw^{SA}_{i,t} * L^{s}_{i,t}$ and $\text{RWA}^{OF}_{i,t}$ stands for RWA obtained with the Output Floor. In line with Poutineau and Vermandel (2017) and Gambacorta and Karmakar (2018), it is assumed that entrepreneurs credit risk using a standardized approach is equal to $rw^{SA}_{i,t} = 1$. Since banks' portfolio is only composed of entrepreneurs' credits in the model, the OF has a direct impact on credit risk :

$$\text{RWA}^{OF}_{i,t}(b) = L^{s}_{i,t}(b) * max\left\{rw^{IRB}_{i,t}(b)\ ; 0.725\right\} \quad (19)$$

Moreover, empirical evidence indicates that major banks mostly use IRB approach in credit risk estimation (Behn et al., 2016). Since it is assumed that each bank in economy i is identical, we take into account of this evidence in the model by assuming that a share γ^{IRB}_{i} of credits is estimated with the IRB approach by bank of economy i. The remaining share $1-\gamma^{IRB}_{i}$ is estimated with a standardized approach such as aggregate RWA of bank b in this economy, that is, $\text{RWA}^{A}_{i,t}(b)$ is given by :

$$\text{RWA}^{A}_{i,t}(b) = \gamma^{IRB}_{i}\text{RWA}^{OF}_{i,t}(b) + (1-\gamma^{IRB}_{i})rw^{SA}_{i,t} * L^{s}_{i,t}$$

As a result, the implementation of the Output Floor influences the optimal marginal cost of credits (equation (15)) such as :

$$1+MC_{i,t}(b) = \frac{1+R_t - \chi^B \left(\frac{BK_{i,t}(b)}{\text{RWA}^A_{i,t}(b)} - v^B_i\right)\left(\frac{BK_{i,t}(b)}{\text{RWA}^A_{i,t}(b)}\right)^2 * \left[(1-\gamma_i^{IRB}) + \gamma_i^{IRB} max\left\{rw^{IRB}_{i,t}(b)\,;0.725\right\}\right]}{1-\mu^B\left(1-\mathbb{E}_t\left\{\eta_{i,t+1}\right\}\right)} \tag{20}$$

In addition to capital requirements, monopolistic banks can set loans and deposits interest rates to create margins. This monopolistic market power generates rigidity in interest rates adjustments. The model uses Calvo's (1983) friction to reflect this rigidity such that at each period, a fraction θ_i^L (or θ_i^D) of banks is not able to adjust its loans (or deposits) interest rate which implies that (or $R^D_{i,t} = R^D_{i,t-1}$). The fraction $1-\theta_i^L$ (or $1-\theta_i^D$) is thus able to set the optimal interest rate $R^{L*}_{i,t}$ (or $R^{D*}_{i,t}$) to maximize its profit. The definition of the optimal rate in the loan and deposit markets is derived from the maximization of the following programs :

For entrepreneurs' credits :

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \left(\theta_i^L\right)^\tau \Lambda_{i,t+\tau}\left(1-\mu^B\left(1-\eta_{i,t+1+\tau}\right)\right)\left[R^{L*}_{i,t} - exp(\varepsilon^L_{i,t+\tau})MC^L_{i,t+\tau}\right] L^s_{i,t+\tau} \tag{21}$$

For households' deposits:

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \left(\theta_i^D\right)^\tau \Lambda_{i,t+\tau}\left[R_{t+\tau} exp(\varepsilon^D_{i,t+\tau}) - R^{D*}_{i,t}\right] D_{i,t+\tau} \tag{22}$$

where $\varepsilon^L_{i,t}$ and $\varepsilon^D_{i,t}$ are stochastic shocks that capture exogenous changes in the loans and deposits interest rates respectively.

After aggregation and setting equilibrium conditions, the evolution of loans and deposits interest rate are given by :

For loans interest rate :

$$\left(R^L_{i,t}\right)^{1-\epsilon_L} = \theta_i^L \left(R^L_{i,t}\right)^{1-\epsilon_L} + \left(1-\theta_i^L\right)\left(R^{L*}_{i,t}\right)^{1-\epsilon_L}$$

For deposits interest rate :

$$\left(R_{i,t}^{D}\right)^{1-\epsilon_D} = \theta_i^{D}\left(R_{i,t}^{D}\right)^{1-\epsilon_D} + \left(1-\theta_i^{D}\right)\left(R_{i,t}^{D*}\right)^{1-\epsilon_D}$$

2.4 Government, central bank and financial regulator

In each economy i, the government finances public spending with the fiscal revenue obtained from households. Hence, the government does not borrow to meet the public budget. As in Smets and Wouters (2007), it is assumed that the evolution of public spending $G_{i,t}$ is exogenous, that is, $G_{i,t} = g\overline{Y}exp(\varepsilon_{i,t}^{G})$ (with $g\overline{Y}$, the constant share of public spending g financed with long-run production $\overline{Y}$). Variable $exp(\varepsilon_{i,t}^{G})$ is a stochastic shock that captures exogenous changes in public spending.

There is also a central bank that sets a common monetary policy for both economies. This monetary policy has the following Taylor rule :

$$R_t - \overline{R} = \rho\left(R_{t-1} - \overline{R}\right) + (1-\rho)\left(\phi^{\pi}\pi_t^{C} + \phi^{\Delta_Y}\left(Y_t - Y_{t-1}\right)\right) + \varepsilon_t^{R} \tag{23}$$

where $\overline{R}$ represents the long-term central bank interest rate. Parameters ϕ^{π} and ϕ^{Δ_Y} respectively denote the sensitivity of monetary policy to changes in inflation and production at the Euro Area level, that is, $\pi_t^C = n\pi_{c,t}^C + (1_n)\pi_{p,t}^C$ and $Y_t = nY_{c,t} + (1-n)Y_{p,t}$. Parameters n reflects the economic weight of core economies in the Euro Area activities. The variable ε_t^R is a stochastic shock that captures exogenous changes in monetary policy.

Finally, in each economy i, there is a financial regulator that sets a prudential policy to maintain financial stability. As explained in previous parts of the section, this policy corresponds to imposing capital requirements of $v_i^B = 10.5\%$ in banks' activity.

2.5 Calibration

Most of the model's parameters calibration follows the values estimated by Poutineau and Vermandel (2017) and are presented in Table 1[5].

[5]Authors estimated parameters using data from Austria, Belgium, Germany, France, Luxembourg and the Netherlands for core economies and Greece, Italy, Ireland, Portugal and Spain for periphery economies.

Table 1: Calibration of structural parameters and shocks

Parameter	Core	Periphery	Monetary union
Structural parameters			
h^C	0.55	0.48	–
h^L	0.79	0.91	–
σ^H	0.79	1.96	–
ξ^P	0.22	0.23	–
ξ^W	0.51	0.18	–
θ^P	0.72	0.72	–
θ^W	0.85	0.89	–
θ^E	0.84	0.52	–
θ^L	0.71	0.74	–
θ^D	0.79	0.73	–
χ^D	0.07	0.07	–
χ^I	6.59	7.83	–
ψ	0.71	0.7	–
$\varkappa$	0.13	0.09	–
α^C	0.08	0.14	–
α^I	0.05	0.08	–
α^L	0.05	0.12	–
$\overline{\sigma_{ln(\omega)}}$	0.181	0.2	–
$\overline{\sigma^{OF}_{ln(\omega)}}$	0.209	0.209	–
γ^{IRB}	0.635	0.4	–
υ^B	0.105	0.105	–
χ^B	11	11	–
β	–	–	$1/1.01$
α	–	–	0.38
δ	–	–	0.025
μ	–	–	1.42
ν	–	–	1.1
ϵ_P	–	–	10
ϵ_W	–	–	10
μ^B	–	–	0.1
$g\overline{Y}$	–	–	0.24
n	–	–	0.58
ρ	–	–	0.84
ϕ^π	–	–	1.65
ϕ^{Δ_Y}	–	–	8

Parameter	Core	Periphery	Monetary union
Shocks			
Parameters ρ^m			
ρ^A	0.98	0.96	–
ρ^G	0.87	0.63	–
ρ^U	0.29	0.82	–
ρ^I	0.79	0.68	–
ρ^P	0.99	0.76	–
ρ^W	0.49	0.16	–
ρ^N	0.86	0.91	–
ρ^D	0.88	0.9	–
ρ^B	0.94	0.96	–
ρ^L	0.71	0.68	–
ρ^σ	–	–	0.98
ρ^R	–	–	0.36
Innovations σ^m (in percentage)			
σ^A	0.82	0.79	–
σ^G	1.43	1.39	–
σ^U	1.24	1.52	–
σ^I	2.55	2.57	–
σ^P	0.1	0.29	–
σ^W	0.45	0.71	–
σ^N	0.36	0.37	–
σ^D	0.3	0.64	–
σ^B	5.89	9.75	–
σ^L	2.31	2.09	–
σ^σ	–	–	0.08
σ^R	–	–	0.09

By using the work of Darracq-Paries et al.(2019), it is supposed that, in absence of Output Floor, long run value of credit risk weight is equal to $rw_c^{IRB} = 0.45$ for core economy and $rw_p^{IRB} = 0.59$ for periphery economy[6]. These values indicate that risk weights in both economies are lower than the level of credit risk imposed by the OF, that is, 0.725. Hence, in the long run, OF implementation in both economies leads to a risk-weight of $rw_c^{IRB-OF} = rw_p^{IRB-OF} = 0.725$.

Parameters $\overline{\sigma_{ln(\omega_c)}}$ and $\overline{\sigma_{ln(\omega_p)}}$ are calibrated such that, in the long run, the default probability of entrepreneurs generates credit risk weights consistent with and without OF setting. This means that, without OF, $\overline{\sigma_{ln(\omega_c)}} = 0.181$ and $\overline{\sigma_{ln(\omega_p)}} = 0.2$ which implies a long run default probability equal to $PD_c = 0.3\%$ for the core economy and $PD_p = 0.7\%$ for the periphery economy[7]. OF implementation provides homogeneity in banking risk because it implies that $\overline{\sigma_{ln(\omega_c)}} = \overline{\sigma_{ln(\omega_c)}} = 0.209$ and long run default probabilities are equal to $PD_c = PD_p = 0.97\%$ for both economies.

Moreover, based on data from the European Banking Authority, it is assumed that $\gamma_c^{IRB} = 0.635$ and $\gamma_p^{IRB} = 0.4$[8].

Finally, regarding parameters of risk shock ε_t^{σ}, the paper follows Darracq-Paries et al.(2019) by assuming that $\rho^{\sigma} = 0.98$ and $\sigma^{\sigma} = 0.08$.

3 Long run effect of the Output Floor

In this section, we first analyze the long run effect of the Output Floor on financial and real activities in the Euro Area. Then, we discuss the best option between a progressive floor on IRB-RWA (i.e. phase-in process) and a non-progressive one.

