EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

Sandra Gomes, Pascal Jacquinot, Matija Lozej

A single monetary policy for heterogeneous labour markets: the case of the euro area

No 2769 / January 2023

Abstract

Differences in labour market institutions and regulations between countries of the monetary union can cause divergent responses even to a common shock. We augment a multi-country model of the euro area with search and matching framework that differs across Ricardian and hand-to-mouth households. In this setting, we investigate the implications of cross-country heterogeneity in labour market institutions for the conduct of monetary policy in a monetary union. We compute responses to an expansionary demand shock and to an inflationary supply shock under the Taylor rule, asymmetric unemployment targeting, and average inflation targeting. For each rule we distinguish between cases with zero weight on the unemployment gap and a negative response to rising unemployment. Across all rules, responding to unemployment leads to lower losses of employment and higher inflation. Responding to unemployment reduces cross-country differences within the monetary union and the differences in consumption levels of rich and poor households.

JEL Classification: E24, E32, E43, E52, F45

Keywords: *DSGE Modelling, Business cycles, Search and matching, Monetary Union*

Non-technical summary

Two of the world's largest central banks, the European Central Bank and the Federal Reserve have recently conducted a review of their monetary policy strategies. A common feature of both strategy reviews was the considerable attention paid to employment-related issues. Distributional issues were an important consideration and both central banks produced background documents that looked at heterogeneity, either between households or among countries in the monetary union.

In the euro area, the heterogeneity dimension is not only important across households, but also across countries within the monetary union. This is particularly the case for labour markets, which are less integrated than those of the US and are governed by country-specific legislations. Differences in labour market institutions between countries of the monetary union can give rise to different responses to shocks across countries, even when the shocks hit all monetary union regions symmetrically. Our paper provides an analytical framework that addresses both cross-country and within-country labour market heterogeneity in a monetary union. In particular, we develop and use a new version of the Euro Area within the GLobal Economy model (the EAGLE model), a large-scale open-economy model that is augmented with an enhanced labour market, modelled using search-and-matching frictions. Each country is modelled as a two-agent New Keynesian model (a so-called TANK model) with Ricardian ("wealthy") and non-Ricardian ("poor") households. Each type of agent faces a labour market with its own particular characteristics regarding job finding and separation rates, bargaining power, and nominal wage rigidity. The latter is modelled so that it allows distinguishing wage stickiness for new hires and for existing employees. Importantly, because non-Ricardian households are constrained in terms of consumption smoothing, their consumption depends mainly on their labour income, which in turn depends on the labour market situation for these households.

We use the model to study the implications of cross-country heterogeneity for the conduct of monetary policy in a monetary union. We first compute responses to a common expansionary demand shock, which increases inflation and reduces unemployment, across the monetary union under three different monetary policy rules: a benchmark Taylor rule that includes a response to inflation and unemployment, a Taylor rule that includes an asymmetric response to unemployment, and average inflation targeting rule. For all these three rules, we distinguish between cases where the central bank does not respond to unemployment and the cases where it does.

We next compute the responses to an inflationary supply shock, which increases both inflation and unemployment. For each type of shock, we compare the performance of rules in terms of inflation and employment stabilisation, and in terms of cross-country and cross-household heterogeneity within the monetary union.

We find that when monetary policy responds to unemployment developments, then this results in stronger unemployment decrease after expansionary demand shocks and lower unemployment increase after a contractionary supply shock. While this does lead to a faster and stronger increase in inflation, it also results in a fast return of inflation to lower levels after the supply shock. Responding to unemployment tends to lower inequality between and within countries of the euro area. If monetary policy ignores unemployment and responds only to inflation, this leads to larger fluctuations of output and (un)employment. Moreover, these fluctuations increase divergence between the euro area economies as well as within-economy divergence among households. The effect on between-household consumption differences is, however, different for expansionary and contractionary shocks. When the central bank does not respond to unemployment, the difference between consumption of different types of households goes in favour of the poor households after an expansionary demand shock, while after an inflationary supply shock this difference goes in favour of richer households.

1 Introduction

Two major central banks, the European Central Bank (ECB) and the Federal Reserve (FED) have recently conducted a review of their monetary policy strategies.[1] A feature of both strategy reviews was that they paid considerable attention to employment-related issues, even when this is not mandated by the law, as is the case of the ECB. The FED examined the relation between monetary policy strategy and employment outcomes, see e.g. Feiveson et al. (2020), and the ECB launched the Workstream on Employment that looked at similar issues in the euro area, see Brand et al. (2021).

Both of these background documents looked at heterogeneity, either between households or among countries in the monetary union. Distributional issues were an important factor in both cases. Chairman Powell explicitly stated that "Our revised statement reflects our appreciation of a strong labour market, particularly for many in low- and moderate-income communities." (Powell, 2020). The ECB similarly mentions concern for heterogeneity by stating "...the medium-term orientation provides flexibility to take account of employment in response to economic shocks, giving rise to a temporary trade-off between short-term employment and inflation stabilisation without endangering medium-term price stability." and "... important to [...] account for uncertainty, heterogeneity and ongoing structural changes shaping the outlook for economic activity and employment in the euro area and its member countries." (ECB, 2021).

In the euro area, the heterogeneity dimension is not only important across households, but also across countries, and this is particularly the case for labour markets, which are less integrated than those of the US and are governed by country-specific legislations. These differences in labour market institutions and regulations between countries of the monetary union can give rise to heterogeneous responses across countries, even in response to a common shock. Our paper provides an analytical framework that addresses both cross-country and within-country labour market heterogeneity in a monetary union. In particular, we develop and use a new version of the Euro Area within the GLobal Economy model (the EAGLE model), augmented with an enhanced labour market that is modelled using search-and-matching frictions as in Mortensen and Pissarides (1999) in all blocs. Each country is modelled as a two-agent New Keynesian model (a so-called TANK model) with Ricardian ("wealthy") and non-Ricardian ("poor") households. Each type of agent faces a labour market with its own particular characteristics regarding job

[1] The Federal Reserve conducted its strategy review in 2019/2020, and the ECB in 2020/2021.

finding and separation rates, bargaining power, and wage rigidity. The latter is modelled following the approach of Bodart et al. (2006) and de Walque et al. (2009), which allows distinguishing wage stickiness for new hires and for existing employees. Importantly, because non-Ricardian households are constrained in terms of consumption smoothing, their consumption depends on their labour income, which in turn depends on the labour market situation for these households.

The presence of non-Ricardian households and different characteristics of the labour market they face are important, as recent evidence has suggested that labour markets do not exhibit the same properties across the entire wealth (or earnings) distribution. A typical finding is that labour market outcomes in terms of employment and hours worked tend to be more volatile at the left tail of the distribution. See, for instance, Guvenen et al. (2017), Cairó and Cajner (2018), Amberg et al. (2022), Broer et al. (2022), Herman and Lozej (2021) and Cantore et al. (2022), who all document higher volatility at the left tail of the labour market in terms of wealth (even though this may not always be for the same reason). Higher labour market volatility at the bottom of the distribution, where most income is from labour earnings and where marginal propensity to consume is high, can have material aggregate implications, as it increases the volatility of aggregate consumption.

After calibrating the model to capture cross-country and cross-household labour market characteristics, we then use the model to study the implications of cross-country heterogeneity in labour market institutions for the conduct of monetary policy in a monetary union. We first compute responses to a common expansionary demand shock across the monetary union under three different monetary policy rules: a benchmark Taylor rule that includes a response to inflation and unemployment (IT rule), a Taylor rule that includes an asymmetric response to unemployment (ASUT), and average inflation targeting (AIT) rule. For all these three rules, we distinguish between cases with zero weight on the unemployment gap and a positive weight on the unemployment gap. We then compute responses to an inflationary supply shock, and compare the performance in terms of inflation and employment stabilisation, and in terms of cross-country and cross-household heterogeneity within the monetary union.

Our paper relates to the literature that assesses the performance of alternative Taylor rules. For a survey see Taylor and Williams (2010). It also relates to the literature about the interaction of monetary policy and labour market frictions as in the seminal work by Cooley and Quadrini (1999) and Faia (2009), among others. In terms of the focus on monetary policy rules, the paper close to ours is Bundick and Petrosky-Nadeau (2021), who investigate possible effects of changing from an interest rate rule that includes a response to deviations of unemployment from its steady state value to one that stabilizes shortfalls. Feiveson et al. (2020) also investigate monetary policy strategies, but focus on household heterogeneity. Our paper is related, but distinct from both, as we use a multi-country open economy model featuring a more detailed labour market structure, and a monetary union setup. This allows us to focus more on cross-country heterogeneity within a monetary union, while it still allows some analysis of monetary policy implications for different households.[2]

Our main findings are as follows. First, if monetary policy responds to the unemployment gap, then this tends to have more favourable effects on unemployment. It results in stronger unemployment decrease after expansionary demand shocks and lower unemployment increase after a contractionary supply shock. While this does lead to a faster and stronger increase in inflation, it also results in a fast return of inflation to lower levels after a supply shock. Responding to unemployment tends to lower inequality between and within countries of the euro area. Second, if monetary policy ignores unemployment and responds only to inflation, this leads to larger fluctuations of output and (un)employment. Moreover, these fluctuations increase divergence between the euro area economies as well as within-economy divergence among households. The effect on between-household consumption differences is, however, different for expansionary and contractionary shocks. When the central bank does not respond to unemployment, the difference between consumption of different types of households goes in favour of the hand-to-mouth (HtM) households after an expansionary demand shock, while after an inflationary supply shock this difference goes in favour of richer Ricardian households.

This paper proceeds as follows. Section 2 presents the details of the model. Section 3 presents the monetary policy rules. Section 4 presents the empirical stylised facts and the way we used them to calibrate the model. Section 5 discusses the results from different shock scenarios and Section 6 concludes.

[2]We cannot, however, investigate these issues using global solution methods and study detailed distributional implications, either across households as in Feiveson et al. (2020) or in time-series sense as in Bundick and Petrosky-Nadeau (2021).

2 The model

2.1 Overview

We first describe the modelling framework that we enhance with the labour market. The core model on which we build is the EAGLE model, which is a multi-country dynamic general equilibrium model of the euro area within the world economy. The EAGLE model was developed as an ESCB project by a team composed of staff from the Bank of Italy, the Bank of Portugal and the ECB, see Gomes et al. (2010) and Gomes et al. (2012). The model shares the same theoretical setup as the ECB New Area Wide model, (Christoffel et al., 2008) or the IMF Global Economy Model, GEM (Laxton and Pesenti, 2003). It is a large scale micro-founded model of a monetary union that consists of an open economy version of the New Keynesian paradigm. Given the purpose of our analysis, the version used here includes a significantly expanded and enhanced labour market block, which we describe in detail in Section 2.2.

In the model, the world economy consists of four blocs. Two blocs are members of a monetary union, the euro area (EA). Thus, these two blocs (Home and the Rest of the euro area, REA) have a common nominal exchange rate and a common nominal interest rate. Regarding the monetary authority, the central bank sets the domestic short-term nominal interest rate according to a Taylor-type rule, by reacting to consumer price inflation, and unemployment gap, both defined at the euro area level. In the simulations we use alternative monetary policy rules for the euro area that are described in Section 3. The remaining two blocs, the US and the rest of the world (RW), have their own nominal interest rates and nominal exchange rates. The monetary authorities in theses blocs set the domestic short-term nominal interest rate according to a Taylor-type rule that reacts to domestic variables (inflation and output growth). In all blocs, fiscal policy is conducted at the country level. All regions trade with each other at the levels of intermediate goods, with a matrix of bilateral trade flows based on recent historical averages. International asset trade is limited to non-contingent nominal bonds denominated in US dollars.

In each country there are two types of firms. One type produces final non-tradable goods under perfect competition using domestic tradable goods, imported tradable goods and non-tradable goods. Final goods can be used for private consumption and for private investment. There is also a final public good that is fully biased towards domestic non-tradable intermediate goods. The other type of firms produces intermediate goods, which are produced by an array of firms under monopolistic competition using domestic labour and capital, combined according to a Cobb–Douglas technology. A set of intermediate goods firms produces tradable goods and another set produces non-tradable goods. The market power implies that firms set nominal prices and charge a markup over marginal costs. Nominal prices are sticky.

There are two types of infinitely-lived households in each country, Ricardian and non-Ricardian (or HtM). Households gain utility from consuming and suffer disutility from working. Ricardian households have access to financial markets, where they buy and sell domestic government bonds and internationally traded bonds denominated in US dollars (as well as an euro denominated bond traded within euro area blocs), accumulate physical capital, rent their services to firms, supply labour and hold money for transactions purposes. Non-Ricardian households have only access to money balances, which means that their ability to intertemporally smooth consumption is limited.

2.2 Labour market

We construct an enhanced labour market structure that we build onto the EAGLE model described above. The labour market features search frictions as in Mortensen and Pissarides (1999), but adds sticky wages by means of staggered wage setting, and a potential to distinguish wage stickiness of new hires and existing workers. This approach follows broadly Bodart et al. (2006) and de Walque et al. (2009). In addition, we distinguish between labour market segments for Ricardian and non-Ricardian households, each of which can have their own unemployment, hours worked, wage setting, and different wage rigidities for new hires and existing workers.

The aim of this relatively complex structure is to capture the labour market more realistically in an otherwise two-agent model, in particular the facts that it is likely that wages for new hires are more volatile than wages for existing workers (see e.g. Haefke et al. (2013) and Lydon and Lozej (2018)) and that it is likely that poorer households are often those for whom employment outcomes are more susceptible to business cycle fluctuations than for richer households. This is in line with the evidence for several countries (see Cairó and Cajner (2018) for the US, and Broer et al. (2022) for Germany).

More volatile employment outcomes for a particular segment of wealth distribution are not important in a representative-agent framework, where income fluctuations can be smoothed by risk sharing among the households. However, as outlined in the above papers, labour market at the bottom of the income distribution is different than at the top. This is why we need this relatively complex setup of the labour market to be able to capture the more volatile properties of the labour market at the bottom of the income distribution, i.e., the labour market for non-Ricardian households. This has broader implications, because the fluctuations in this labour market, due to the inability to smooth consumption, affect aggregate consumption and aggregate fluctuations.

There are two labour market segments, one for Ricardian and one for non-Ricardian households. There is a continuum of labour firms in each labour market segment, with each labour firm employing one worker. Labour firms pay labour taxes, bargain with households over wages, and post vacancies at a per-period fixed cost. If they find a worker, they sell homogeneous labour services to a labour packer, which aggregates labour from the Ricardian and non-Ricardian labour market segments and sells aggregated labour services to intermediate goods firms.

The flows on the labour market are as follows. The number of workers in segment s ($s = i$ for Ricardian and $s = j$ for non-Ricardian households) that are employed after the matching process has been completed, $nde_{s,t}$, evolves as follows:

$$nde_{s,t} = (1 - \delta_x)\ nde_{s,t-1} + M_{s,t}, \tag{1}$$

where $M_{s,t}$ is the number of new matches formed in a period (with $M_{s,t} > 0$), and δ_x is the fraction of existing employment relationships that have (exogenously) separated in each period (i.e. it is the exogenous separation rate, $0 < \delta_x < 1$). The number of matches $M_{s,t}$ is defined according to the following matching function:

$$M_{s,t} = \phi_{s,M}(un_{s,t})^{\mu_s}(vac_{s,t})^{1-\mu_s} = p^W_{s,t} un_{s,t} = p^F_{s,t} vac_{s,t}, \tag{2}$$

where $\phi_{s,M}$ is matching efficiency, $un_{s,t}$ is the number of searching workers in each segment, $vac_{s,t}$ is the number of vacancies, $p^W_{s,t}$ is the matching probability for workers of each type, $p^F_{s,t}$ is the matching probability for firms, and μ_s, with ($0 < \mu_s < 1$), is the elasticity of the matching function with respect to unemployment in each segment.

The probability for a searching worker to find a job is

$$p^W_{s,t} = \frac{M_t}{un_{s,t}} = \phi_{s,M}(\frac{vac_{s,t}}{un_{s,t}})^{1-\mu_s} \tag{3}$$

and the probability of a firm finding a worker is

$$p^F_{s,t} = \frac{M_{s,t}}{vac_{s,t}} = \phi_{s,M}(\frac{vac_{s,t}}{un_{s,t}})^{-\mu_s} \tag{4}$$

The number of unemployed workers who search for work at the beginning of period t (i.e., the number of workers who enter the matching process, $un_{s,t}$) is equal to those who were unemployed at the end of period $t-1$ after the $t-1$ matching has been completed (i.e., $une_{s,t-1}$), plus the newly separated workers (i.e., $\delta_x nde_{s,t-1}$):

$$un_{s,t} = une_{s,t-1} + \delta_x nde_{s,t-1}, \tag{5}$$

These workers are the ones who receive unemployment benefits. The population of each bloc in the model is standardised to 1, and so is the mass of households in each segment, so that the number of unemployed at the end of the period in a segment s is $une_{s,t} = 1 - nde_{s,t}$. Total unemployment in a bloc is a weighted unemployment across labour market segments, where ω is the share of non-Ricardian households: $une_t = \omega\ une_{j,t} + (1-\omega)une_{i,t}$.

2.2.1 Value functions

We will require two sets of value functions. One set of value functions is for wages that have been renegotiated in the current period, and one set of values for wages that have not been renegotiated. We assume that wages that have not been renegotiated are indexed to inflation. The notation follows closely the notation used in Bodart et al. (2006) and de Walque et al. (2009).

Value functions for a labour firm Let $A^F(w^*_{s,t})$ denote the value of a job for a firm employing a worker from household type $s \in [i,\ j]$, where $w^*_{s,j}$ is the renegotiated wage, and i stands for a Ricardian and j for a non-Ricardian household. Following Bodart et al. (2006), it will be convenient to use this value in marginal utility terms, so we define $\mathcal{A}^F(w^*_{s,t}) \equiv u'(c_{s,t})A^F(w^*_{s,t})$, where $u'(c_{s,t})$ is the marginal utility of consumption of household s. The value of a job with a renegotiated wage for a labour firm can then be written as

$$\begin{aligned}\mathcal{A}^F_t(w^*_{s,t}) = {} & u'(c_{s,t})\left(h^{\alpha_H}_{s,t}x_{s,t} - h_{s,t}w^*_{s,t}(1+\tau^{wf}_t)\right) \\ & + \beta(1-\delta_{x,s})\left[(1-\xi_w)\mathcal{A}^F_{t+1}(w^*_{s,t+1}) + \xi_w\mathcal{A}^F_{t+1}(w^*_{s,t})\right]\end{aligned} \tag{6}$$

Here the term $h_{s,t}^{\alpha_H}$ denotes the effective hours that a labour firm produces from hours $h_{s,t}$ supplied by the worker from household s.[3] $x_{s,t}$ is what the labour packer pays for such unit of labour. The first term in equation 6 therefore measures earnings of the labour firm from selling hours worked. But for these hours it has to pay to the household hourly wage, which is in this case newly renegotiated, $w_{s,t}^*$. Because we assume that labour firms pay some labour taxes (social security contributions), the cost for the labour firm is increased by taxes paid, at the rate τ_t^{wf}. In the next period, if the firm and the worker do not separate, which occurs with probability $(1-\delta_{x,s})$, two cases can arise. In the first case, which occurs with the probability $(1-\xi_w)$, wages are renegotiated and the value of the worker for the labour firm is again the value of a worker with a renegotiated wage, just in the next period, $\mathcal{A}_{t+1}^F(w_{s,t+1}^*)$. With probability ξ_w wages are not renegotiated and the firm is in next period stuck with the worker value at the current wage, $\mathcal{A}_{t+1}^F(w_{s,t}^*)$.

The value at $t+1$ of the worker with renegotiated wage from time t is

$$\begin{aligned}\mathcal{A}_{t+1}^F(w_{s,t}^*) = u'(c_{s,t+1})&\left(h_{s,t+1}^{\alpha_H}x_{s,t+1} - h_{s,t+1}w_{s,t}^*\frac{(1+\overline{\pi})P_t}{P_{t+1}}(1+\tau_{t+1}^{wf})\right)\\ &+\beta(1-\delta_{x,s})\left[(1-\xi_w)\mathcal{A}_{t+2}^F(w_{s,t+2}^*)+\xi_w\mathcal{A}_{t+2}^F(w_{s,t}^*)\right]\end{aligned} \tag{7}$$

The wage from the previous period has been indexed by the ratio of trend inflation $\overline{\pi}$ and the price level growth, $P_t/P_{t+1} = (1+\pi_{t+1})$.[4]

If we substitute equation 7 into equation 6, and do this for every future period, we arrive at the following expression:

$$\begin{aligned}\mathcal{A}_t^F(w_{s,t}^*) = &\sum_{k=0}^{\infty}\left[\beta(1-\delta_{x,s})\xi_w\right]^k u'(c_{s,t+k})h_{s,t+k}^{\alpha_H}x_{s,t+k}\\ &- w_{s,t}^*\sum_{k=0}^{\infty}\left[\beta(1-\delta_{x,s})\xi_w\right]^k u'(c_{s,t+k})\frac{(1+\overline{\pi})^k P_t}{P_{t+k}}h_{s,t+k}(1+\tau_{t+k}^{wf})\\ &+\sum_{k=0}^{\infty}\beta(1-\delta_{x,s})(1-\xi_w)\left[\beta(1-\delta_{x,s})\xi_w\right]^k\mathcal{A}_{t+k+1}^F(w_{s,t+k+1}^*)\end{aligned} \tag{8}$$

[3] Note that α_H is very close to 1.

[4] Indexation can be with respect to trend inflation or any other inflation rate that has the same trend growth as trend inflation. In the simulations we will assume that indexation is with respect to current inflation. The reason is that if nominal wages are indexed to trend inflation, real average wages fall when current inflation rises, even when newly negotiated wages rise. This makes only minor differences for the outcomes of our simulations, but would unnecessarily complicate the explanation.

As in Bodart et al. (2006), we can define auxiliary variables and write the infinite sums in recursive form. For the first line in equation 8, define

$$S_t^x \equiv \sum_{k=0}^{\infty} \left[\beta(1-\delta_{x,s})\xi_w\right]^k u'(c_{s,t+k}) h_{s,t+k}^{\alpha_H} x_{s,t+k} = u'(c_{s,t}) h_{s,t}^{\alpha_H} x_{s,t} + \beta(1-\delta_{x,s})\xi_w S_{t+1}^x \quad (9)$$

Similarly, for the second line, define

$$\begin{aligned} S_t^w &\equiv \sum_{k=0}^{\infty} \left[\beta(1-\delta_{x,s})\xi_w\right]^k u'(c_{s,t+k}) h_{s,t} \frac{(1+\bar{\pi})^k P_t}{P_{t+k}} (1+\tau_t^{wf}) \\ &= u'(c_{s,t}) h_{s,t}(1+\tau_t^{wf}) + \beta(1-\delta_{x,s}) \frac{(1+\bar{\pi})}{(1+\pi_{t+1})} \xi_w S_{t+1}^w \end{aligned} \quad (10)$$

Using these definitions, we can simplify equation 8 to

$$\begin{aligned} \mathcal{A}_t^F(w_{s,t}^*) &= \left(S_t^x - S_t^w w_{s,t}^*\right) + \sum_{k=0}^{\infty} \beta(1-\delta_{x,s})(1-\xi_w) \left[\beta(1-\delta_{x,s})\xi_w\right]^k \mathcal{A}_{t+k+1}^F(w_{s,t+k+1}^*) \\ &= \left(S_t^x - S_t^w w_{s,t}^*\right) - \beta(1-\delta_{x,s})\xi_w \left(S_{t+1}^x - S_{t+1}^w w_{s,t+1}^*\right) + \beta(1-\delta_{x,s}) \mathcal{A}_{t+1}^F(w_{s,t+1}^*) \end{aligned} \quad (11)$$

To get rid of the infinite sum in the first line of equation 11 we used the fact that $\mathcal{A}_t^F(w_{s,t}^*)$ can be multiplied by $\beta(1-\delta_{x,s})\xi_w$, forwarded by one period, and the result subtracted from both sides of the first line. After rearranging, we obtain the second line.

We can then similarly define the value of a worker with an average wage for a labour firm:

$$\begin{aligned} \mathcal{A}_t^F(w_{s,t}) &= u'(c_{s,t}) \left(h_{s,t}^{\alpha_H} x_{s,t} - h_{s,t} w_{s,t}(1+\tau_t^{wf})\right) \\ &\quad + \beta(1-\delta_{x,s}) \left[(1-\xi_w)\mathcal{A}_{t+1}^F(w_{s,t+1}^*) + \xi_w \mathcal{A}_{t+1}^F(w_{s,t})\right] \end{aligned} \quad (12)$$

Following the same steps as above, we obtain, after some algebra

$$\mathcal{A}_t^F(w_{s,t}) = \left(S_t^x - S_t^w w_{s,t}\right) - \beta(1-\delta_{x,s})\xi_w \left(S_{t+1}^x - S_{t+1}^w w_{s,t+1}\right) + \beta(1-\delta_{x,s}) \mathcal{A}_{t+1}^F(w_{s,t+1}) \quad (13)$$

Free entry condition A firm posting a vacancy for household type s must pay a per-period constant cost ψ_s for having a vacancy open. If κ_{ws} denotes the probability that a firm cannot renegotiate the wage for a newly hired worker from household type s, then the value of employing a new worker is, in monetary terms (recall, $\mathcal{A}^F(w^*_{s,t}) \equiv u'(c_{s,t})A^F(w^*_{s,t})$, and the same for the value at average wage), equal to the weighted average of the value of a worker at a newly-renegotiated job and the value of a worker hired at average wage. The free-entry condition is therefore:

$$\psi_s = p^F_t \beta \frac{u'(c_{s,t+1})}{u'(c_{s,t})} \left[(1-\kappa_{ws})\mathcal{A}^F_t(w^*_{s,t+1}) + \kappa_{ws}\mathcal{A}^F_t(w_{s,t+1})\right]. \tag{14}$$

Value functions for a worker Similarly as for labour firms, we can define value functions for workers. Again we have two types of value functions, one for a newly-renegotiated wage and one for the average wage, for each type of household. The value of a job, net of the value of unemployment, for a worker with newly-renegotiated wage is

$$\begin{aligned}\mathcal{A}^H_t(w^*_{s,t}) &= u'(c_{s,t})\left(h_{s,t}w_{s,t}(1-\tau^{wh}_t) - b_{s,t}\right) - \chi\frac{h^{1+\varphi}_{s,t}}{1+\varphi} \\ &+ \beta(1-\delta_{x,s})\left[(1-\xi_w)\mathcal{A}^H_{t+1}(w^*_{s,t+1}) + \xi_w\mathcal{A}^H_{t+1}(w^*_{s,t})\right] \\ &- \beta p^W_{s,t}\left[(1-\kappa_{ws})\mathcal{A}^H_{t+1}(w^*_{s,t+1}) + \kappa_{ws}\mathcal{A}^H_{t+1}(w_{s,t+1})\right]\end{aligned} \tag{15}$$

The first line of equation 15 denotes, in utility terms, first the net gain of having a job, which is hours worked times wage net of taxes paid by the household, at a rate τ^{wh}_t and net of opportunity cost of having a job, which are unemployment benefits, $b_{s,t}$.[5] The second term in the first line is the disutility of hours worked.[6] The second line represents the value of having a job in the next period, which occurs with the probability $(1-\delta_{x,s})$. This job can be either at the newly renegotiated wage or at the current wage. The last row of equation 15 is the value of the opportunity cost of having a job, which is the value of being unemployed. If a worker is unemployed, then there is a probability $p^W_{s,t}$ to find a job, which can be either at a newly-renegotiated wage with probability $(1-\kappa_{ws})$, or at an average wage, with probability κ_{ws}.

[5]We assume that unemployment benefits are a fraction (replacement ratio) of average wage and are indexed in the same way as the average wage.

[6]We assume that the household as a whole sends its members to work, so that the marginal disutility for the household is the disutility for the worker.