3.1 Does Output Floor beneficial for Euro Area in the long run ?

One of the main questions for European financial regulators about the OF setting is its potential long run benefits on the financial and real economic sectors in the Euro Area. This question

[6]Values are based on the average between France and Germany for core economies and Italy and Spain for periphery economies.

[7]Long run default probabilities are obtained by fixing steady state value of ω^C at 0.6 in both economies. The value of ω^C is close to the one obtained in Poutineau and Vermandel (2017).

[8]Calibration of γ_c^{IRB} and γ_p^{IRB} corresponds to the average value in Austria, Belgium, Germany, France, Luxembourg and Netherlands for core economies and Greece, Italy, Ireland, Portugal and Spain for periphery economies. EBA dataset comes from the 2021 - EU Wide Transparency Exercise and is available *via* following URL link : https://www.eba.europa.eu/risk-analysis-and-data/eu-wide-transparency-exercise/2021

is also important to counterbalance the banking industry arguments regarding the potential short and medium-term costs of the prudential instrument. Budnik et al.(2021) find a potential long-term benefits of Output Floor implementation but highlights that alternative Output Floor settings designed to reduce OF transitory costs leads to a decrease in long run benefits[9].

In this section, we check the existence of these benefits and study their consequences on welfare for Euro Area economies. To do so, we first assume that, in both economies, credit risk estimated using a standardized approach is fixed at 100% as in Gambacorta and Karmakar (2018). This calibration implies that credit risk estimated with IRB approach is lower than the one required by the Output Floor for both economies ($rw_c^{IRB} = 0.45 < 0.725$ and $rw_p^{IRB} = 0.59 < 0.725$). As a result, in the model, OF implementation forces banks to adjust their borrowers' default probability upward. This adjustment has a structural impact on banking and real activities in the Euro Area. Moreover, the new long run risk weights calibration implied by the OF setting homogenizes financial and economic conditions in the Euro Area. Hence, the OF favors financial and economic convergence between core and peripheral economies. To examine this convergence, Figure 3 depicts the long run changes in the main macrofinancial and macroeconomic variables in both economies after OF implementation. In each histogram of the figure, first and second bar ('S1' and 'S2' on graphs) denotes long run changes for core and peripheral economies respectively, while the last bar ('S3') corresponds to the heterogeneity evolution between both economy types. For each variable x displayed in the figure, the heterogeneity is given by :

$$\text{Heterogeneity} = abs\left(\frac{x^{core}}{x^{periphery}} - 1\right)$$

where $abs(.)$ is the absolute value of the spread between heterogeneity observed in the model and perfect homogeneous situation (i.e. a ratio equal to 1).

As expected, Figure 3 shows that the OF implementation increases banks' RWA in both economies.

[9]Alternative Output Floor settings suggested by the authors are as follows : 1) applying Pillar 2 requirements and systemic risk buffer (SRB) to unfloored RWAs; 2) defining capital requirements as the higher between floored requirements excluding Pillar 2 and SRB and the unfloored requirements including Pillar 2 and the SRB (parallel stacks approach).

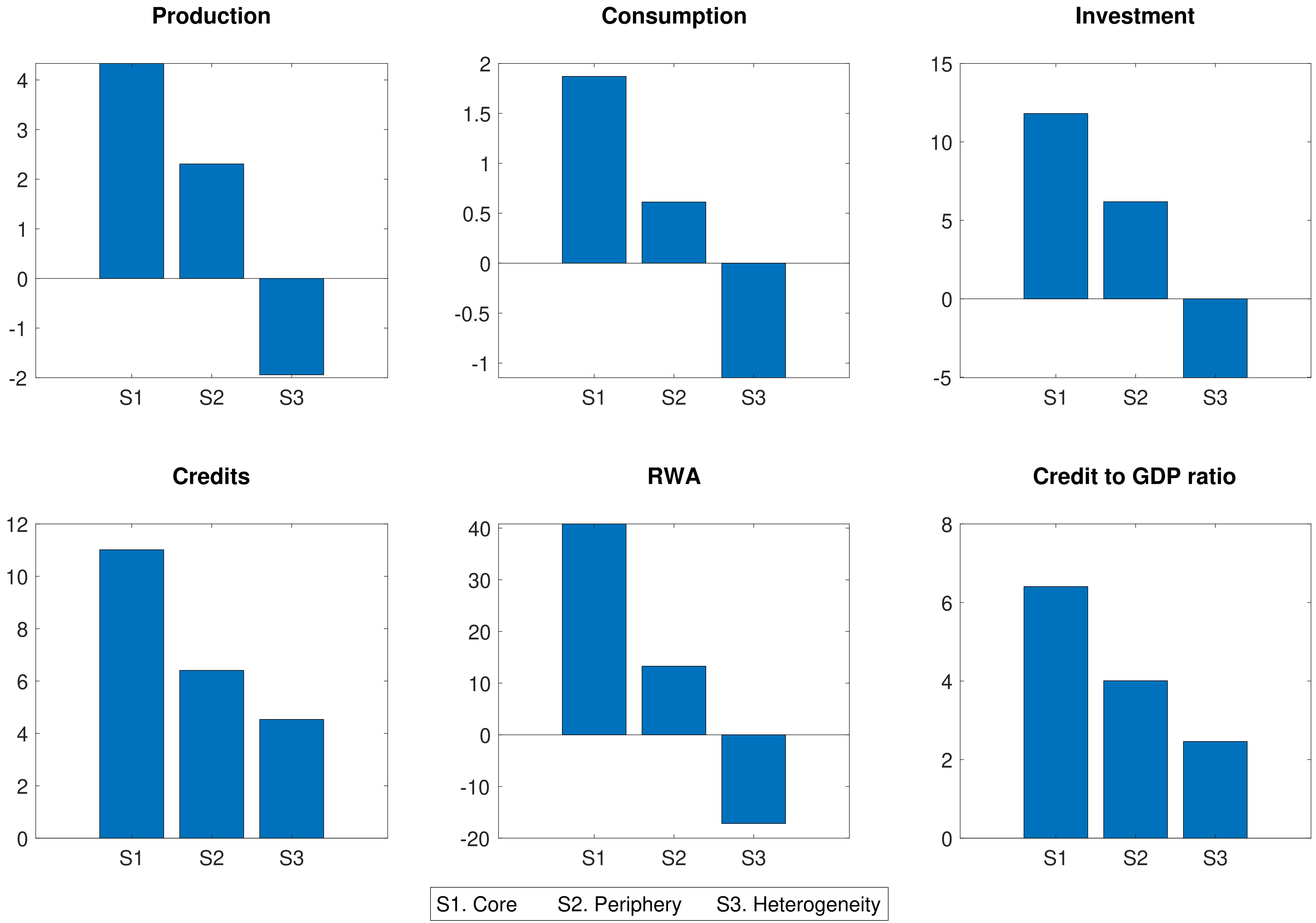


Figure 3: Long run effect of Output Floor on banking and economic activities in the Euro Area.

Note : For 'S1' et 'S2', values are expressed in percentage deviation with respect to steady-state level of variables without OF setting. For 'S3', values are expressed in percentage absolute deviation, i.e. $(\text{Hétérogénéité}^{OF} - \text{Hétérogénéité}) * 100$. 'Credits' variable stands for banks credit supply.

Note that this increase is higher for core banks because of the larger spread between the old and new steady-state risk weight (from 0.45 to 0.725). The higher share of IRB estimation in core banks' credit portfolio amplifies the increase of RWA ($\gamma_c^{IRB} = 0.635$ for core banks and $\gamma_f^{IRB} = 0.4$ for periphery banks). However, OF implementation allows periphery banks to get a long run level of RWA closer to that of core banks (decrease in heterogeneity index in the figure), which improves the comparability of the capital adequacy ratio between both bank types. This effect is in line with the OF role expected by Basel Committee.

Moreover, the rise in RWA for core and periphery banks leads to an increase in banks' capital to meet capital requirements (i.e. $v^B = 10.5\%$). Since banks' capital is fueled by banks' profit, the increase in bank capital means that banks provides more loans to generate more profits. At the equilibrium, the expansion of credit supply encourages entrepreneurs to finance more firms' projects, which stimulates investment and production in the real sector. This surplus production is partly redistributed in additional wages for households. The latter uses revenue surplus to increase their consumption, which amplifies the rise of production to satisfy higher demand.

Nevertheless, the surge in credit supply leads to higher banking funding for the production sector, which translates into an increase in the credit-to-GDP ratio for both economies. Furthermore, an increase in credit supply is very different between the two economies and generates a stronger heterogeneity in financial conditions between core and periphery entrepreneurs.

Despite this unintended effect, OF implementation seems to favor convergence of banking risk and economic activity among Euro Area countries (decrease in heterogeneity in RWA and real sector variables). This result is in line with the financial and economic integration promoted by European regulators.

Consequently, Figure 3 indicates that, in the long run, the OF provides benefits for the financial and economic sector, which confirm sconclusions obtained by Budnik et al.(2021).

However, these OF benefits do not inform the social gains of the instrument for Euro Area agents. To examine these social gains, our model follows Chen and Columba (2016) by assuming that, in each economy i, social gains come from an increase in households welfare. As in Cole et al.(2020), welfare $\mathcal{W}_{i,t}$ in economy i is defined with respect to the inter-temporal utility function of households in this economy. Recursively, the welfare index is given by :

$$\mathcal{W}_{i,t} = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U(C_{i,t}, H_{i,t}) \tag{24}$$

$$\mathcal{W}_{i,t} = U(C_{i,t}, H_{i,t}) + \beta \mathcal{W}_{i,t+1} \tag{25}$$

Where $U(C_{i,t}, H_{i,t})$ is the utility function. The utility function has a positive relationship with households consumption $C_{i,t}$ and a negative relationship with the number of hours worked $H_{i,t}$ by the households in firms activity. Similar to Poutineau and Vermandel (2017), the welfare index for the Euro Area corresponds to the sum of the welfare indices in both economies i weighted by their economic importance in the monetary union :

$$\mathcal{W}_t^{EA} = n * \mathcal{W}_{c,t} + (1-n) * \mathcal{W}_{p,t}$$

where $n \in [0,1]$ denotes the economic importance of core countries in the Euro Area.

Because the utility level is constant in the long run, it is possible to rewrite the welfare index as follows :

$$\mathcal{W}_i = \frac{U(C_i, H_i)}{1-\beta} \qquad \forall i \in \{c, p\}$$

$$\mathcal{W}^{EA} = n * \mathcal{W}_c + (1-n) * \mathcal{W}_p$$

Figure 4 depicts the evolution of the welfare index for both economies when the Output Floor is activated. Surprisingly, the implementation of the instrument reduces welfare in both economies while Figure 3 shows an increase in households consumption. This result could be explained by the fact that the structural rise in production requires an increase in hours worked by households. This increase overcompensates fot the elevation of households consumption, which generates a decrease in the welfare.