If we follow the same sequence of steps as we did for the firm and define an additional auxiliary variable to sum the disutility of labour terms,

$$S^h_{s,t} = \chi \frac{h^{1+\varphi}_{s,t}}{1+\varphi} + \beta(1-\delta_{x,s})\xi_w S^h_{s,t+1}, \tag{16}$$

then we can write the net value of a job for a new wage for the household:

$$\begin{aligned} \mathcal{A}^H_t(w^*_{s,t}) = {} & \left(S^w_t(w^*_{s,t} - b_{s,t})\right) - \beta(1-\delta_{x,s})\xi_w \left(S^w_{t+1} w^*_{s,t+1} - b_{s,t+1}\right) \\ & - S^h_{s,t} + \beta(1-\delta_{x,s})\xi_w S^h_{s,t+1} \\ & + \beta\left[1 - \delta_{x,s} - (1-\kappa_{ws})p^W_{s,t}\right] \mathcal{A}^H_{t+1}(w^*_{s,t+1}) - \beta\kappa_{ws} p^W_{s,t} \mathcal{A}^H_{t+1}(w_{s,t+1}) \end{aligned} \tag{17}$$

In a similar fashion, we can obtain the value of a job for an average wage for the household:

$$\begin{aligned} \mathcal{A}^H_t(w_{s,t}) = {} & S^w_t(w_{s,t} - b_{s,t}) - \beta(1-\delta_{x,s})\xi_w \left(S^w_{t+1} w_{s,t+1} - b_{s,t+1}\right) \\ & - S^h_{s,t} + \beta(1-\delta_{x,s})\xi_w S^h_{s,t+1} \\ & + \beta\left[(1-\delta_{x,s})(1-\xi_w) - (1-\kappa_{ws})p^W_{s,t}\right] \mathcal{A}^H_{t+1}(w^*_{s,t+1}) \\ & + \beta\left[(1-\delta_{x,s})\xi_w - \kappa_{ws} p^W_{s,t}\right] \mathcal{A}^H_{t+1}(w_{s,t+1}) \end{aligned} \tag{18}$$

2.2.2 Wages and hours

We assume that wages and hours are determined using Nash bargaining. Assuming standard (efficient) Nash bargaining between households and labour firms, every period, wages and hours worked are determined by maximising the following expression, where $0 < \eta_s < 1$ measures the bargaining power of workers of type s:

$$\max_{w^*_{s,t}, h_{s,t}} \left(A^H_t(w^*_{s,t})\right)^{\eta_s} \left(A^F_t(w^*_{s,t})\right)^{1-\eta_s}. \tag{19}$$

The result is that wages are split according to the Nash sharing rule:

$$\eta_s(1-\tau^{wh}_t) A^F_t(w^*_{s,t}) = (1-\eta_s)(1+\tau^{wf}_t) A^H_t(w^*_{s,t}). \tag{20}$$

The intuition for the above rule is that households and labour firms bargain over each other's matching surpluses, where the surplus of the firm is the value of the worker (because in equilibrium the value of the vacancy is zero), and for the household the value of the match is the net gain from being employed (relative to being unemployed), both evaluated at the currently-negotiated wage. The above equation thus determines $w^*_{t,s}$.

The average wage is determined by using the law of motion of labour as follows:

$$\begin{aligned} nde_{s,t}h_{s,t}w_{s,t} = (1-\delta_{x,s})nde_{s,t-1}\left[\xi_w \frac{1+\overline{\pi}}{1+\pi_{t-1}}w_{s,t-1}h_{s,t} + (1-\xi_w)w^*_{s,t}h_{s,t}\right] \\ + M_{s,t}\left[\kappa_{ws}w_{s,t}h_{s,t} + (1-\kappa_{ws})w^*_{s,t}h_{s,t}\right], \end{aligned} \tag{21}$$

where the first row is the average wage of existing workers and the second row is the average wage of new hires, with the number of new matches $M_{s,t}$ counting the number of new hires.[7]

Similarly, hours worked are determined by per-period Nash bargaining, and after taking into account the wage decision (equation 20), hours worked expression is:

$$\alpha_H x_{s,t}(h_{s,t})^{\alpha_{H-1}} = \frac{\chi}{u'(c_{s,t})}\frac{(1+\tau^{wf}_t)}{(1-\tau^{wh}_t)}(h_{s,t})^{\varphi}. \tag{22}$$

The term on the left is the marginal revenue from labour services brought about by an additional hour worked and the term on the right is the marginal disutility of having to work an additional hour, in after-tax consumption terms.

Note that throughout our notation we have assumed that hours worked do not depend on wages. Equation (22) shows that under the assumption of efficient Nash bargaining, this is indeed the case.[8]

2.2.3 Labour packer

Labour from Ricardian and non-Ricardian households is aggregated by a labour packer using a CES technology, as follows:

$$n_t^{1-\frac{1}{\eta}} = \left[(1-\omega)^{\frac{1}{\eta}}\left(nde_{i,t}h^{\alpha_H}_{i,t}\right)^{1-\frac{1}{\eta}} + \omega^{\frac{1}{\eta}}\left(nde_{j,t}h^{\alpha_H}_{j,t}\right)^{1-\frac{1}{\eta}}\right], \tag{23}$$

where n_t are aggregate labour services and $nde_{s,t}h^{\alpha_H}_{s,t}$ are total labour services provided by labour

[7] If indexation is with respect to current-period inflation, the ratio of inflation rates that multiplies the previous-period wage drops out, because previous-period wage is indexed to previous-period inflation.

[8] There are other cases, which change the relation between hours and wages and open the so-called wage channel, see Christoffel and Linzert (2010) and the application in Bodart et al. (2006) and de Walque et al. (2009).

firms in household segment s. Parameter ω measures the share of non-Ricardian households in the economy.

3 Monetary policy rules

We consider three different types of monetary policy rules in the euro area.

Benchmark Taylor rule

$$r_t = \varphi_r \; r_{t-1} + (1 - \varphi_r) \left(r^* + \pi^* + \varphi_\pi \left(\pi_t - \pi^* \right) + \varphi_u \; \hat{u}_t \right) + \epsilon_t^R \tag{24}$$

where r_t is the annualised nominal interest rate, r^* is the annualised long-run equilibrium real interest rate, π_t is the annual price inflation rate, π^* is the annual inflation target, and $\hat{u}_t$ is the unemployment gap, i.e. the gap between the unemployment rate une_t and its steady-state level, $\overline{une}$.[9] ϵ_t^R is a shock.

Taylor rule with an asymmetric response to unemployment

$$r_t = \varphi_r \; r_{t-1} + (1 - \varphi_r) \left(r^* + \pi^* + \varphi_\pi \left(\pi_t - \pi^* \right) + I_{u>u^*} \varphi_U \; \hat{u}_t \right) + \epsilon_t^R \tag{25}$$

where $I_{u>u^*} \varphi_U$ is an indicator function that takes the value 1 if the unemployment rate is above its steady-state value u^* and 0 otherwise. This rule follows Board of Governors of the Federal Reserve System (2022) and Bundick and Petrosky-Nadeau (2021).

Average inflation targeting rule

$$r_t = \varphi_r \; r_{t-1} + (1 - \varphi_r) \left(r^* + \pi^* + \varphi_\pi \left(\bar{\pi}_t^T - \pi^* \right) + \varphi_u \; \hat{u}_t \right) + \epsilon_t^R \tag{26}$$

where $\bar{\pi}_t^T$ is the annualised average inflation rate over the past T years (T is the averaging window, which we set to be equal to 4 years).

[9] The monetary policy increases (decreases) interest rates when the unemployment rate is below (above) its steady state value. For convenience purposes, the gap is defined such that the parameter φ_u is positive.

4 Calibration

This section describes the sources used for the calibration and the rationale for the choices that were made when calibrating the model. We have made two major updates to the calibration of the original EAGLE model. First, in line with the existing models of similar size (e.g., Bayoumi et al. (2004), Faruqee et al. (2008)), we calibrate the great ratios and trade direction based on national accounts, while keeping in line with the empirical estimates in Christoffel et al. (2008)) for the euro area. Second, we provide more detail on the calibration of the labour market in the model, which is a novel feature of the model, with more focus on heterogeneity, both across countries and between the agents within each country.

The values for the great ratios are reported in Table 1. The sample we use is from 1999-2019, which covers the period from the start of the euro to the beginning of the COVID-19 crisis. Compared to earlier calibrations (Gomes et al. (2010) and Gomes et al. (2012)) countries have become more open, the share of public investment in Europe has declined, and the interest rate has been lower. Table 2 reports the corresponding trade matrix.

TABLE 1. Steady-State National Accounts (Ratio to GDP, %)

	Home	REA	US	RW
Domestic demand				
Private consumption	59.90	58.19	62.50	61.30
Private investment	18.20	18.30	17.20	20.00
Public consumption	19.3	20.00	16.00	16.00
Public investment	2.20	3.40	3.80	3.00
Trade				
Imports (total)	35.60	19.20	15.20	16.39
Imports of consumption goods	23.73	16.24	9.63	9.46
Imports of investment goods	11.87	2.96	5.57	6.93
Net foreign assets (ratio to annual GDP)	40	-15	-	40
Production				
Tradables	39.00	35.16	34.59	37.52
Non-tradables	61.00	65.14	65.41	62.48
Labour				
Share of world GDP	5.4	13.8	25.5	55.3

Note: REA=Rest of the euro area; US=United States; RW=Rest of world

For nominal rigidities related to goods prices, we report the markups in Table 3. These follow the estimates from Christoffel et al. (2008) and the calibration in Gomes et al. (2012).

Table 4 shows the calibration of the household and firm sectors. In line with the low real interest rates observed in the sample period, we calibrate the household discount factor to

Table 2. International Linkages (Trade Matrix, Share of Domestic GDP, %)

	Home	REA	US	RW
Consumption-good imports				
Total consumption good imports	23.73	16.24	9.63	9.46
From partner				
Home	-	2.46	0.41	1.17
REA	11.25	-	1.03	3.89
US	1.48	0.38	-	4.40
RW	10.99	13.40	8.18	-
Investment-good imports				
Total investment good imports	11.87	2.96	5.57	6.93
From partner				
Home	-	1.79	0.25	0.80
REA	5.63	-	0.50	2.41
US	0.75	0.53	-	3.72
RW	5.50	0.65	4.83	-

Note: REA=Rest of the euro area; US=United States; RW=Rest of world

Table 3. Price Markups (Implied Elasticities of Substitution)

	Tradables (θ_T)	Non-tradables (θ_N)
Home	1.20 (6.0)	1.50 (3.0)
REA	1.20 (6.0)	1.50 (3.0)
US	1.20 (6.0)	1.28 (4.6)
RW	1.20 (6.0)	1.28 (4.6)

Note: REA=Rest of the euro area; US=United States; RW=Rest of world

Table 4. Households, Entrepreneurs and Firms Behaviour

	Home	REA	US	RW
Households				
Discount factor (β)	$1.01^{-\frac{1}{4}}$	$1.01^{-\frac{1}{4}}$	$1.01^{-\frac{1}{4}}$	$1.01^{-\frac{1}{4}}$
Intertemporal elasticity of substitution (σ^{-1})	1.00	1.00	1.00	1.00
Habit persistence (κ)	0.70	0.70	0.70	0.70
Capital depreciation rate (δ^K)	0.025	0.025	0.025	0.025
Share of non-Ricardian households (ω)	0.25	0.25	0.25	0.25
Interm.-good firms (trad. and non-trad. sectors)				
Subst. btw. labour and capital	1.00	1.00	1.00	1.00
Bias towards capital - tradables (α_T)	0.30	0.30	0.30	0.30
Bias towards capital - non-tradables (α_N)	0.30	0.30	0.30	0.30
Production - labour services (α_H)	0.99	0.99	0.99	0.99
Final consumption-good firms				
Subst. btw. domestic and imported trad. goods (μ_{TC})	0.60	0.60	0.60	0.60
Bias towards domestic tradable goods (υ_{TC})	0.28	0.22	0.65	0.59
Subst. btw. tradables and non-tradables (μ_C)	0.50	0.50	0.50	0.50
Bias towards tradable goods (υ_C)	0.45	0.45	0.35	0.35
Substitution btw. consumption good imports (μ_{IMC})	0.60	0.60	0.60	0.60
Final investment-good firms				
Subst. btw. domestic and imported trad. goods (μ_{TI})	0.60	0.60	0.60	0.60
Bias towards domestic tradable goods (υ_{TI})	0.40	0.76	0.71	0.56
Substitution btw. tradables and non-tradables (μ_I)	0.50	0.50	0.50	0.50
Bias towards tradable goods (υ_I)	0.75	0.75	0.75	0.75
Substitution btw. investment good imports (μ_{IMI})	0.60	0.60	0.60	0.60

Note: REA=Rest of euro area; US=United States; RW=Rest of world correspond to 1% real interest rate per annum.

The details of the labour market calibration are reported in Table 5. The labour supply elasticity is set to 0.2 (its inverse, $\zeta = 5$) and is lower than typically in the literature (0.5, or its inverse $\zeta = 2$) to mitigate the response of hours worked, in line with empirical evidence that hours per worker (intensive margin) are relatively stable compared to unemployment (extensive margin).[10] Matching probabilities of Ricardian and non-Ricardian workers come from own estimates, computed using the OECD and Eurostat data for unemployment duration by educational attainment for 2017 and 2018 using the method of Shimer (2012), where we assume that non-Ricardian households are those with below upper-secondary education and Ricardians are those above upper secondary education.[11] The matching probability for firms in both segments is based on the estimates for the US in Ramey et al. (2000) (similar values are used in Stähler and Thomas (2012)). Unemployment rates are averages from 2004-2019, based on OECD data. As for job finding rates, we assume that the unemployment rate for non-Ricardian households is the unemployment rate for persons with educational attainment below upper-secondary. Matching efficiency and vacancy posting costs are calibrated to fit matching probabilities. The outcomes are roughly in line with the literature (for instance, Jung and Kuhn (2014) find that the matching efficiency in Germany is low compared to the US, which also comes out of our calibration). We calibrate the break-up rate of non-Ricardians to match the level of unemployment in this group in each bloc, while we use the break-up rate of Ricardians to match the overall rate of unemployment. Because the unemployment rate of non-Ricardians is larger, this also results in larger break-up rate for this group of households across blocs. Bargaining power has been set to 0.5, for both groups of households, in line with the literature. We calibrate the matching elasticity for Ricardian households to 0.5, which is in the middle of the range reported by Petrongolo and Pissarides (2001). For the non-Ricardian households, we set this elasticity to a lower value of 0.2, to prevent that a cyclical increase in unemployment of non-Ricardians would generate numerous new matches. Unemployment benefits are set as a proportion of the steady-state wage (the replacement ratio). Replacement ratios are based on the OECD estimates. We use one-year horizon for Ricardian households and two-year horizon for non-Ricardian households,

[10] Recall that the model has an intensive and extensive margin, so that aggregate hours worked do fluctuate more than individual hours worked.

[11] The estimates are population-weighted across countries. Because we only have data for OECD countries (and not all of them), we made the following approximations. The REA is based on Austria, Belgium, Estonia, Finland, France, Greece, Italy, Latvia, The Netherlands, Slovakia, Slovenia, and Spain. The RW is based on Czechia, Denmark, Hungary, Norway, Sweden and Poland.

reflecting the fact that the latter are more likely to be long-term unemployed, to determine the replacement ratios. Finally, probabilities to renegotiate an existing wage and the probabilities to start the new job at the average wage were taken from de Walque et al. (2009). Because we have no evidence that these rates differ between Ricardian and non-Ricardian households, we kept them the same across both groups.