Nevertheless, this statement does not mean that, in the long run, OF implementation is detrimental to European societies for two reasons. The first is that OF stimulates consumption and production even if the increase in labor desutility contributes to reducing welfare. The second reason is that the main goal of the Output Floor is to improve banks' robustness in order

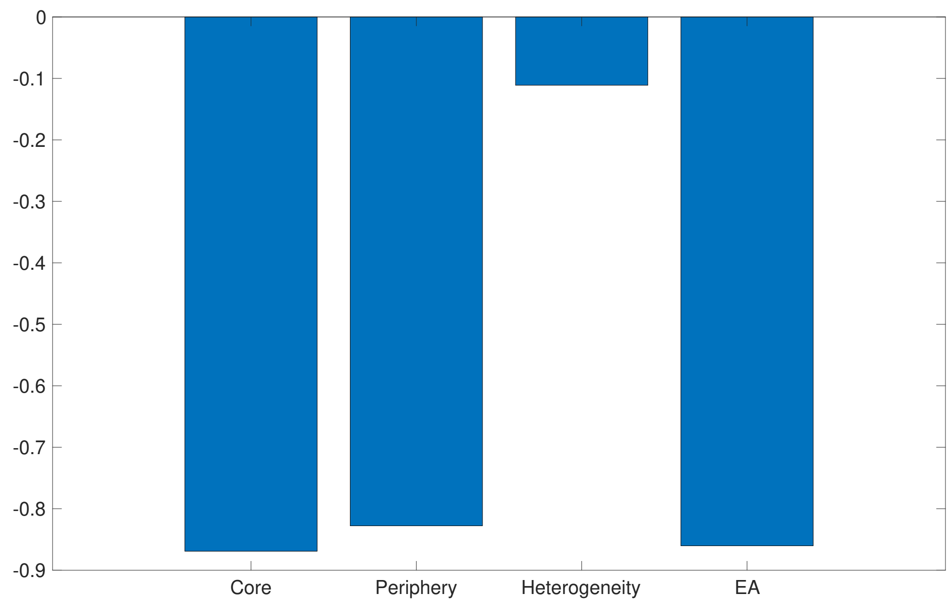


Figure 4: Long run impact of Output Floor setting on welfare in the Euro Area.

Note : Variable for core, periphery and Euro Area are expressed in percentage deviation with respect to their steady-state level without OF setting. The value of the variable 'Heterogeneity' is expressed in percentage absolute deviation i.e. $(\text{Heterogeneity}^{OF} - \text{Heterogeneity}) * 100$.

to promote financial stability.

3.2 Discussion about benefits of phase-in process for Output Floor

The previous subsection of this paper has shown that OF generates long run impacts on banking and economic activities in the Euro Area. Moreover, the finalization of Basel 3, published in 2017, has suggested the progressive implementation of the OF in order to give banks enough time to adapt their activities to this new prudential regulation (BCBS, 2017b). This progressive OF implementation, also called the phase-in process, consists of gradually raising the floor of the IRB-RWA estimation over a defined period.

Initially, the phase-in process was applicable in January 2022. However, the Basel Committee suggested postponing it in January 2023 because of the sanitary crisis (BCBS, 2023b). Furthermore, in the Euro Area, the European Commission and the European Council proposed that the Output Floor be phased in from the start of 2025 (50 percent of SA-RWA) to the start of 2030 (72.5 percent) (Andersen and Johnsen, 2023). As shown by Table 2, the beginning of the European phase-in process is two years later than that suggested by the Basel Committee but the pace of increase in the floor remains the same :

Table 2: Calendar of Output Floor phase-in process.

Date	01/2025	01/2026	01/2027	01/2028	01/2029	01/2030
OF	50%	55%	60%	65%	70%	72.5%

Source : BCBS (2023b), Andersen and Johnsen (2023).

For European financial regulators, the adoption of a phase-in process limits the OF implementation costs on banking activity because the floor binds at the end of process[10] which is also confirmed by the work of Andersen and Johnsen (2023). In our paper, long run risk-weights calibration implies that core banks bind the floor at each step of the phase-in process ($rw_c^{IRB} = 0.45$) while peripheral banks bind the floor in the middle or end of the process ($rw_p^{IRB} = 0.59$). This statement provides a more granular analysis of the potential benefits of the phase-in process to limit OF implementation costs in banking and economic activities. This analysis is perfomed by simulating the progressive increase in the floor *via* successive deterministic shocks. These shocks enter into force every year over a period of five years with respect to the time intervals defined by the Basel Committee. Moreover, it is assumed that the financial regulator announces the beginning of the phase-in process five years before its implementation. This permits banks (and all other agents in the model) to anticipate credit and deposit activities[11]. It is also assumed that OF can be implemented without a phase-in process to highlight the contribution of this process in limiting OF implementation costs for macrofinancial and macroeconomic variables. Figure 5 depicts the dynamics of the main macrofinancial and macroeconomic variables with (solid black line on graphs of the figure) and without (dashed black line) the phase-in process. The x-axis in each graph describes the time horizon, expressed in a quarter. The first and second row of the graphs correspond to variables of core and periphery economies respectively. The last row represents key macrofinancial and macroeconomic variables common to both economies.

[10]See the speech made by Elizabeth McCaul, Member of the Supervisory Board of the ECB, at the Working Group Financial Services. URL link of speech : https://www.bankingsupervision.europa.eu/press/speeches/date/2021/html/ssm.sp210908_1~2f82d84760.en.html

[11]The announcement of five years replicates time period between Basel 3 finalization publication in 2017 and the first calendar of phase-in process, i.e. from January 2022 to January 2027. Since COVID-19 crisis and European regulators decision about phase-in postponing happened after the Basel 3 finalization publication, it is more complex to integrate these phenomena in our anticipation exercise.

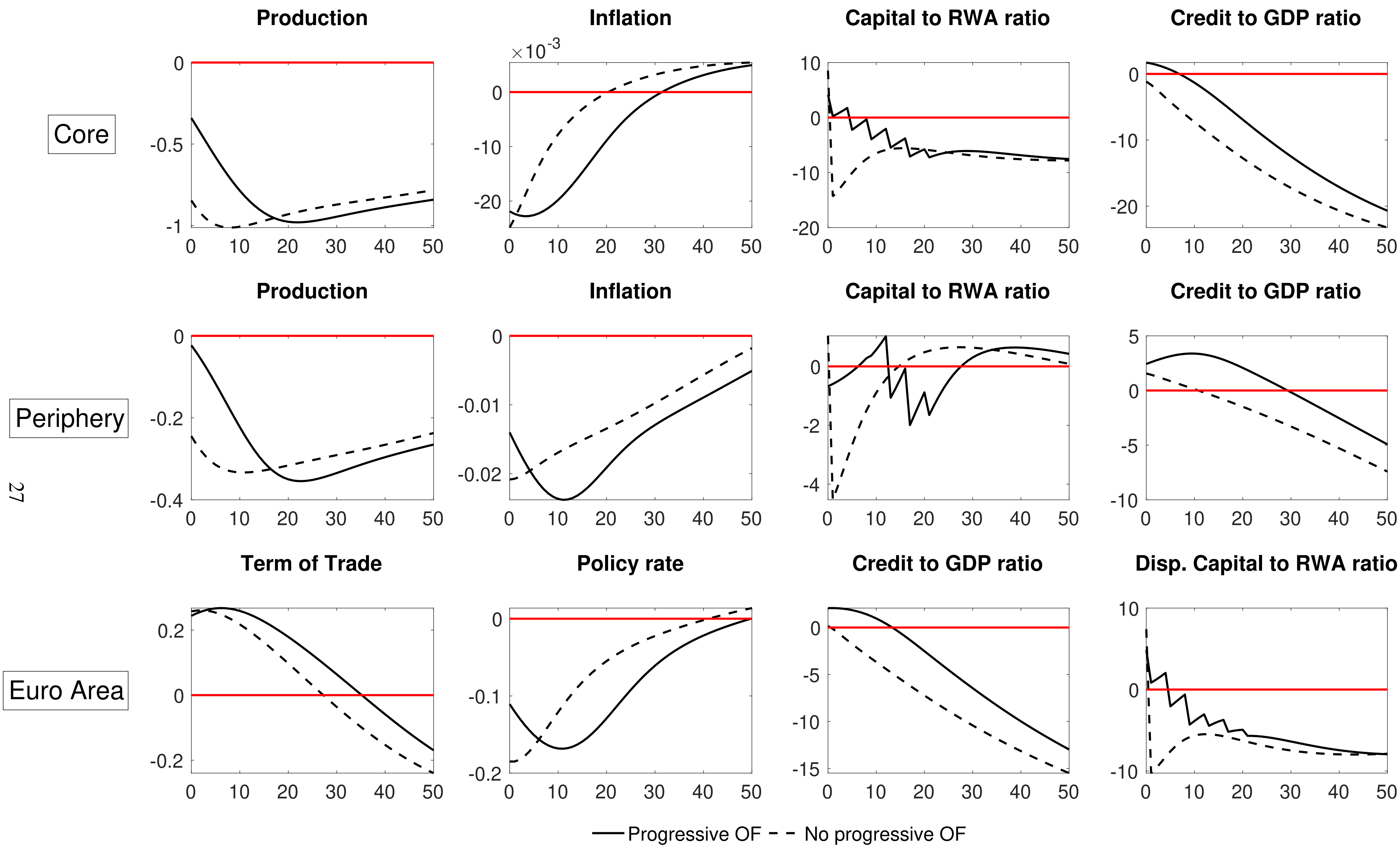


Figure 5: Phase-in versus full OF implementation : impact on banking and economic activities.

Note : Interest rates are annualized and expressed in percentage point deviation from their steady-state values. Other variables are expressed in percentage deviation from their steady-state values. Variables responses come from a simulation over a period of 2000 quarters. In order to get round instability problems of permanent shock in simulation and preserve consistent agents behavior, last deterministic shock is activated until the 1800th quarters.

Among these variables, the 'Term of Trade' denotes the ratio between periphery and core production good price, that is, $P_{p,t}/P_{c,t}$. The variable 'Disp. Capital to RWA ratio' expresses the dispersion (or variability) of banks capital-to-RWA ratio between core and periphery banks. Dispersion of this ratio is one of the key variables for studying OF efficiency and is equal to :

$$\text{Dispersion}_t = \frac{BK_{c,t}(b)}{\text{RWA}_{c,t}(b)} \frac{\text{RWA}_{p,t}(b)}{BK_{p,t}(b)}$$

As mentioned previously, in the model, the phase-in process implies that the risk-weights of core banks binds gradual floors earlier than those of periphery banks. This difference in the sequence of binding floors leads to a more progressive decline in capital-to-RWA ratio for core banks. Binding floors for periphery banks occurs at the third step of the phase-in process, but really affects the ratio at the fourth step (when the floor is equal to 65%). Compared to core banks, binding floors for periphery banks generates smaller adjustments of their capital-to-RWA ratio. After the end of the phase-in process, for core banks, this ratio remains below the value required by prudential regulation, while the opposite is true for periphery banks. This result provides a more granular view of the potential OF impacts on banks' capital management in Euro Area countries. Furthermore, in comparison with no gradual floors (dashed black line on graphs), the phase-in process reduces the volatility of the ratio and its variability between core and periphery banks (smaller amplitude changes in the dispersion of the ratio). Hence, the phase-in process limits the increase in capital requirements costs for banks, and the latter dampen entrepreneurs' credit restrictions implied by OF implementation.

A smaller reduction in credit access slows the production downturn in both economies. Despite the decrease in inflation in these economies, term of trade of trade appreciation provides better support in the production downturn of core economies.

Faced with the fall of good prices, the central bank sets an accommodating monetary policy, which dampens the increase in loan interest rates and improves entrepreneurs' credit access. During the phase-in process, this improvement generates an increase in the credit-to-GDP ratio among Euro Area countries.

However, at the end of the phase-in process, for both economies, the reduction in production is stronger than in the scenario without gradual floors. Therefore, the process produces a tradeoff between lower economic cost in the short run and a larger one in the medium run (i.e. after the end of the process).

Consequently, in comparison with no gradual floors, all results highlighted in this sub-section indicate that the phase-in process allows the reducction of banking and economic costs in the short run (i.e. during the process) implied by OF implementation. Nevertheless, these benefits are at a higher economic cost in the medium run, that is, after the completion of the process. In the long run, the previous sub-sections have shown that bank OF implementation incites banks to increase their credit activity, which stimulates investment and production in the real sector. Hence, the higher medium run economic cost implied by the phase-in process is temporary.

4 Output Floor and banking solvency along financial and business cycle

As previously explained, the main goal of the Output Floor is to limit the volatility and variability (or dispersion) of bank capital-to-RWA ratio. Reaching this goal also permits the reduction of banking solvency risks represented by significant changes in the ratio. The aim of this section is to examine whether OF can reach this goal along financial and business cycle driven by financial and real shocks.

To do so, we select three exogenous stochastic shocks consistent with the study of the Output Floor : a negative policy rate shock ; a negative risk shock and a positive productivity shock in firms of core economies.

The first shock is similar to an accommodated conventional monetary policy, which corresponds to a decrease in the central bank interest rate. This shock could trigger the Output Floor during financial and economic cycles. Moreover, as mentioned by Acosta-Smith et al.(2021), this shock is a consistent choice to analyze the impact of the Output Floor on banking activity because accommodating monetary policy contributes to banks' risk-taking (Delis and Kouretas, 2011; Heider et al., 2019 ; Bubeck et al., 2020 among others).

The second shock (i.e. ε_t^{σ}) reflects a decrease in entrepreneurs default probability. As in

Darracq-Paries et al. (2019), this shock is set at the Euro Area level to underline the importance of financial and international trade channels in transmitting shocks across borders.

While the two previous shocks are common to both economies, productivity shock triggers only the production sector of core economies. As mentioned by Poutineau and Vermandel (2017), this shock is one of the key drivers of financial indicators used in prudential regulation.

Moreover, OF activation under these shocks implies the introducection of a piece-wise linear regime in RWA evolution. Similar to the work of Acosta-Smith et al.(2021), we use *DynareOBC* software of Holden (2016) to solve the DSGE model by taking into account of the regime switching.

Then, we examine the OF's influence on banking solvency and the real sector in Euro Area *via* Impulse Response Functions (IRFs) of appropriate macrofinancial and macroeconomic variables for our study.

Figure 6 depicts the IRFs of the key indicators in Output Floor efficiency with respect to the three shocks. In each graph of the figure, the dashed and solid black lines denote responses of these indicators with and without OF setting respectively.

Regarding the negative policy rate, we observe that accommodating monetary policy diminishes the capital-to-RWA ratio for banks in both economies and thus, increases banking solvency risk. In addition to this detrimental effect on banks' robustness, the shock increases the variability in the ratio between these banks. As displayed in Figure 8 (presented in the appendix), the increase in banks leverage is explained by the fact that lower central bank rate incites financial intermediaries to decrease their credits interest rate. Better credit access allows entrepreneurs to increase their investment in firms' projects. A rise in productive investment stimulates production and improves projects' returns. An increase in profitable projects favors a reduction in entrepreneurs' default probability. Moreover, due to the financial accelerator designed in the model, better quality projects today incites entrepreneurs to get an overoptimistic view of future projects' returns. This overoptimistic behavior amplifies the decrease in entrepreneurs default probability expected by banks, which in turn further reduces credits restriction.

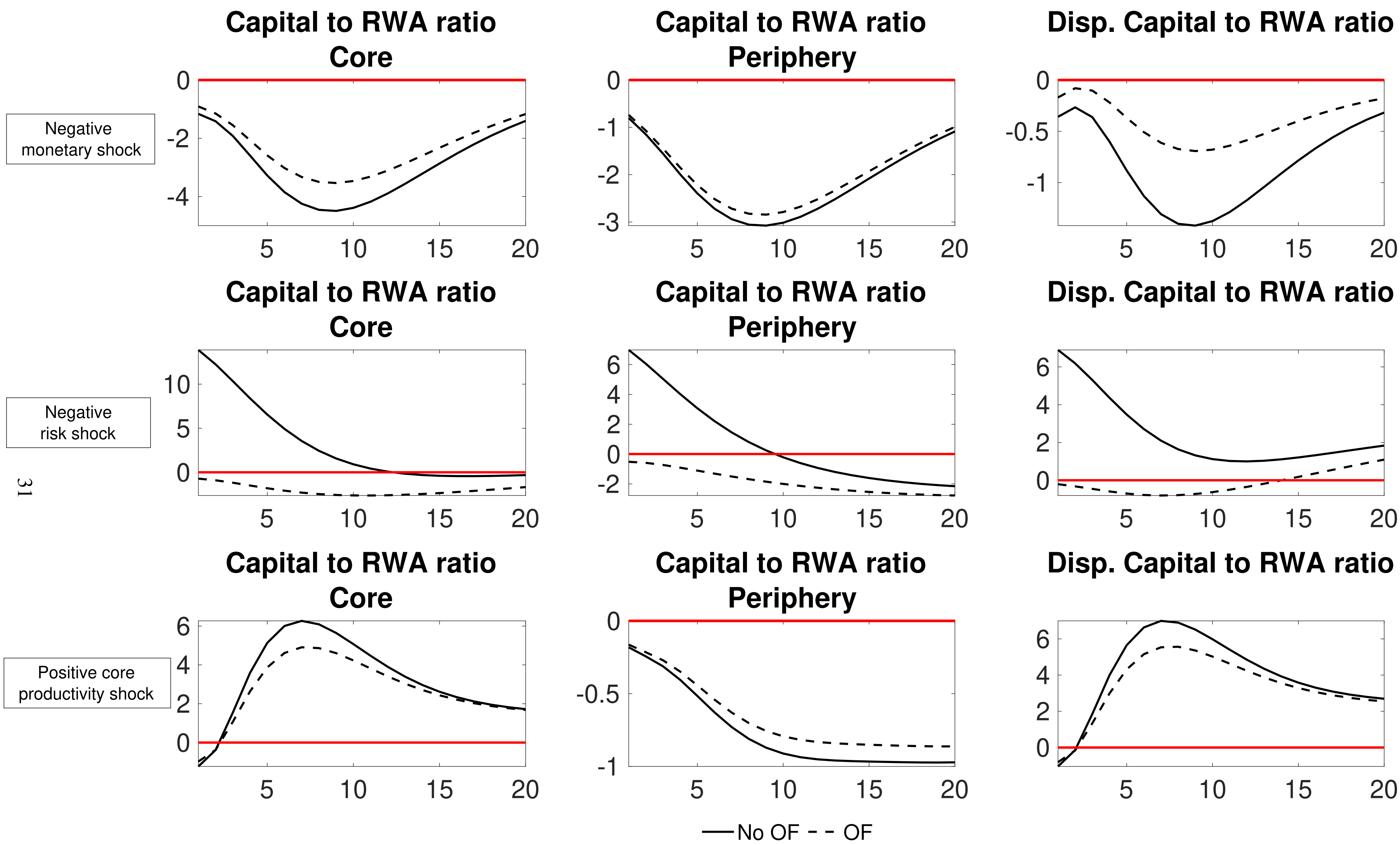


Figure 6: Efficiency of Output Floor in banking solvency across financial and economic shocks.

Note : Values are expressed in percentage deviation from steady-state level of variables (i.e. $v^b = 10.5\%$).

Besides, the appreciation of the term of trade creates a stronger attraction for core production goods in the Euro Area and emphasizes the increase in returns for core firms' projects. This international trade effect contributes to explaining the stronger reduction in banks' credits interest rate in the core economy.

When the Output floor is implemented, Figure 6 indicates that the prudential instrument curbs the reduction in bank capital-to-RWA ratio in the both economies (dashed black lines in figure). This effect diminishes the volatility of the ratio and its variability (or dispersion) between core and peripheral banks. Therefore, the Output Floor can reach its goals when an accommodated monetary policy shock occurs.

Note that the OF setting has almost no impact on the reduction of policy rate and credits interest rate, which confirms the compatibility between the prudential instrument and accommodating monetary policy[12].

Regarding the negative risk shock, Figure 6 shows that this shock boosts the capital-to-RWA ratio for banks in both economies. However, this result does not mean that banks are better capitalized because the rise in the ratio is mostly due to the strong decrease in entrepreneurs' credit risk fueled by the reduction in their default probability. Furthermore, strong variations in the ratio in the Euro Area banking system lead to more variability in the ratio between core and peripheral banks, which erodes its reliability for financial investors.

In addition, as reflected in Figure 9 (presented in the appendix), a strong decrease in entrepreneurs' default probability encourages banks to relax their credits access condition *via* a significant reduction in their loans interest rate. Entrepreneurs can finance more firms' projects at a lower cost, which stimulates investment and production in the real sector.

Once the Output Floor is activated, Figure 6 reveals that the prudential instrument limits the strong decrease in entrepreneurs credit risk. Moreover, the shock leads credit risk to bind the floor of the prudential instrument, which prevents banks to display an "artificial" better capitalization fueled the decrease of credit risk. Instead, in both economies, banks are not sufficiently capitalized and financial regulator sets prudential sanction in banking activity. As

[12]Since steady-state values for policy rate and credits interest rate do not change with OF implementation, on the figure, we can easily deduce the lower or higher short / medium term impact of the prudential instrument on these variables. However, production, credits and credit-to-GDP-ratio have a different steady-state values with OF implementation. Hence, it is more complex to interpret OF impact in the short / medium run for these variables.

Figure 9 shows, this sanction curbs the reduction in credits interest rate set by banks.

In addition, OF implementation allows to reduce the volatility and variability of the capital-to-RWA ratio between core and periphery banks. These results confirms the crucial role of the Output Floor in limiting banks' capacity to artificially improve their financial wealth. Hence, OF preserves financial confidence in the bank solvency indicator (i.e. capital-to-RWA ratio).

Regarding the positive productivity shocks in core economies, Figure 6 shows that this shock generates better capitalization for core banks, but not for periphery banks. This asymmetric effect contributes to the increased variability in the capital-to-RWA ratio between both bank types.