TABLE 5. Labour market

	Home	REA	US	RW
Inverse of the Frisch elasticity of labour supply (ζ)	5.00	5.00	5.00	5.00
Matching probability, Ricardian workers, (p_i^W)	0.3021	0.2238	0.5292	0.3442
Matching probability, HtM workers, (p_j^W)	0.2090	0.1848	0.5385	0.2598
Matching probability, firms, (p_s^F)	0.70	0.70	0.70	0.70
Matching efficiency, Ric. w., ($\varphi_{i,M}$)	0.4598	0.3957	0.6086	0.4908
Matching efficiency, HtM w. ,($\varphi_{j,M}$)	0.5496	0.5363	0.6642	0.5741
Vac. posting cost, Ric. w.,(Ψ_i)	0.4091	0.6768	1.1325	0.9170
Vac. posting cost, HtM w., (Ψ_j)	1.2933	1.0133	0.8246	1.1525
Break-up rate, Ric. w., (δ_{xi})	0.0203	0.0298	0.0592	0.0344
Break-up rate, HtM w., (δ_{xj})	0.0443	0.0348	0.1179	0.0359
Disutility of labour, Ric. w., (χ_i)	1.1481	1.2333	1.3882	1.4416
Disutility of labour, HtM w., (χ_j)	4.6902	4.2066	4.8728	4.4392
Matching elasticity, Ric. w., (μ_i)	0.50	0.50	0.50	0.50
Matching elasticity, HtM w., (μ_j)	0.20	0.20	0.20	0.20
Bargaining power, Ric. w., (η)	0.50	0.50	0.50	0.50
Bargaining power, HtM w., (η)	0.50	0.50	0.50	0.50
Replacement ratio, Ric. w., ($rrat_i$)	0.590	0.590	0.084	0.386
Replacement ratio, HtM w., ($rrat_j$)	0.228	0.486	0.084	0.320
Unemployment rate, (un)	0.0696	0.1038	0.0605	0.0694
Unemployment rate, HtM w., (un_j)	0.1437	0.1334	0.0918	0.0930
Prob. to renegotiate existing wage, Ric. w., (ξ_{wi})	0.8879	0.8879	0.8879	0.8879
Prob. to renegotiate existing wage, HtM w., (ξ_{wj})	0.8879	0.8879	0.8879	0.8879
Prob. to start job at avg. wage, Ric. w., (κ_{wi})	0.7	0.7	0.7	0.7
Prob. to start job at avg. wage, HtM w., (κ_{wj})	0.7	0.7	0.7	0.7

Note: REA=Rest of the euro area; US=United States; RW=Rest of world

We parametrise the euro area monetary policy rules as shown in Table 6. The parameters are in line with Gomes et al. (2010) and Gomes et al. (2012).[12] The new parameters φ_u and φ_I that determine the weight on unemployment and asymmetric reaction to are set in line with Rudebusch (2010) and Elias et al. (2014). We consider several weights for the response of the central bank to unemployment.

[12]We keep the monetary policy rule in the RW and in the US at the standard Taylor rule form, where the central bank responds to inflation and the output growth, with the interest rate inertia set to 0.87, the response to the deviation from the annual inflation target at 1.70, and the response to the output growth at 0.10.

Table 6. Monetary policy rules

	Euro area
Interest rate smoothing, φ_r	0.87
Response to inflation, φ_π	1.70
Response to unemployment, φ_u	(0.00, 2.00, 3.00)
Inflation target, π^*	2.00
Real rate, r^*	1.00

5 Scenarios

We compute the responses of a number of variables to an expansionary (inflationary) aggregate demand shock across the euro area. This is a type of shock that pushes inflation and real activity in the same direction and therefore a shock where a central bank can counter an increase in inflation likely without causing a recession. Next, we consider an inflationary aggregate supply shock, which is contractionary for real activity (and employment), and therefore leads to a trade-off between stabilising prices and worsening economic activity.

These shocks provide us the framework to analyse and compare the performance of different monetary policy rules (benchmark Taylor rule with IT, ASUT, AIT) for a stylised set of circumstances encountered by policymakers. The three rules by design already differ in terms of how actively the central bank responds to an increase in inflation. In addition, for each rule, we also distinguish between cases with zero weight on the unemployment gap and with positive weight on unemployment gap (defined as the difference between steady state unemployment and actual unemployment), where the policy rate falls if unemployment increases.

5.1 Expansionary demand shock

For the expansionary demand shock we consider a combination of a preference shock and an investment technology shock, symmetrically in both regions that constitute the euro area.[13] The reason for opting for a combination of shocks is that we wanted to mimic a broad increase in consumption and investment demand, rather than a shift between consumption and investment, which is what only one of the two structural shocks would generate. The shock sizes are standardised to achieve a 1 p.p. maximum increase in inflation (annualised) under the benchmark rule (IT) with a positive weight on unemployment, and this size of the shocks is kept fixed across simulations with different monetary policy rules.

[13]Shocks are persistent with the quarterly AR(1) coefficient of 0.9.

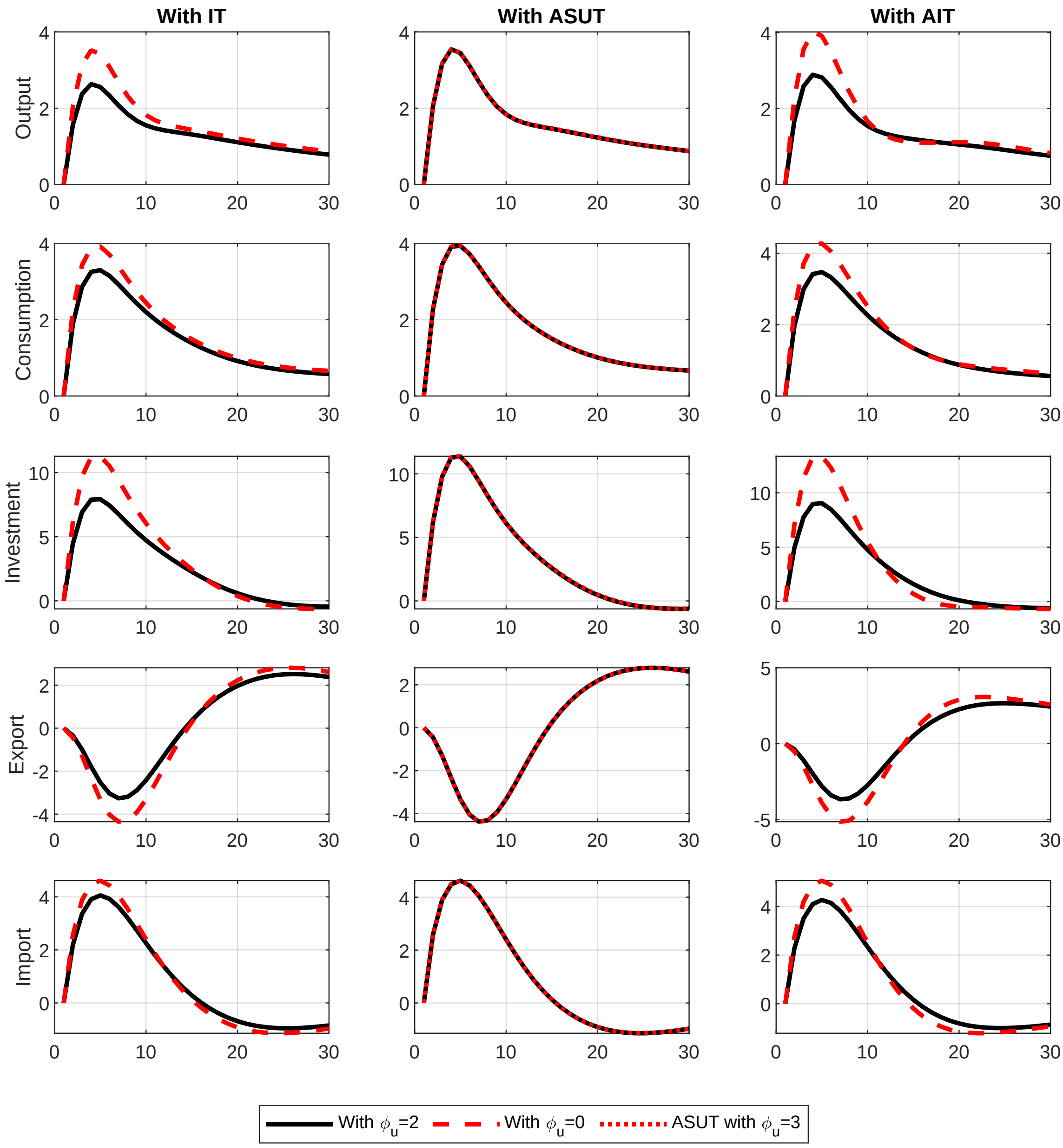
Figures 1 and 2 show the euro-area-wide variables for the three interest rate rules, one in each column and for different weights placed on unemployment. The full black line shows the case when the central bank responds to the unemployment rate and the dashed red line shows the case where the central bank does not respond to unemployment. For the ASUT rule the case where the weight on unemployment is zero always corresponds to the strict inflation targeting rule, i.e., to dashed red lines in the leftmost column of the figure.

Three observations stand out. First, not reacting to unemployment tends to exacerbate fluctuations in all variables (except the nominal interest rate), under all rules. This is expected, because placing some weight on unemployment implies that the central bank tightening in an economic expansion should be stronger if unemployment decreases in addition to an inflation increase. When monetary authority responds to unemployment, it counteracts the decline in unemployment, the expansion of economic activity is smaller and the increase in inflation is also milder. Note that in the case of the ASUT, given that the shock implies a decrease in unemployment, the rule's response to the unemployment rate is not triggered, so the rule boils down to a "pure" IT rule (i.e. a rule that only responds to inflation developments). This implies that a stronger response to unemployment (which we show with dotted red line) coincides with the less aggressive reaction to unemployment and both coincide with strict inflation targeting. In the case of a negative (i.e. deflationary) demand shock the opposite happens, the response to unemployment is triggered and the responses would basically correspond to the benchmark case or be more inflationary with lower employment losses in case of the more aggressive rule (see Appendix A).

Second, fluctuations tend to be more pronounced under the AIT rule, even when the rule does include a response to unemployment. The reason is that the AIT rule is relatively slow to react, so interest rates rise more slowly in response to an economic expansion, which delays the dampening of demand. This can be seen in a slower and weaker increase in nominal rates and a stronger decrease in real interest rates under the AIT compared to other rules. Including the response to unemployment in the AIT rule helps dampening the fluctuations, because unemployment has a non-zero weight in the rule and an unemployment decrease implies that under the AIT the central bank can respond less sluggishly (see the bottom-right panel of Figure 2).

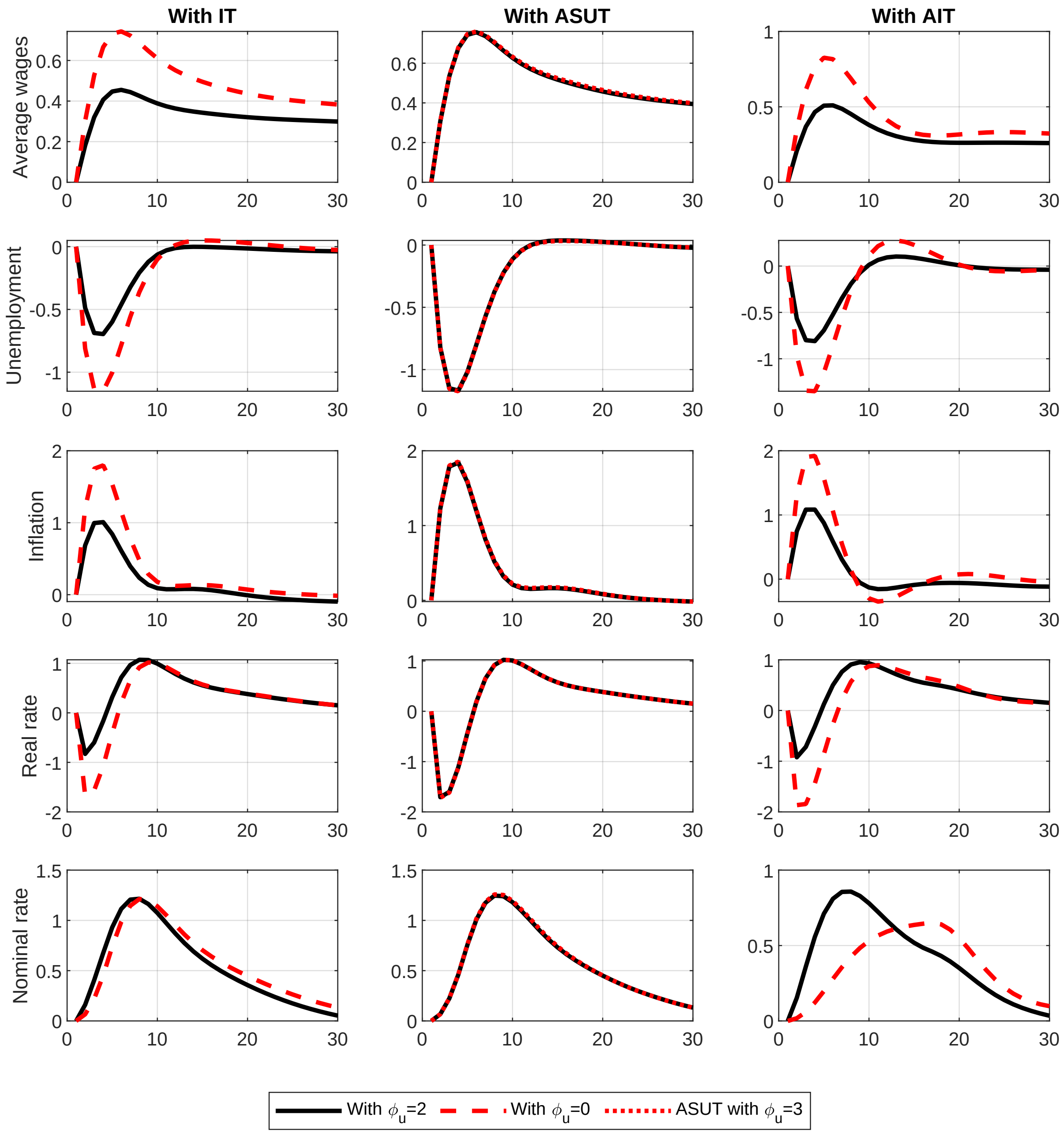
Figures 3 to 5 show country-specific outcomes in the euro area for the three monetary policy rules. The Home country is shown with red lines and the rest of the euro area with black lines. The first thing to note are considerable differences between the two regions regardless of

FIGURE 1. Expansionary demand shock: area-wide demand components



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

FIGURE 2. Expansionary demand shock: area-wide variables



Horizontal axes: quarters; vertical axes: percentage point deviations from the steady state, except wages, which are in precent deviations. Interest rates and inflation are annualised.

the monetary policy rule. This reflects in part the differences in the labour markets, but also differences in the structure of the economy. One such difference between the EA blocs is in terms of import-content of investment, where Home imports a much bigger share of investment goods than the REA. This is part of the reason why imports in Home increase as much as in the REA even though investment and consumption increase by less. Another reason for the differences is the export orientation of the two euro-area blocs. Home is much more open to outside-euro-area blocs, i.e., the RW and the US, while the REA is more closed. This leads to a different degree of exposure to the euro exchange rate and therefore different fluctuations in exports, as can clearly be seen in Figure 3. The REA finances its increase in consumption and investment by running a large trade deficit, while Home runs a lower trade deficit because it finances it by an increase in exports.