Looking at Figure 10 (presented in the appendix), we observe that the asymmetric effect is driven by the asymmetric impact of shocks on core and periphery firms' productivity. Indeed, this shock benefits production in core economies mostly. Part of the extra revenue created by the rise of core production is dedicated to domestic households' wage who decide to increase their consumption of domestic and foreign goods. Higher demand for foreign goods stimulates the production of periphery firms. Nevertheless, the shock produces a significant decrease in the price of core firm goods and generates a term of trade appreciation. Core firms are more competitive than periphery firms, dampening the increase in periphery production. Moreover, differences in firms competition cause asymmetry in projects quality, as proposed by core and peripheral entrepreneurs. As a result, core banks are more incite to relax financial restrictions (i.e. a decrease in credit interest rate) than periphery ones (increase of credit interest rate) despite the reduction of the central bank rate in the short-term.

When the Output Floor is implemented, Figure 6 shows that the prudential instrument reduces the volatility and variability of banks capital-to-RWA ratio. Similar to the policy rate and risk shock, the Output Floor reaches its goal when an asymmetric real shock occurs in the Euro Area.

Consequently, all results explained in this section lead to the conclusion that, along the financial and economic cycle, the OF setting can limit banking solvency risk (i.e. less volatility of capital-to-RWA ratio) and improves credibility in banks' solvency indicators for financial investors (i.e. less variability of the ratio). These short and medium run OF benefits on banking solvency complete financial and economic long run OF benefits observed in the previous sections.

5 Is Euro Area banking integration fit with Output Floor efficiency ?

Since its creation in January 1999, one of the main goals of the Euro Area has been to promote financial integration among members countries. As mentioned in the European Central Bank (ECB) report published in 2018, full financial integration in the Eurozone is gauged by the following characteristics of market participants : 1) they face a single set of rules when they decide to deal with financial instruments and / or services; 2) they have equal access to these financial instruments and / or services; 3) they are treated equally when these instruments and / or services are active in the market (ECB, 2018).

Since Output Floor setting would be common to all the Euro Area countries, the prudential instrument would match the first and second characteristic. However, the third one could be debated because, in our model, financial integration corresponds to banking integration and does not mean a homogeneous economic structure between Euro Area economies. In this case, OF activation could lead to different banking effect between core and periphery economies and thus, banking integration could influence OF efficiency.

This section studies this influence by examining changes in OF efficiency with respect to banking openness in the Euro Area. In the model, banking openness is measured by parameters α_i^L. To obtain a consistent analysis, we assume three different banking openness scenarios : banking autarky (i.e. $\alpha_c^L = \alpha_p^L = 0$), baseline openness estimated by Poutineau and Vermandel (2017) (i.e. $\alpha_c^L = 12\%$ and $\alpha_p^L = 5\%$) and banking union (i.e. $\alpha_c^L = \alpha_p^L = 0.5$).

Figure 7 depicts the IRFs of banks capital-to-RWA ratio for core and periphery banks and the dispersion of the ratio between both bank types when the Output Floor is activated.[13].

[13]IRFs without Output Floor implementation are not displayed because it is not possible to solve the model at steady-state under a banking union. This difficulty comes from the incompatibility between fully homogeneous cross-border financial trades (i.e. banking union) and heterogeneous domestic financial structures without OF implementation (i.e. heterogeneous long run credit risk between core and periphery banks).

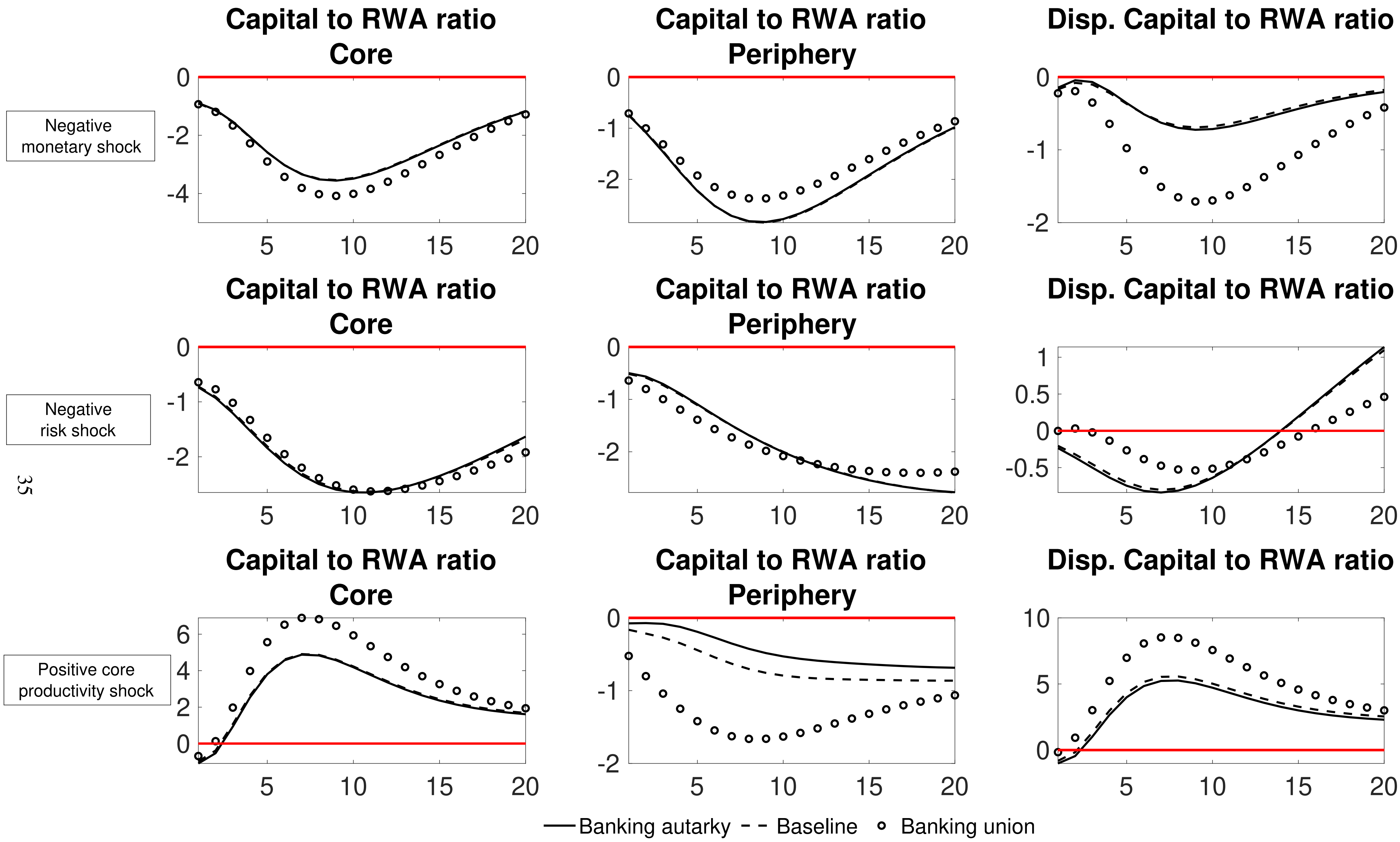


Figure 7: Impact of banking integration on Output Floor efficiency across financial and economic shocks.

Note : Values are expressed in percentage deviation from steady-state level of variables (i.e. $v^b = 10.5\%$).

In each graph, the solid black line corresponds to the banking autarky scenario, the dashed black line integrates baseline openness estimated by Poutineau and Vermandel (2017) and the black circles represent the banking union case.

The first results to underline in this figure are the almost similar OF effects on banking solvency between the banking autarky and baseline scenarios. This means that, up to a certain threshold, banking openness does not have significant impact on OF efficiency.

Interestingly, in the banking union scenario, the OF setting generates a substitution effect between core and peripheral banks capital-to-RWA ratio. However, this effect amplifies the variability of the ratio between core and peripheral banks, which erodes comparability of the ratio and thus, is detrimental to OF efficiency.

As shown in Figure 11 and 12, under common financial shocks to Euro Area members (i.e. policy rate and risk shock), the substitution effect tends to homogenize the credit cost (credit interest rate in figures) between core and periphery entrepreneurs. Nevertheless, under asymmetric real shocks, the substitution effect exacerbates the heterogeneous credit costs between both types of entrepreneurs.

Consequently, the results highlight three main conclusions. First, current (i.e. estimated) banking openness is not detrimental to OF efficiency. Second, in the Euro Area, the influence of banking union on homogeneous banking activity depends crucially on the symmetrical dimension of the shocks. Third, the homogenizing effect of the banking union comes at a higher cost for OF efficiency. Therefore, a banking union seems incompatible with Output Floor goals.

6 Conclusion

This paper examined the potential impacts of the Output Floor (OF) on the Euro Area banking system and real sector from a macro perspective. Since this new prudential instrument would enter into force in January 2025 in the area, this paper proposed an *ex-ante* study of these impacts through the use of a monetary union DSGE model. This model encompasses a core-periphery banking system close to that designed in the Euro Area and allows the incorporation of credit risk and OF setting in a consistent way. The results of this paper indicate that OF implementation is beneficial for banking and economic activity in the long run, which confirms empirical guesses made by European regulators. Moreover, the way to implement the OF is important to consider in analysis since phase-in process in OF implementation limits macrofinancial and macroeconomic cost in the short run (i.e. during the process) but not in the medium run (i.e. after the end of the process). Furthermore, financial and economic cycle analyses show that the Output Floor can reach its goal, that is, to reduce the volatility of banks capital-to-RWA ratio and the dispersion (or variability) of this ratio between core and peripheral banks. Reaching these goals limits the banking solvency risk and reinforce the reliability of this ratio as a good banking solvency indicator for financial investors. However, banking openness and Output Floor efficiency seems compatible up to a certain openness threshold. Indeed, a banking union (i.e. perfect banking openness) is detrimental to OF efficiency. This last result calls for the implementation of a specific OF at the national level instead of the common OF at the federal scale to achieve compatible objectives with banking integration promoted by European financial regulators.

Looking forward, the analyses outline several areas for future research. It would be interesting to evaluate the optimal IRB-RWA floor with respect to OF goals because the empirical floor (i.e. 72.5% of RWA estimated using a standardized approach) seems to result from a bargaining process between the banking industry and financial regulators (Mérő, 2021). Another possible extension of this paper would be the assignement of default probability for banks. This would permit the reintegration of inter-bank loans and the construction of banks' portfolio that are more consistent with Output floor analysis. Incorporating mortgages in the portfolio would also enrich OF study within this framework. Finally, the introduction of macroprudential instruments, such as counter-cyclical buffers on banks capital, would allow the detections of potential complementary or conflicting effects between main prudential regulations.

References

Acosta-Smith, J., Bassanin, M., and Sabuga, I. (2021), 'Dynamics of the Output Floor: A Model-Based Assessment', pp.1-40.

Andersen, H., and Johnsen, J. (2023), 'Effects of the new standardised approach and the new output floor for IRB banks', *Norges Bank Staff Memo*, N°8, pp.1-47.

Angelini, P., Neri, S., and Panetta, F. (2014), 'The interaction between capital requirements and monetary policy', *Journal of Money, Credit and Banking*, 46 (6), pp.1073–1112.

Angeloni, I. and Faia, E. (2013), 'Capital regulation and monetary policy with fragile banks', *Journal of Monetary Economics*, 60(3), pp.311-324.

Avramova, S. and Le Leslé, V. (2012), 'Revisiting Risk Weight Asset. Why Do RWAs Differ Across Countries and What Can Be Done About It ?', *IMF Working Paper*, WP/12/90, pp.1-48.

Badarau, C., and Roussel, C. (2022), 'A theoretical foundation for prudential authorities decision making', *International Economics*, Volume 172, pp.451-462.

Bayoumi T. and B. Eichengreen (1993), 'Shocking aspects of European Monetary Integration', in Torres F. and F. Giavazzi (eds.), *Adjustment and Growth in the European Monetary Union*, Cambridge University Press: Cambridge.

BCBS (2013), 'Regulatory Consistency Assessment Programme (RCAP). Analysis of risk-weighted assets for credit risk in the banking book', *BIS document* Bank for International Settlements, pp.1-57.

BCBS (2017a), 'Basel Committee on Banking Supervision Basel III: Finalising post-crisis reforms', *BIS document* Bank for International Settlements, pp.1-162.

BCBS (2017b), 'Finalising Basel III. In brief', *BIS document* Bank for International Settlements, pp.1-9.

BCBS (2023b), 'Risk-based capital requirements. Transitional arrangements', *BIS document* Bank for International Settlements, pp.1-3.

Belke, A., Domnick, C. and Gros, D. (2017), 'Business cycle synchronization in the EMU: Core vs. periphery', *Open Economies Review*, 28, pp.863-892.

Behn, M., Haselmann, R. and Vig, V. (2016), 'The limits of model-based regulation' *ECB Working Papers*, No 1928, pp.1-59.

Bernanke, B. S., Gertler, M. and Gilchrist, S. (1999), 'The financial accelerator in a quantitative business cycle framework' *Handbook of macroeconomics*, vol. 1, pp.1341-1393.

Berrospide, J.M. and Edge, R.M. (2019), 'The effects of bank Capital buffers on bank lending and firm activity: What can we learn from five years of stress-test results ?', *Finance and Economics Discussion Series*, 2019-050, Washington: Board of Governors of the Federal Reserve System, pp.1-47.

Binder, C. and Lehner, O. (2020), 'The problem of heterogeneity within risk weights : Does basel IV contain the solution?', *ACRN Journal of Finance and Risk Perspectives*, Vol.8, No.1, pp.183-205.

Brzoza-Brzezina, M., Kolasa, M., and Makarski, K. (2017), 'Monetary and macroprudential policy with foreign currency loans', *Journal of Macroeconomics*, vol.54, pp.352-372.

Bubeck, J., Maddaloni, A. and Peydró, J. L. (2020), 'Negative monetary policy rates and systemic banks' risk-taking: Evidence from the euro area securities register'. *Journal of Money, Credit and Banking*, 52(S1), pp.197-231.

Budnik, K., Dimitrov, I., Groß, J., Lampe, M., and Volk, M. (2021), 'Macroeconomic impact of Basel III finalisation on the euro area', *Macroprudential Bulletin*, Issue 14, ECB, Frankfurt am Main.

Calvo, G. (1983), 'Staggered Prices in a Utility-Maximizing Framework', *Journal of Monetary Economics*, 12(3), pp. 383-98.

Chen, J. and Columba, F. (2016), 'Macroprudential and monetary policy interactions in a DSGE model for Sweden', *IMF Working Papers*, 16/74, International Monetary Fund, pp.1-189.

Darracq-Paries, M. D., Kok, C., Rodriguez-Palenzuela, D. (2011), 'Macroeconomic propagation under different regulatory regimes: Evidence from an estimated dsge model for the euro area', *International Journal of Central Banking*, 7 (4), pp.49-113.

Darracq Pariès, M., Jacquinot, P. and Papadopoulou, N. (2016), 'Parsing financial fragmentation in the euro area: a multi-country DSGE perspective', *EBC Working Paper*, No 1891, pp.1-103.

Darracq-Paries, M. D., Kok, C. and Rancoita, H. (2019), 'Macroprudential Policy in a Monetary Union with Cross-Border Banking', *ECB Working Paper*, No. 2260, pp.1-72.

De Grauwe, P. (2010), 'The scientific foundation of dynamic stochastic general equilibrium (dsge) models', *Public choice*, Vol.144, pp.413-443.

Delis, M. D. and Kouretas, G. P. (2011), 'Interest rates and bank risk-taking', *Journal of Banking & Finance*, 35(4), pp.840-855.

EBA, (2018), 'Basel III Monitoring Exercise: Results based on data as of 31 December 2017', *European Banking Authority*, pp.1-40.

European Central Bank (2018), 'Financial integration in Europe', *ECB reports*, pp.1-159.

Emter, L., Schmitz, M. and Tirpák, M. (2019), 'Cross-border banking in the EU since the crisis: what is driving the great retrenchment ?', *Review of world economics*, 155, pp.287-326.

Fraisse, H., Lé, M. and Thesmar, D. (2020). 'The real effects of bank capital requirements'. *Management Science*, 66(1), pp.5-23.

Garcia-Revelo, J.D. and Levieuge, G. (2022), 'When could Macroprudential and Monetary Policies be in Conflict ?', *Journal of Banking and Finance*, Volume 139, 106484.

Gambacorta, L. and Karmakar, S. (2018), 'Leverage and risk-weighted capital requirements', *International Journal of Central Banking*, 14(5), pp.153–191.

Gerali, A., Neri, S., Sessa, L. and Signoretti, F. (2010), 'Credit and banking in a DSGE model of the Euro Area', *Journal of Money, Credit and Banking*, 42(s1), pp.107-141.

Heider, F., Saidi, F. and Schepens, G. (2019), 'Life below zero: Bank lending under negative policy rates', *The Review of Financial Studies*, 32(10), pp.3728-3761.

Hoffmann, M., Maslov, E. and Sørensen, B. E. (2022), 'Small firms and domestic bank dependence in Europe's Great Recession', *Journal of International Economics*, 137, 103623.

Holden, T. (2016), 'Computation of solutions to dynamic models with occasionally binding constraints.', *EconStor Preprints 144569, ZBW - Leibniz Information Centre for Economics*.

Kashyap, A.K. and Stein, J.C. (2004), 'Cyclical implications of the Basel II capital standards'. *Economic Perspectives-Federal Reserve Bank Of Chicago*, Vol. 28, no 1, pp.18-33.

Meh, C. A., Moran, K. (2010), 'The role of bank capital in the propagation of shocks', *Journal of Economic Dynamics and Control*, 34 (3), pp.555-576.

Mendicino, C., Nikolov, K., Suarez, J. and Supera, D. (2018), 'Optimal Dynamic Capital Requirements', *Journal of Credit, Money and Banking*, Volume 50, Issue 6, pp.1271-1297.

Mérő, K. (2021), 'The ascent and descent of banks' risk-based capital regulation', *Journal of Banking Regulation*, 22(4), pp.308-318.

Neisen, M. and Schulte-Mattler, H. (2021), 'Eliminating the negative impacts of the Basel IV output floor by adjusting a bank's business model', *Journal of Risk Management in Financial Institutions*, Vol.14, No.3, p. 256-267.

Pfeifer, L. and Hodula, M. (2021), 'New kid on the block: leverage ratio and its implications for banking regulation', *The European Journal of Finance*, 27(10), pp.1009-1028.

Pop, A. and Pop, D. (2022), 'Output Floors', *38th Symposium in Money Banking and Finance*, Strasbourg, France.

Poutineau, J. C., and Vermandel, G. (2015), 'Cross-border banking flows spillovers in the Eurozone: Evidence from an estimated DSGE model', *Journal of Economic Dynamics and Control*, 51, pp.378-403.

Poutineau, J.C., and Vermandel, G. (2017), 'Global banking and the conduct of macro- prudential policy in a monetary union', *Journal of Macroeconomics*, vol 54, pp.306–331.

Schmitz, B. and Von Hagen, J. (2011), 'Current account imbalances and financial integration in the euro area', *Journal of International Money and Finance*, 30(8), pp.1676-1695.

Stewart, R. (2021), 'Improving regulatory capital allocation: a case for the internal ratings-based approach for retail credit risk exposures', *Journal of Financial Regulation and Compliance*, Vol.29, No.3, pp.317-335.

Van den Heuvel, S. J. (2008), 'The welfare cost of bank capital requirements', *Journal of Monetary Economics*, 55 (2), pp.298-320.

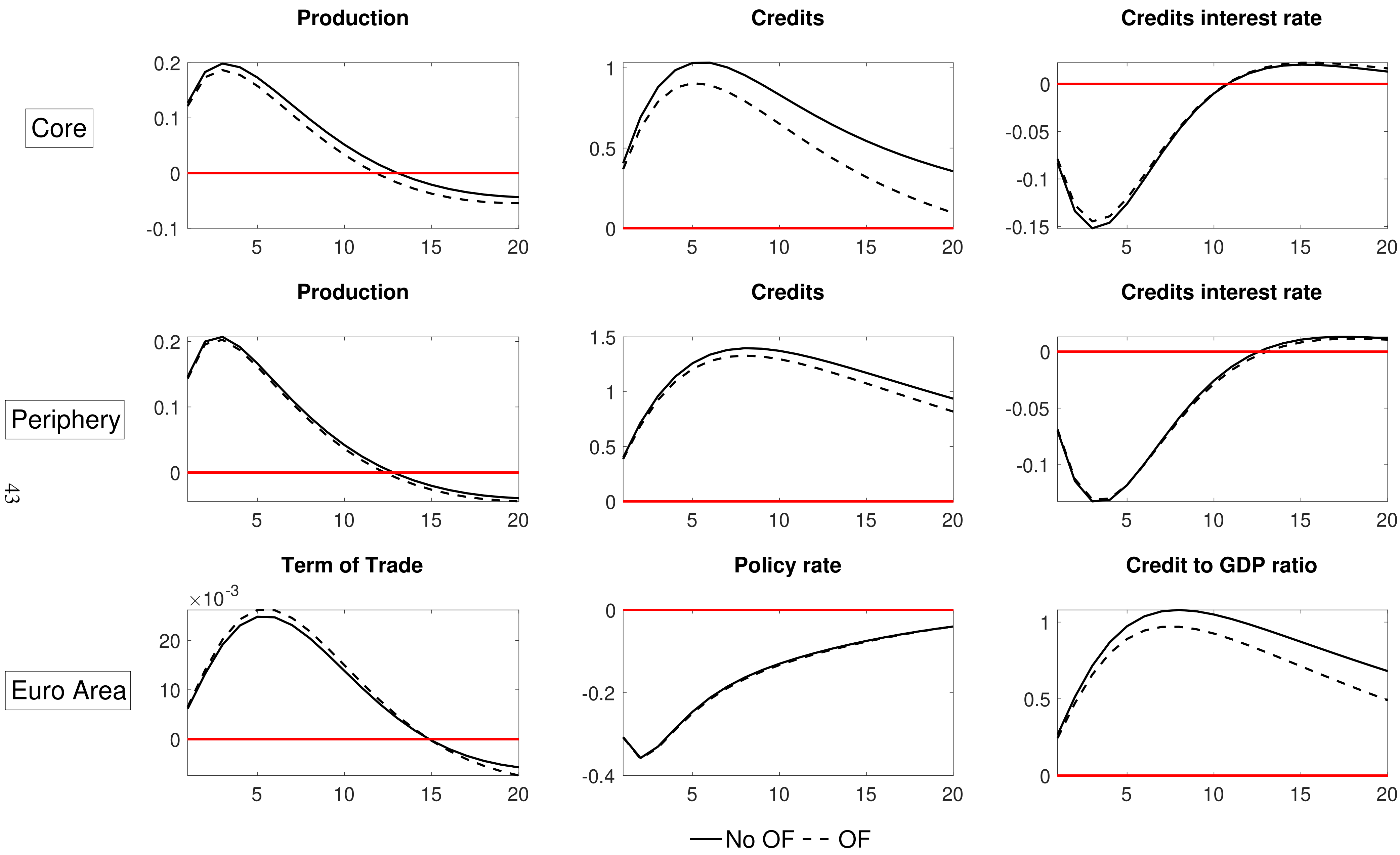


Figure 8: Impact of Output Floor in banking and real sector under negative monetary policy shock.