Differences in labour market structure also lead to some divergence between countries. For instance, while Home's output increases by about a two thirds as much as the REA output, unemployment drops by half as much as in the REA. The reason for this more sluggish response of unemployment is that wages in Home increase by about half as much as in the REA, but more persistently, which dampens hiring.

Figure 5 explains where among the households this dampening of hiring occurs. In Home, most of the dampening of hiring is among the poor HtM households. There, the job finding probability increases the least, compared with the Ricardian households. This is not the case in the REA, where most of the adjustment in employment and job finding is on the side of the poor HtM households. This holds throughout the rules and regardless of whether the central bank attaches some weight to unemployment or not.

Interestingly, if the central bank does *not react* to unemployment after an expansionary shock, this implies that consumption level of the poor households in both EA regions increases by more than the consumption level of richer Ricardian households and therefore leads to a reduction in consumption inequality. Here it is appropriate to recall part the statement of Chairman Powell (2020) that we cited in the Introduction, namely the "... appreciation of a strong labour market, particularly for many in low- and moderate-income communities ...". In the case of an expansionary demand shock, this line of thinking implies that central banks seeking to reduce inequality in consumption should allow for somewhat higher inflation by not tightening in response to a strong labour market. This is akin to the asymmetric unemployment targeting rule, which would ignore unemployment whenever it decreased below its steady-state value (or respond less to its decrease), as displayed in the middle panel of the figure, where the full and dotted lines coincide.[14]

Another important takeaway from the cross-country comparison is that the divergence between two intra-EA regions tends to be the strongest when fluctuations are large in absolute terms, which happens when monetary policy does not respond to unemployment. Similarly, the divergence in consumption levels of households within each country also tends to be higher when the central bank does not respond to unemployment (that is, the inequality in consumption in the REA is reduced more strongly than in Home when central bank does not react to unemployment).

5.2 Inflationary supply shock

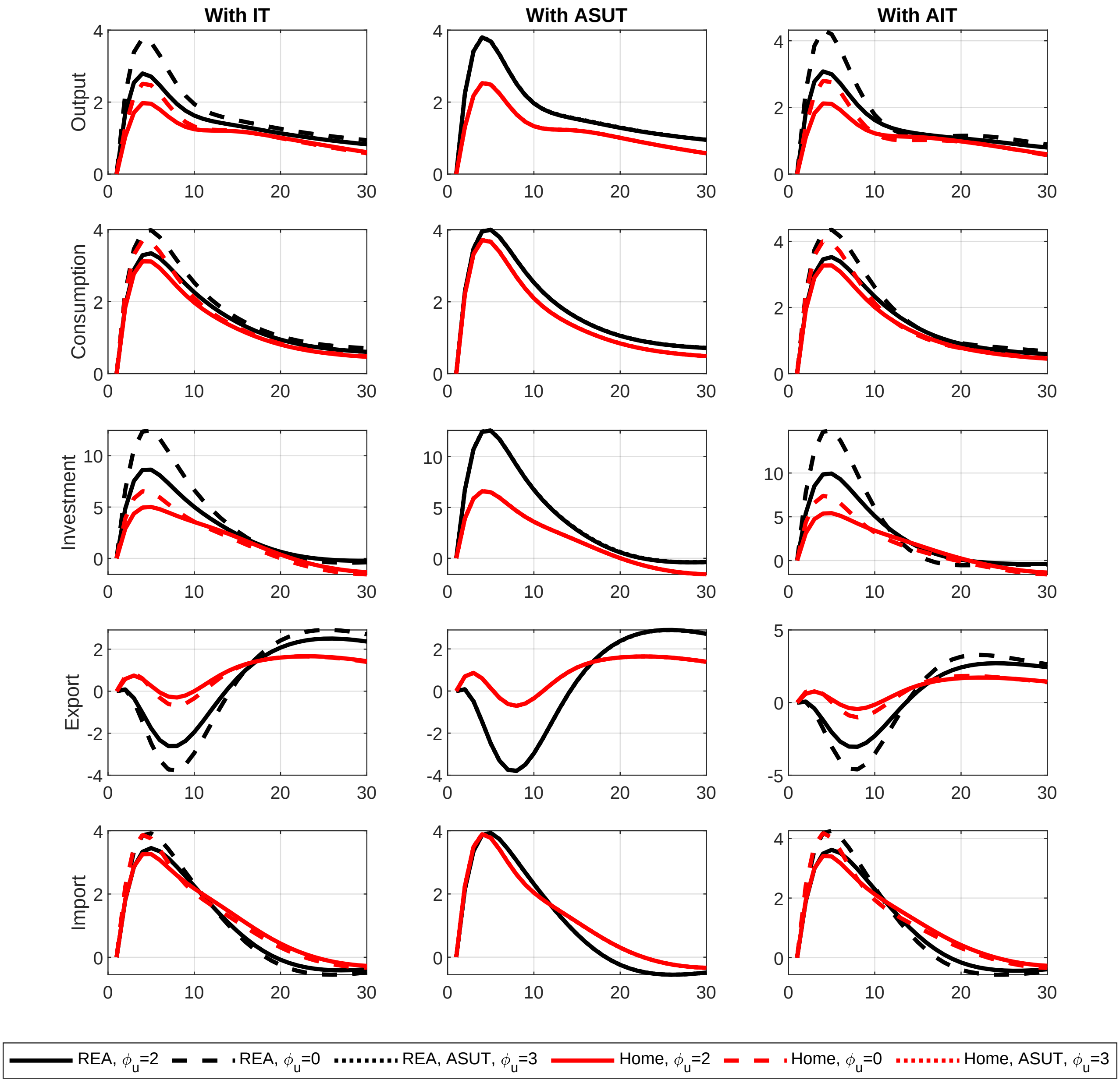
We now investigate the performance of monetary policy rules under the shock scenario that induces a trade-off between stabilizing inflation and unemployment. To achieve this, we simulate an asymmetric and equal increase in markups in tradable and non-tradable sectors in both blocs of the euro area.[15] As before, the size of the shock is calibrated to achieve a 1 p.p. maximum increase in the euro-area-wide inflation under the benchmark ¡rule and the size of the shock is kept the same across policy rules.

Figures 6 and 7 show the euro area-wide outcomes. The supply shock generates an increase in inflation and a negative impact on economic activity. Also in this case the fluctuations in (un)employment, aggregate demand and its components are stronger if the central bank pays no attention to unemployment, while in this case inflation shows a much milder increase.

Compared to the other two rules, AIT tends to attenuate or even neutralise the negative real impact of the shock in the first few quarters when the central bank reacts to unemployment, mainly because this rule stipulates a slower increase in the nominal rate, which results in a stronger drop in real interest rate and hence an increase in Ricardian households' consumption in the short run. Recall that these households represent 75% of all households and that their consumption level is about a quarter higher than consumption of HtM households, so that Ricardian households have a strong influence on aggregate consumption. This effect on Ricardian households' consumption due to a lower real rate is present for all rules and can also be observed for the more aggressive ASUT rule in the middle column. Moreover, in the case of the AIT rule

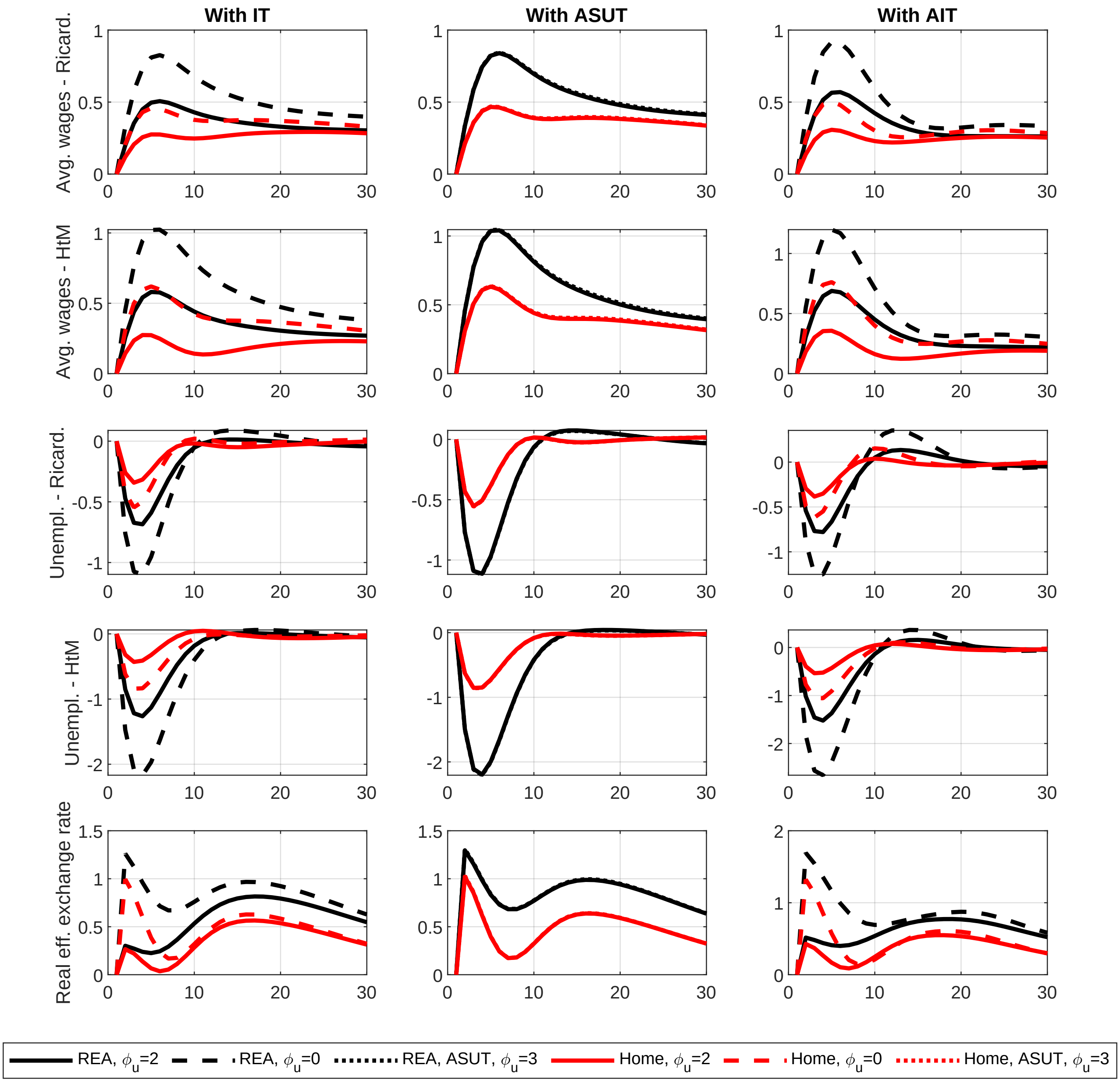
[14] We are grateful to Jelena Zivanovic for alerting us to asymmetric unemployment targeting.
[15] Shocks are persistent with the quarterly AR(1) coefficient of 0.9.

FIGURE 3. Expansionary demand shock: country-specific demand components



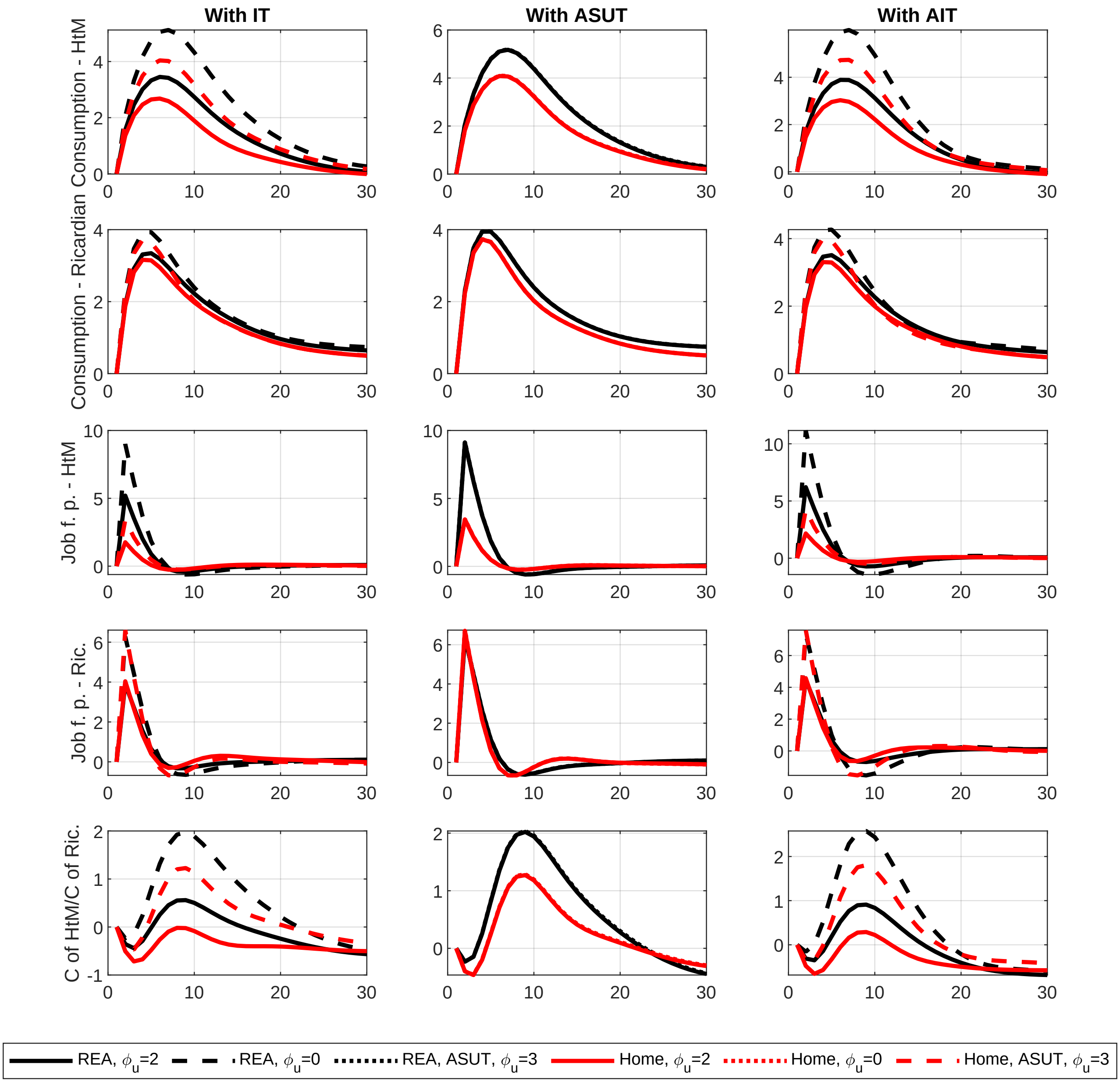
Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

FIGURE 4. Expansionary demand shock: country-specific variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

FIGURE 5. Expansionary demand shock: country-specific variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except job finding rates and relative consumption, which are in p.p. deviations. All variables are in real terms.

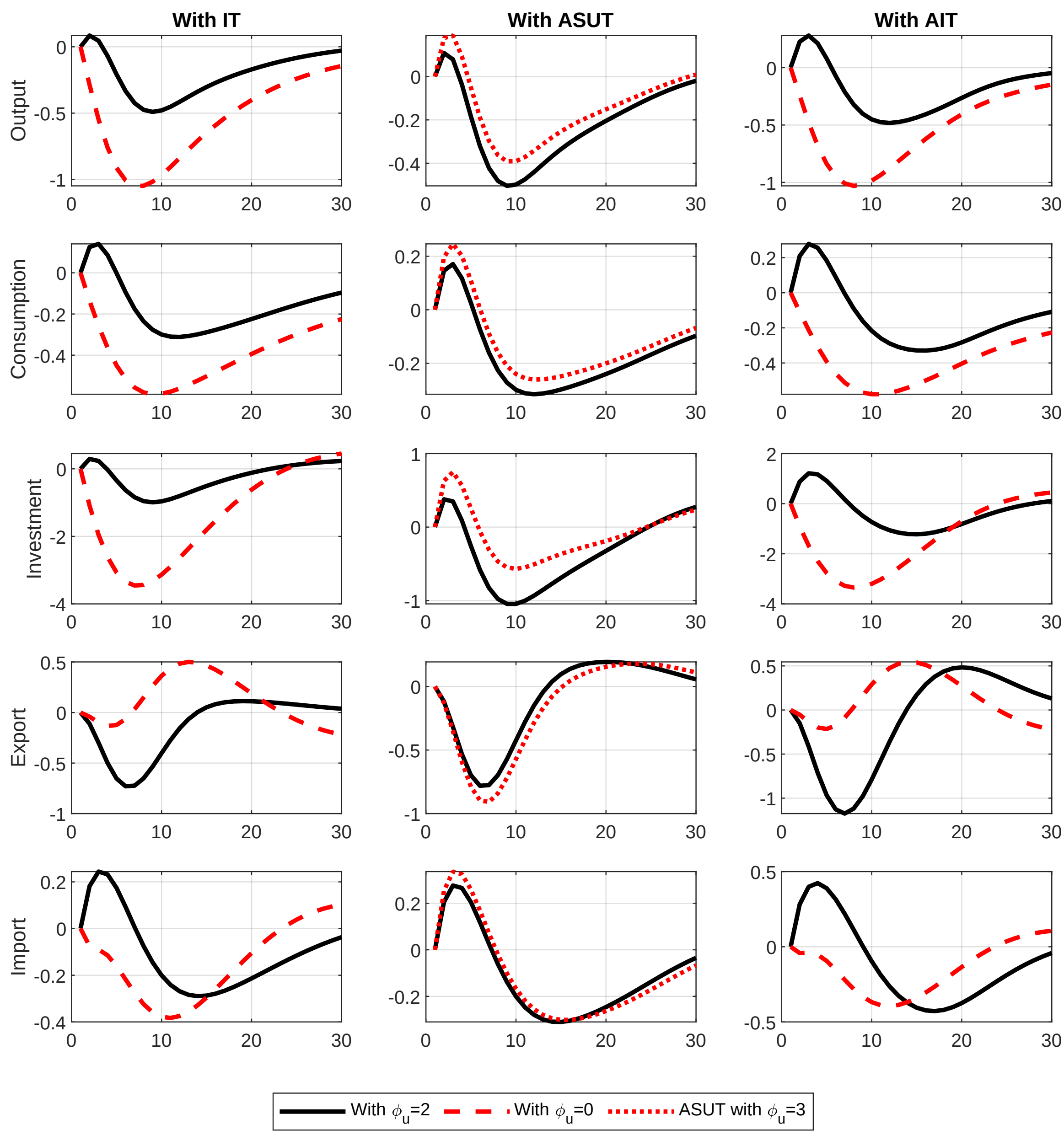
this effect is sufficiently strong that it prevents the short-run increase in unemployment, which shields the income and consumption of HtM households in the short run (these effects can most clearly be seen by looking at full lines in Figure 10).

Unlike for the expansionary demand shock, the supply shock generates an increase in unemployment and therefore triggers a monetary policy response. For instance, the ASUT rule in its more aggressive version achieves a lower peak increase in unemployment than AIT that responds to unemployment. Therefore, the ASUT rule mitigates the effect of the shock on unemployment but at the cost of higher inflation.

Figures 8 to 10 show the responses across countries, members of the euro area. Home is shown in black and the REA in red lines. Compared to the expansionary demand shock, the responses of both EA blocs to the shock are less divergent. The main reason for this is that production functions of Home and the REA do not differ as much as their structures of aggregate demand. Nevertheless, we still see some common properties of the monetary policy rules. First, we again observe a much stronger divergence between Home and the REA when monetary policy only responds to inflation (impulse responses shown with dashed lines tend to be more apart than impulse responses shown with full lines, with the exception of wages and consumption of HtM households). This holds across all three types of rules (IT, ASUT, AIT).

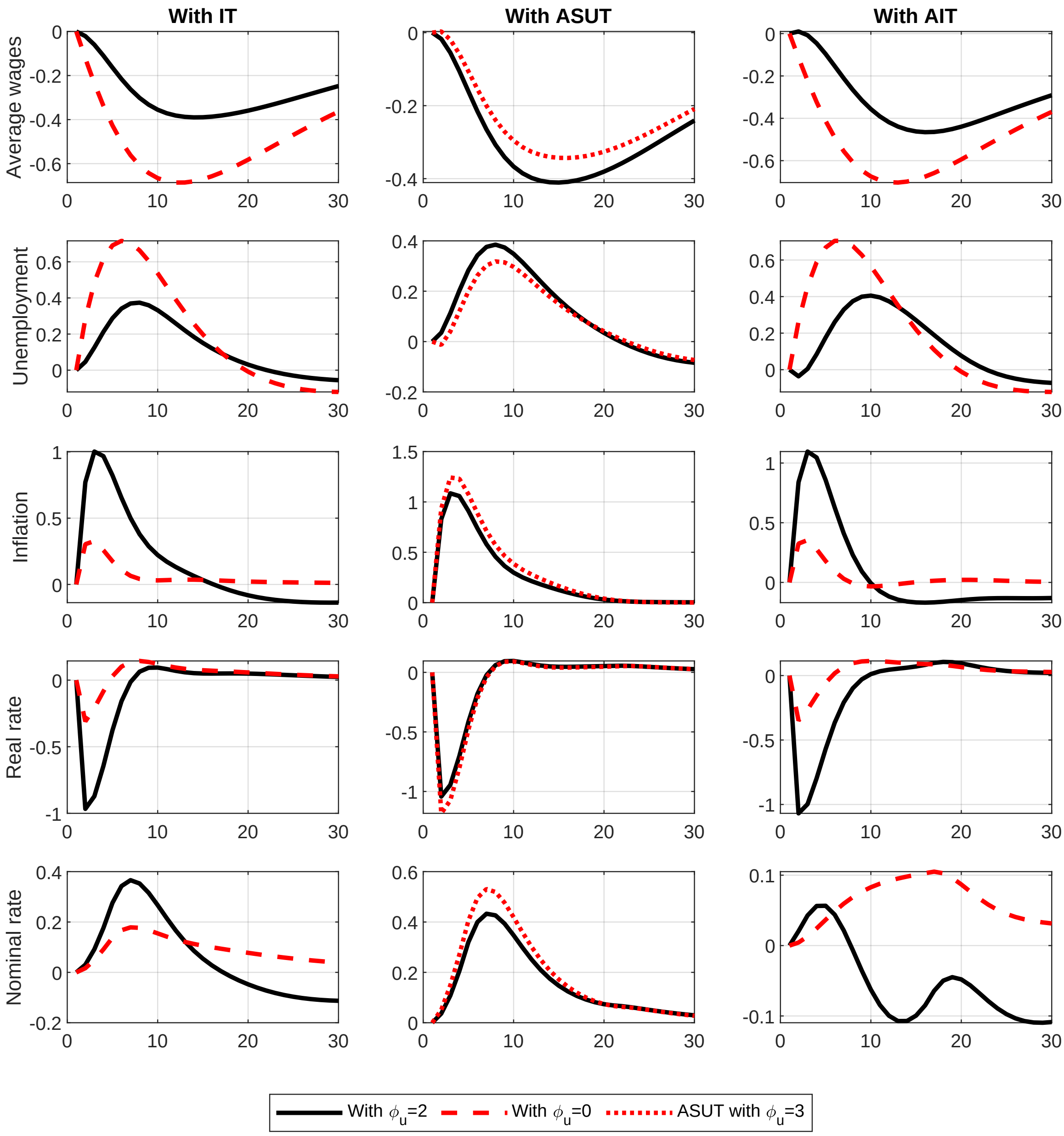
Second, we can see how the effect of lower real rate stimulates consumption of Ricardian households in the short run when central bank reacts to unemployment in Figure 10. Across the rules, but especially for ASUT and AIT, this temporary increase in aggregate demand increases job finding probability of HtM households, which for a short period of time protects their employment, income and consumption. The reason why there is an increase in job finding probability for HtM households is that their wages decrease by more than wages of Ricardian households, which shifts aggregate labour demand from firms more towards the now cheaper labour of HtM households. In this case we also observe that the divergence between Ricardian and HtM households' consumption is limited. This is in stark contrast with the case where central bank only responds to inflation and where employment, wages, and job finding probabilities fall across the board already on impact. In this case, we also see a strong increase in inequality in terms of consumption in both EA blocs, as HtM households' consumption decreases my much more than consumption of Ricardian households.

Figure 6. Inflationary supply shock: area-wide demand components



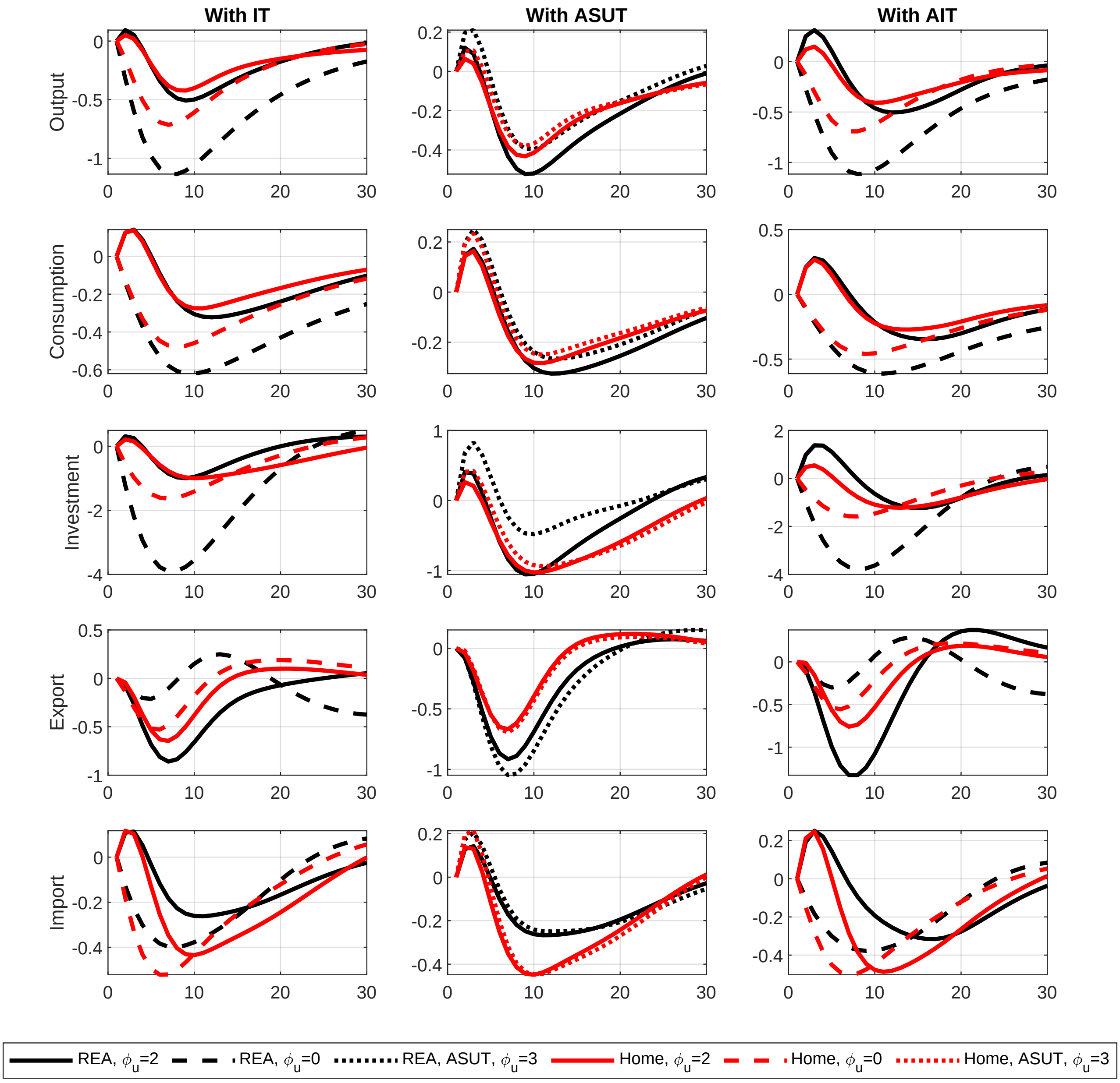
Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