Note : Rates variables are expressed in percentage point deviation from their steady-state level. Other variables are expressed in percentage deviation from steady-state level of variables.

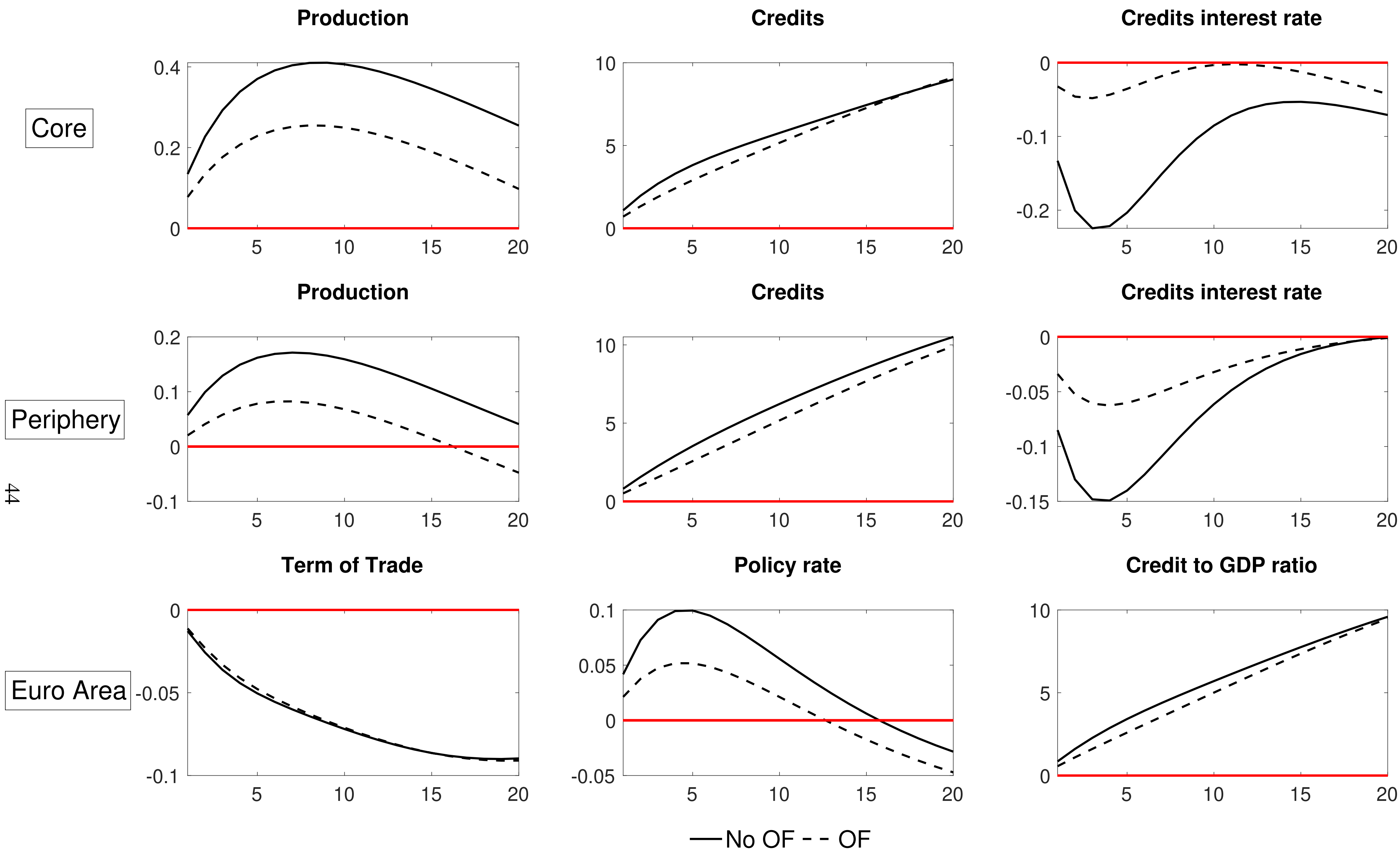


Figure 9: Impact of Output Floor in banking and real sector under negative risk shock.

Note : Rates variables are expressed in percentage point deviation from their steady-state level. Other variables are expressed in percentage deviation from steady-state level of variables.

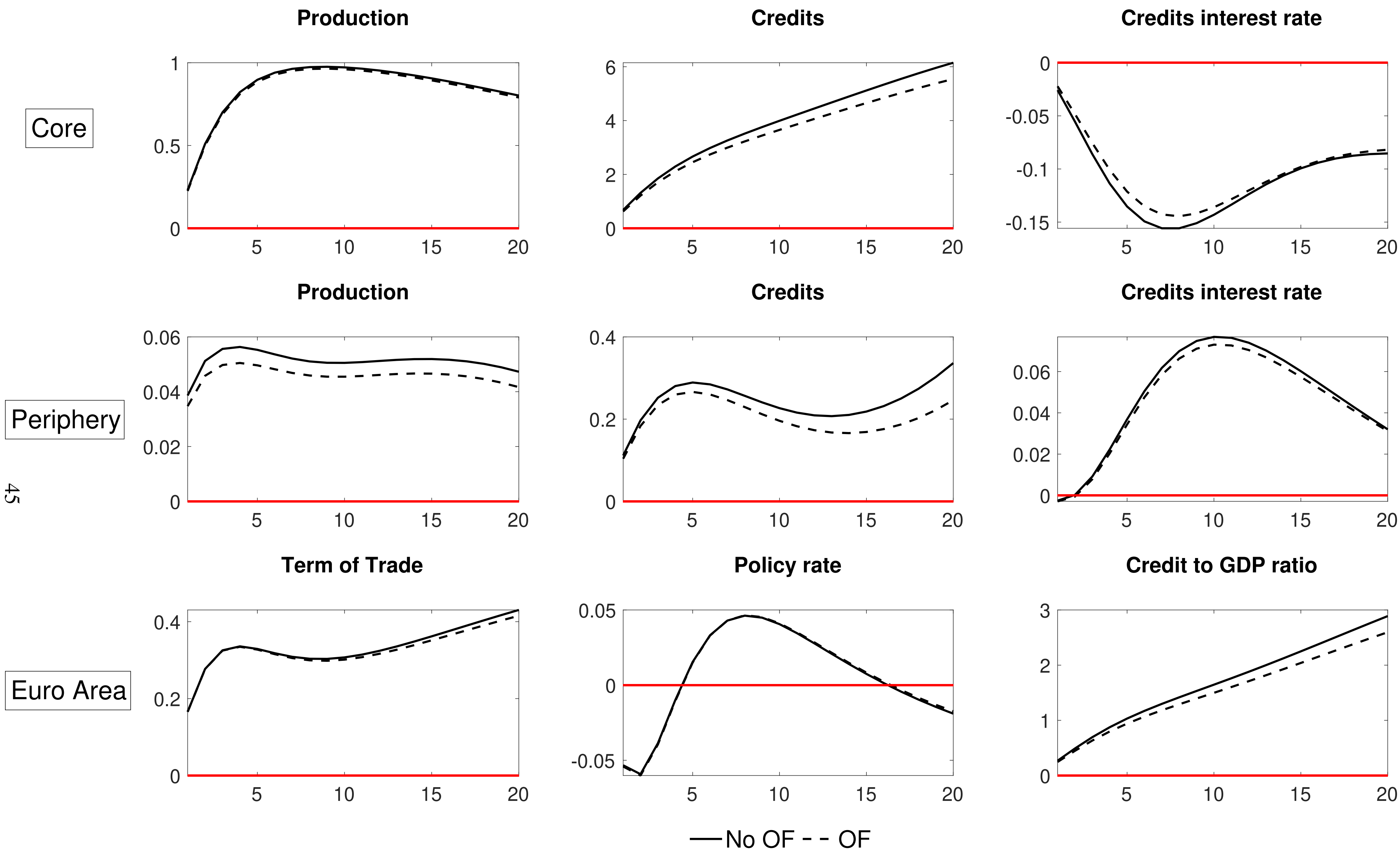


Figure 10: Impact of Output Floor in banking and real sector under positive productivity shock in core economies.

Note : Rates variables are expressed in percentage point deviation from their steady-state level. Other variables are expressed in percentage deviation from steady-state level of variables.