FIGURE 7. Inflationary supply shock: area-wide variables



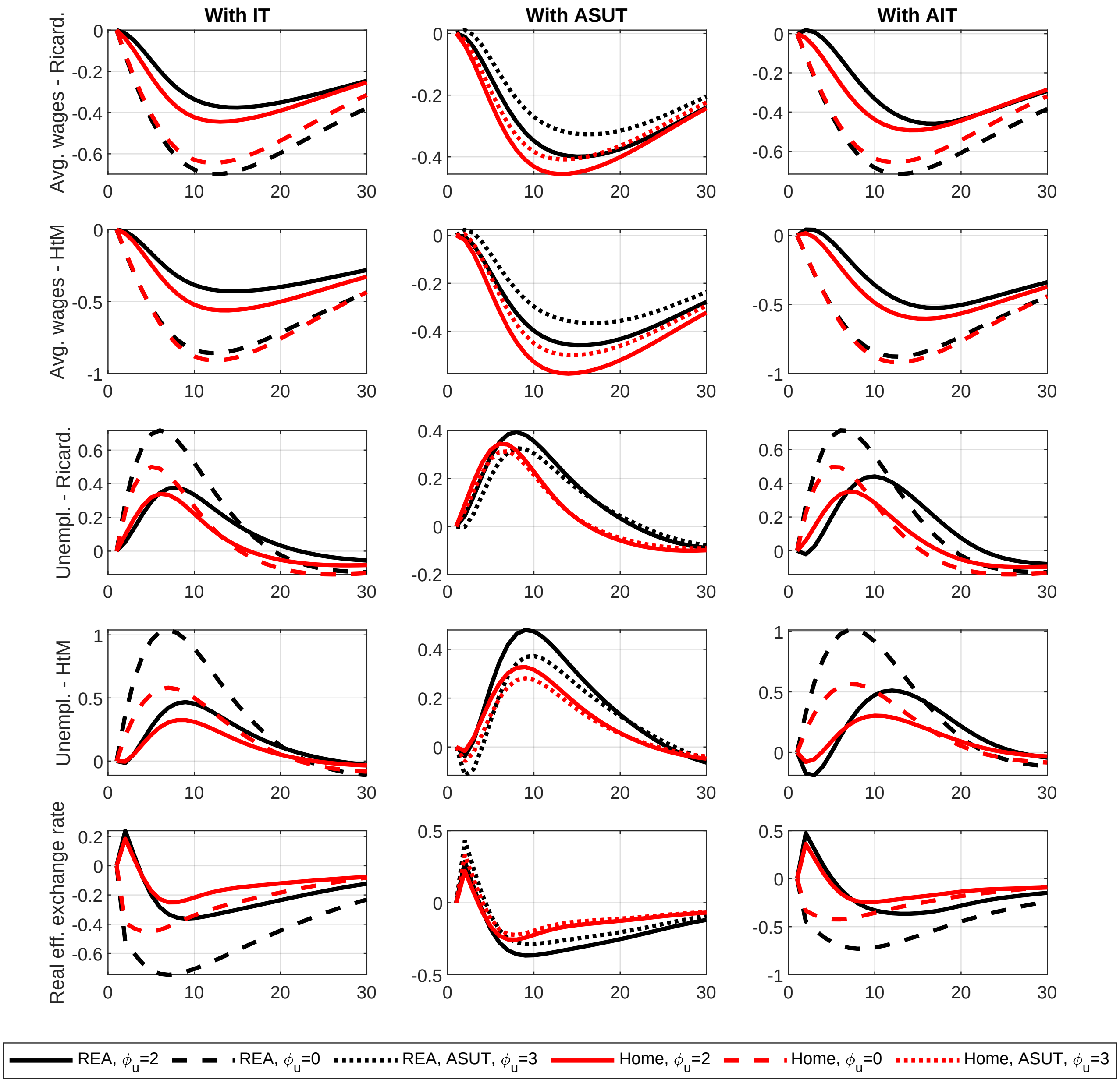
Horizontal axes: quarters; vertical axes: percentage point deviations from the steady state, except wages, which are in precent deviations. Interest rates and inflation are annualised.

Figure 8. Inflationary supply shock: country-specific demand components



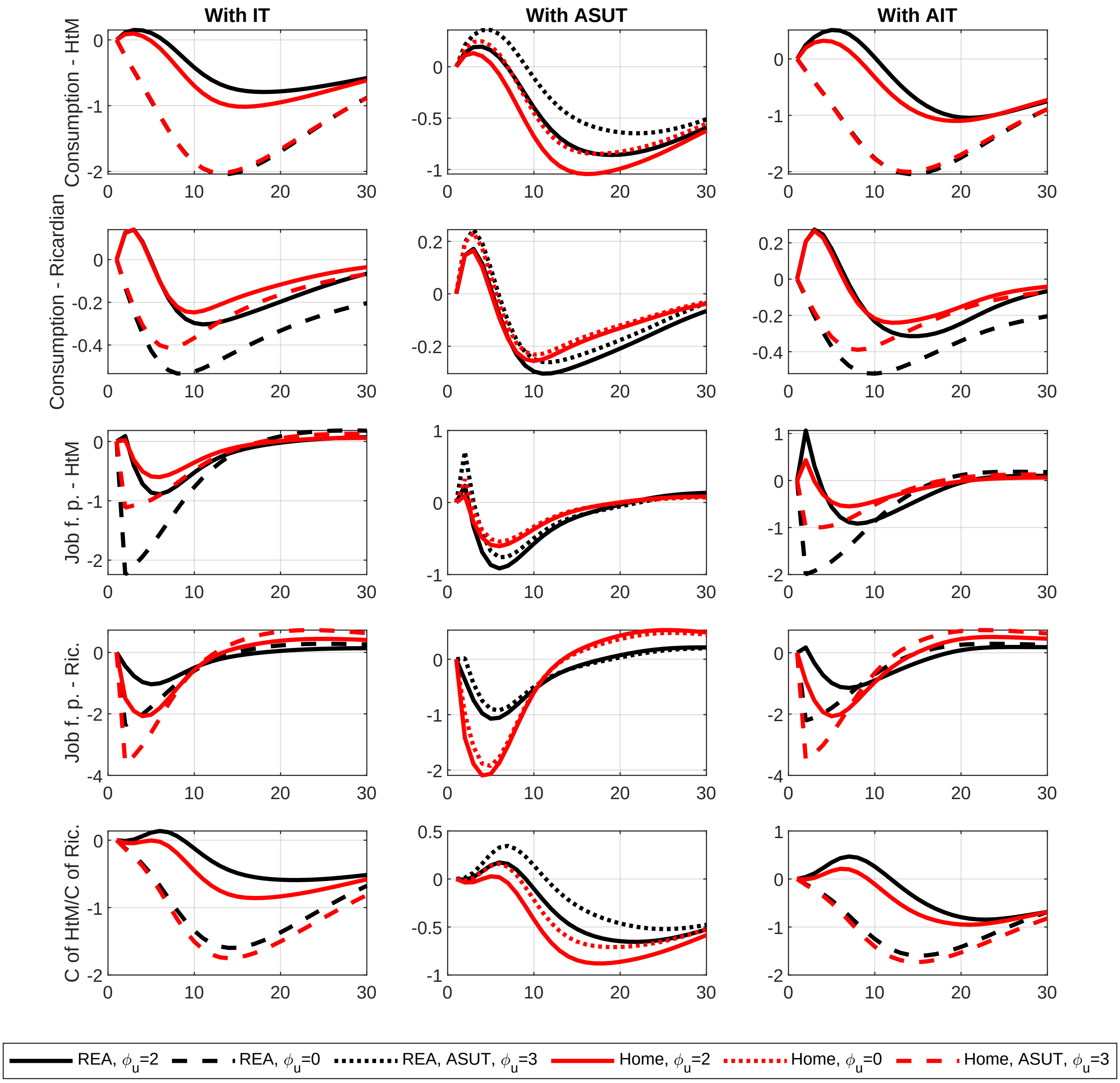
Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

FIGURE 9. Inflationary supply shock: country-specific variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

FIGURE 10. Inflationary supply shock: country-specific variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except job finding rates and relative consumption, which are in p.p. deviations. All variables are in real terms.

6 Conclusion

In this paper we analyse the concerns of policymakers regarding the degree to which central banks should pay attention to unemployment, in addition to inflation. One reason that has been mentioned for the importance of looking at the labour market is because of its importance for the incomes low- and medium-income households. In the euro area, an important consideration is also heterogeneity in labour market institutions across countries. To analyse these issues, we build a model that has realistic features that enable us to analyse the issues faced by the policymakers. We do so by first augmenting a global model of the euro area within the global economy with real and nominal frictions on the labour market. Real frictions take the form of Diamond-Mortensen-Pissarides search-and-matching frictions, which give us unemployment in equilibrium. Then we add nominal wage rigidities using the staggered wage setting, adapted to search models. Moreover, we distinguish between Ricardian and non-Ricardian households. This gives us a realistic framework, with a global TANK model of the euro area with labour market frictions that differ across types of households.

Using this augmented model we look at the performance of several monetary policy rules, namely inflation targeting, inflation targeting with an asymmetric response to unemployment, and average inflation targeting, where each of these rules includes some interest rate inertia, and can respond to the inflation gap and to the unemployment gap, to different degrees. We then analyse the performance of these rules, conditional on whether they feature the response to unemployment gap or not, in two settings. The first setting is an expansionary aggregate demand shock, where inflation and employment move in the same direction, so that there is no trade-off between inflation and unemployment. The second shock we consider is an inflationary supply shock that increases inflation and reduces employment. This shock creates a trade-off for a central bank between stabilising inflation and unemployment.

We then compare the performance of different rules in the monetary union along several dimensions. We investigate how do different rules affect the overall output and inflation responses in the euro area, but then we examine in more depth how do they affect the cross-country differences and within-country differences between Ricardian and HtM households.

Our main findings are the following. First, across all types of rules, responding to unemployment leads to lower fluctuations in unemployment and real economic activity, but with higher inflation in the short term in the case of the supply shock. Second, across all types of rules, assigning some weight to (un)employment tends to reduce cross-country differences within the monetary union. Third, also across all types of rules, assigning some weight to unemployment tends to reduce the differences in consumption levels of different types of households within the economy. However, when the central bank does not respond to unemployment after an expansionary demand shock, the difference between consumption of different types of households goes in favour of poor HtM households, while after an inflationary supply shock this difference goes in favour of richer Ricardian households.

References

Amberg, N., Jansson, T., Klein, M., Picco, A.R., 2022. Five facts about the distributional income effects of monetary policy shocks. American Economic Review: Insights 4, 289–304.

Bayoumi, T., Laxton, D., Pesenti, P., 2004. Benefits and spillovers of greater competition in Europe: A macroeconomic assesment. Working Paper 10416. National Bureau of Economic Research.

Board of Governors of the Federal Reserve System, 2022. Monetary Policy Report. Technical Report 17 June 2022. US Federal Reserve System.

Bodart, V., de Walque, G., Pierrard, O., Sneessens, H.R., Wouters, R., 2006. Nominal wage rigidities in a New Keynesian model with frictional unemployment. Discussion Paper 2528. IZA.

Brand, C., Coenen, G., Lydon, R., Obstbaum, M., Sondermann, D., 2021. Employment and the conduct of monetary policy in the euro area. Occasional Paper 275. European Central Bank.

Broer, T., Kramer, J., Mitman, K., 2022. The curious incidence of monetary policy shocks across the income distribution. Working Paper Series 416. Sveriges Riksbank (Central Bank of Sweden).

Bundick, B., Petrosky-Nadeau, N., 2021. From deviations to shortfalls: The effects of the FOMC's new employment objective. Working Paper Series 2021-18. Federal Reserve Bank of San Francisco.

Cairó, I., Cajner, T., 2018. Human capital and unemployment dynamics: Why more educated workers enjoy greater employment stability. The Economic Journal 128, 652–682.

Cantore, C., Ferroni, F., Mumtaz, H., Theophilopoulou, A., 2022. A tail of labour supply and a tale of monetary policy. Staff Working Paper 989. Bank of England.

Christoffel, K., Coenen, G., Warne, A., 2008. The New Area-Wide Model of the euro area: a micro-founded open-economy model for forecasting and policy analysis. Working Paper Series 944. European Central Bank.

Christoffel, K., Linzert, T., 2010. The role of real wage rigidity and labor market frictions for inflation persistence. Journal of Money, Credit and Banking 42, 1435–1446.

Cooley, T.F., Quadrini, V., 1999. A neoclassical model of the Phillips curve relation. Journal of Monetary Economics 44, 165–193.

de Walque, G., Pierrard, O., Sneessens, H., Wouters, R., 2009. Sequential bargaining in a Neo-Keynesian model with frictional unemployment and staggered wage negotiations. Annals of Economics and Statistics 95/96, 223–250.

ECB, 2021. An overview of the ECB's monetary policy strategy. URL: https://www.ecb.europa.eu/home/search/review/html/ecb.strategyreview_monpol_strategy_overview.en.html.

Elias, E., Irvin, H., Òscar Jordà, 2014. Monetary policy when the spyglass is smudged. Economic Letter 2014-35.

Faia, E., 2009. Ramsey monetary policy with labor market frictions. Journal of Monetary Economics 56, 570–581.

Faruqee, H., Laxton, D., Muir, D., Pesenti, P., 2008. Would protectionism defuse global imbalances and spur economic activity? A scenario analysis. Journal of Economic Dynamics and Control 32, 2651–2689.

Feiveson, L.J., Gornemann, N., Hotchkiss, J.L., Mertens, K., Sim, J.W., 2020. Distributional considerations for monetary policy strategy. Finance and Economics Discussion Series 2020-073. US Board of Governors of the Federal Reserve System.

Gomes, S., Jacquinot, P., Pisani, M., 2010. The EAGLE. A model for policy analysis of macroeconomic interdependence in the euro area. Working Paper Series 1195. European Central Bank.

Gomes, S., Jacquinot, P., Pisani, M., 2012. The EAGLE. A model for policy analysis of macroeconomic interdependence in the euro area. Economic Modelling 29, 1686–1714.

Guvenen, F., Schulhofer-Wohl, S., Song, J., Yogo, M., 2017. Worker betas: Five facts about systematic earnings risk. American Economic Review 107, 398–403.

Haefke, C., Sonntag, M., Van Rens, T., 2013. Wage rigidity and job creation. Journal of Monetary Economics 60, 887–899.

Herman, U., Lozej, M., 2021. Who gets jobs matters: monetary policy and the labour market. Mimeo. Central Bank of Ireland.