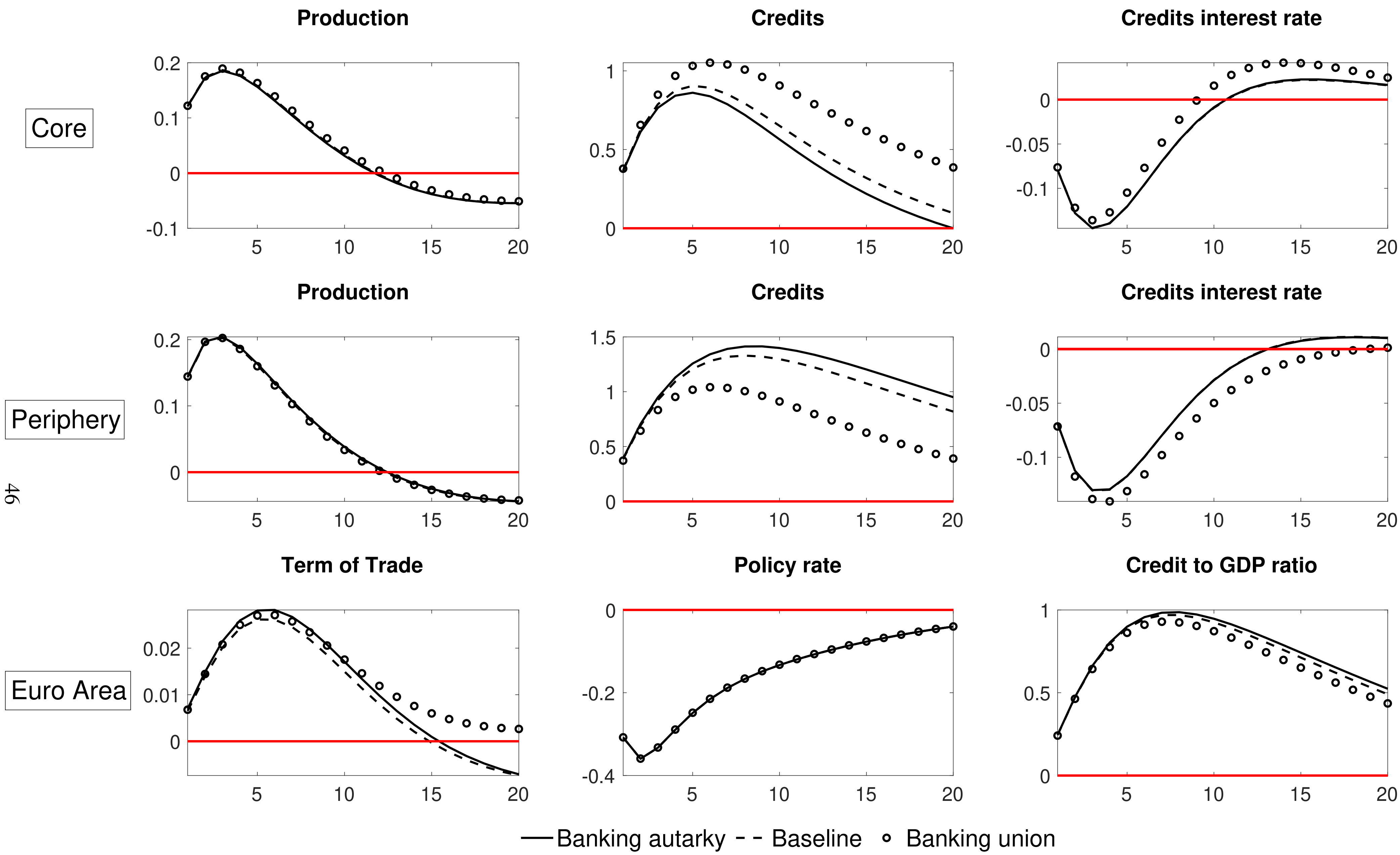


Figure 11: Impact of Output Floor in banking and real sector under negative monetary policy shock and different banking openness scenario.

Note : Rates variables are expressed in percentage point deviation from their steady-state level. Other variables are expressed in percentage deviation from steady-state level of variables.

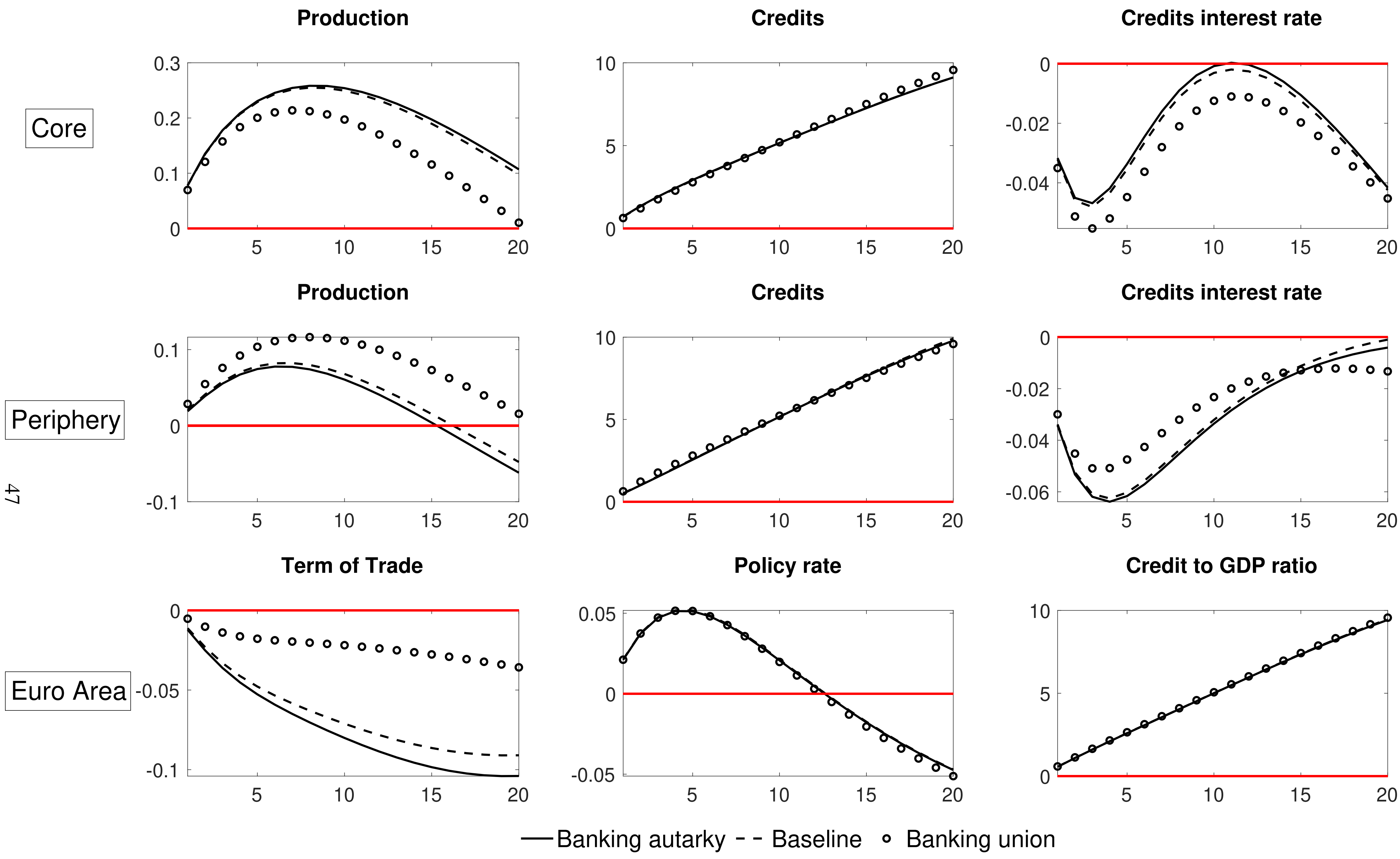


Figure 12: Impact of Output Floor in banking and real sector under negative risk shock and different banking openness scenario.

Note : Rates variables are expressed in percentage point deviation from their steady-state level. Other variables are expressed in percentage deviation from steady-state level of variables.

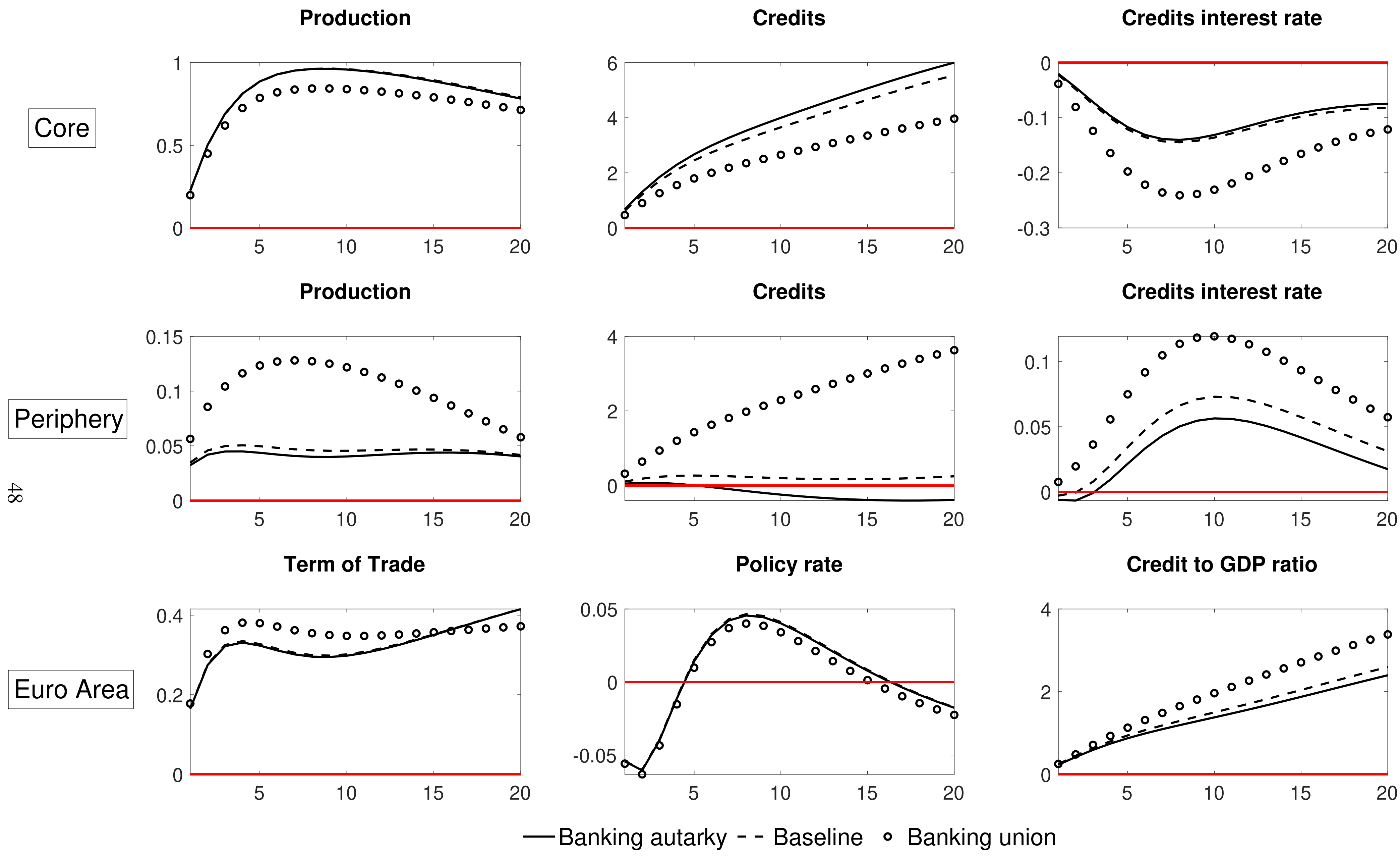


Figure 13: Impact of Output Floor in banking and real sector under positive productivity shock in core economies and different banking openness scenario.

Note : Rates variables are expressed in percentage point deviation from their steady-state level. Other variables are expressed in percentage deviation from steady-state level of variables.