Jung, P., Kuhn, M., 2014. Labour market institutions and worker flows: comparing Germany and the US. The Economic Journal 124, 1317–1342.

Laxton, D., Pesenti, P., 2003. Monetary rules for small, open, emerging economies. Journal of Monetary Economics 50, 1109–1146.

Lydon, R., Lozej, M., 2018. Flexibility of new hires' earnings in Ireland. Labour Economics 53, 112–127.

Mortensen, D.T., Pissarides, C.A., 1999. Job reallocation, employment fluctuations and unemployment, in: Taylor, J.B., Woodford, M. (Eds.), Handbook of Macroeconomics. Elsevier. volume 1 of *Handbook of Macroeconomics*. chapter 18, pp. 1171–1228.

Petrongolo, B., Pissarides, C.A., 2001. Looking into the black box: A survey of the matching function. Journal of Economic Literature 39, 390–431.

Powell, J., 2020. New economic challenges and the Fed's monetary policy review. URL: `https://www.federalreserve.gov/newsevents/speech/powell20200827a.htm`. Speech at Navigating the Decade Ahead: Implications for Monetary Policy, Federal Reserve Bank of Kansas City, Jackson Hole.

Ramey, G., den Haan, W.J., Watson, J., 2000. Job destruction and propagation of shocks. American Economic Review 90, 482–498.

Rudebusch, G.D., 2010. The Fed's exit strategy for monetary policy. Economic Letter 2010-18. Federal Reserve Bank of San Francisco.

Shimer, R., 2012. Reassessing the ins and outs of unemployment. Review of Economic Dynamics 15, 127–148.

Stähler, N., Thomas, C., 2012. FiMod—A DSGE model for fiscal policy simulations. Economic Modelling 29, 239–261.

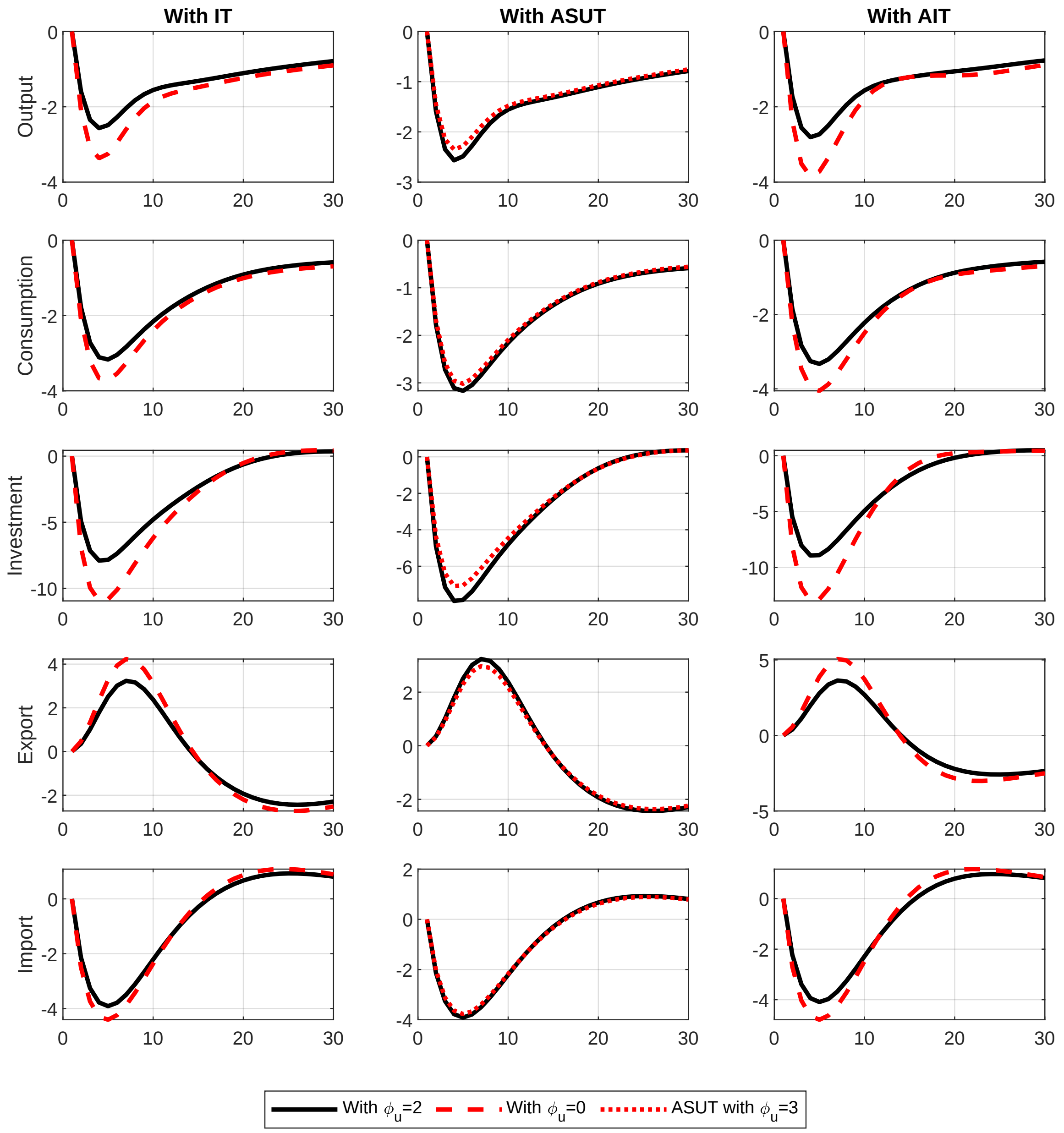
Taylor, J.B., Williams, J.C., 2010. Simple and Robust Rules for Monetary Policy, in: Friedman, B.M., Woodford, M. (Eds.), Handbook of Monetary Economics. Elsevier. volume 3 of *Handbook of Monetary Economics*. chapter 15, pp. 829–859.

A Negative demand shock

This appendix shows the responses to a *negative* demand shock, where the asymmetric unemployment targeting rule kicks in (unemployment rises in the case of a negative demand shock).[16] Figures 11 and 12 show the euro area responses, and Figures 13 to 15 show the country-specific responses. Recall, however, that the ASUT rule only makes sense when $\phi_U > 0$ (if $\phi_U = 0$, it is identical to strict inflation targeting rule). Therefore, for a fair comparison of strict inflation targeting rule and an ASUT rule, one should compare the dashed red lines in the left column of the charts with the full black lines (for a moderate response to unemployment, $\phi_U = 2$) and the red dotted lines (for the more aggressive response to unemployment, $\phi_U 30$) in the middle column of the charts. At the same time, one should keep in mind that in Figures 1 to 5 the performance of the ASUT rule is also identical to strict inflation targeting rule. This makes it clear that the the ASUT rule preserves the benefits of expansionary demand shocks for employment, while it mitigates the downturns in employment caused by contractionary demand shocks.

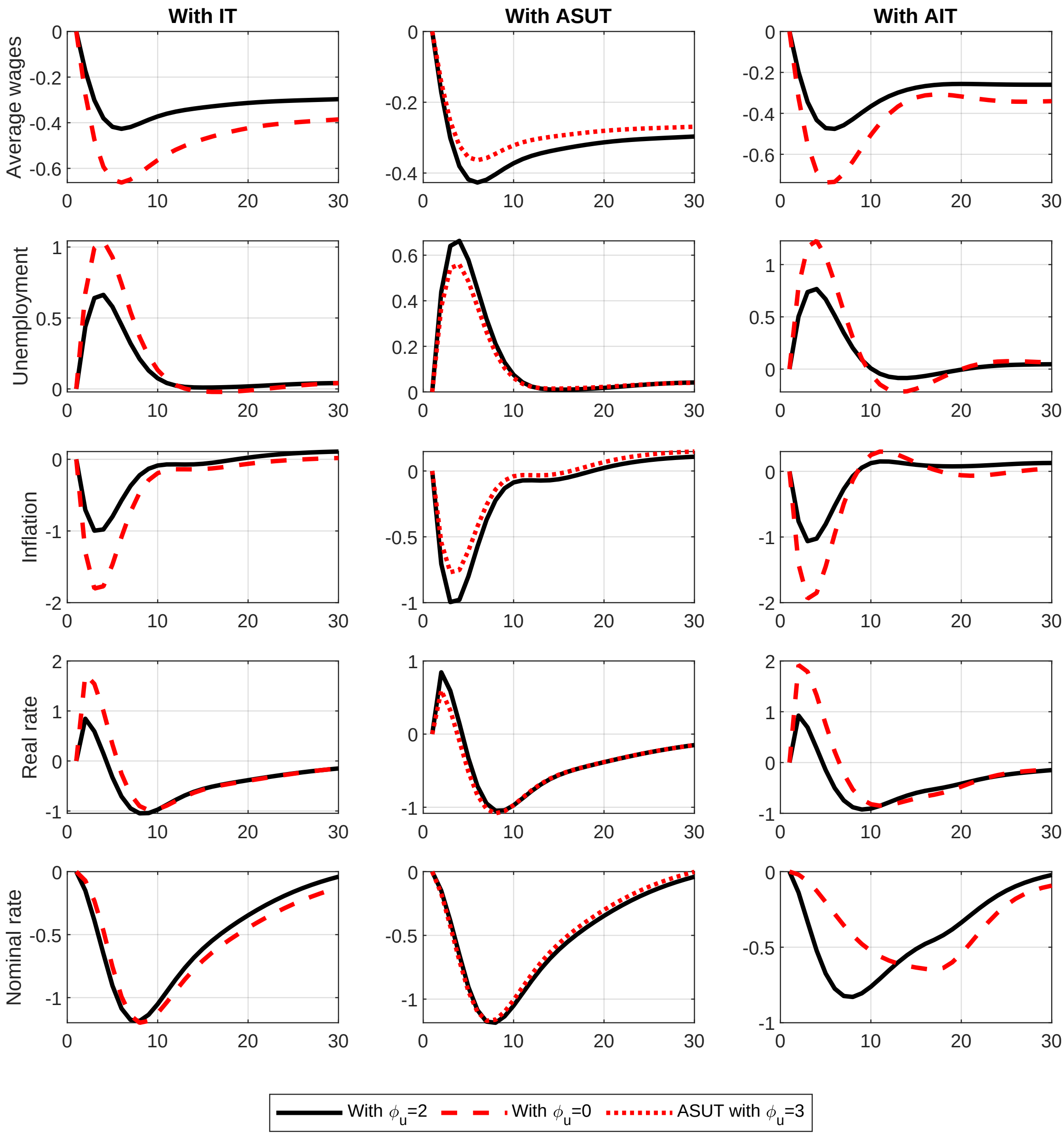
[16] The shock has been calibrated to achieve a 1 p.p. decrease in the euro-area-wide inflation rate at the trough.

Figure 11. Contractionary demand shock: area-wide demand components



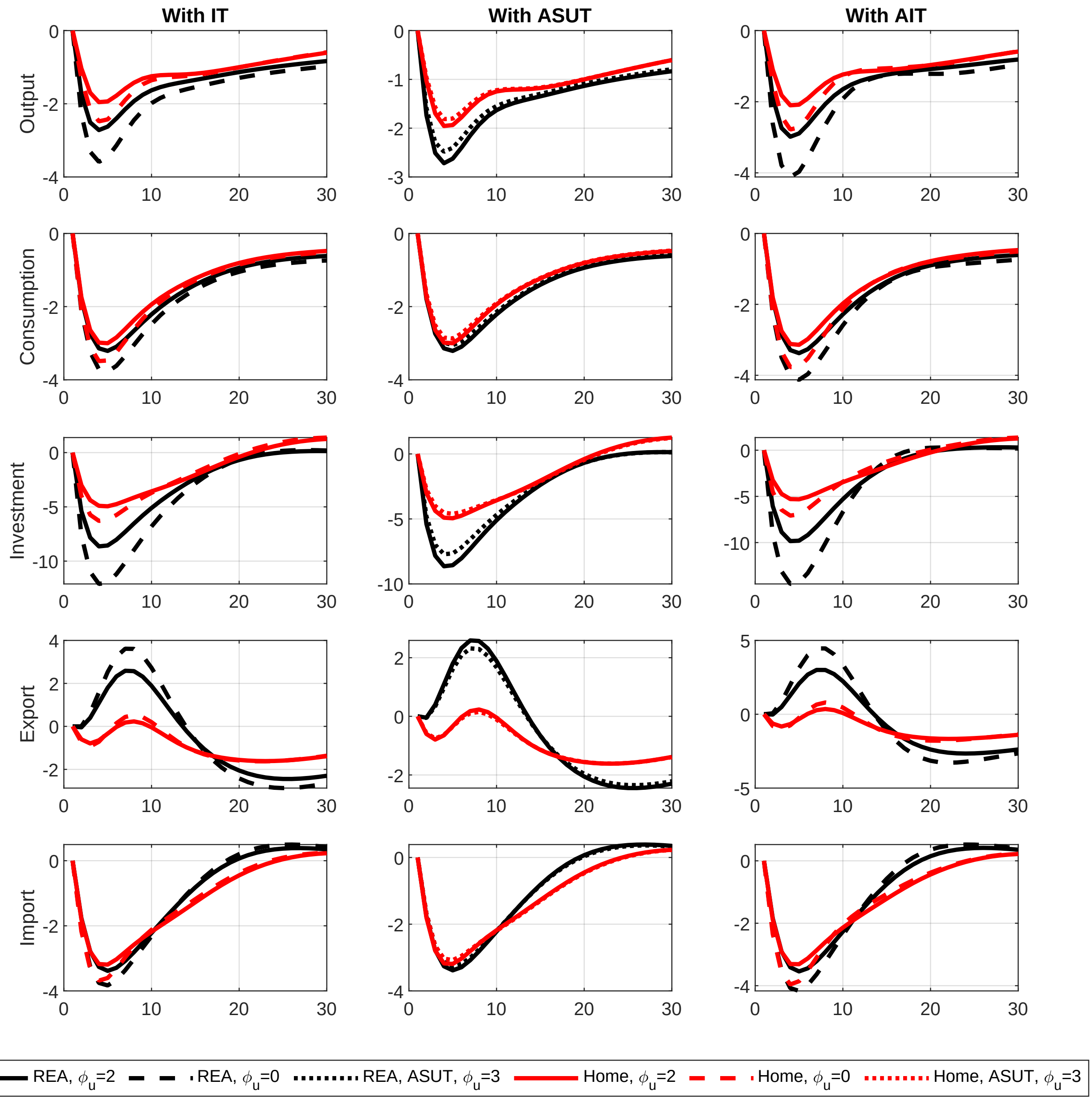
Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

FIGURE 12. Contractionary demand shock: area-wide variables



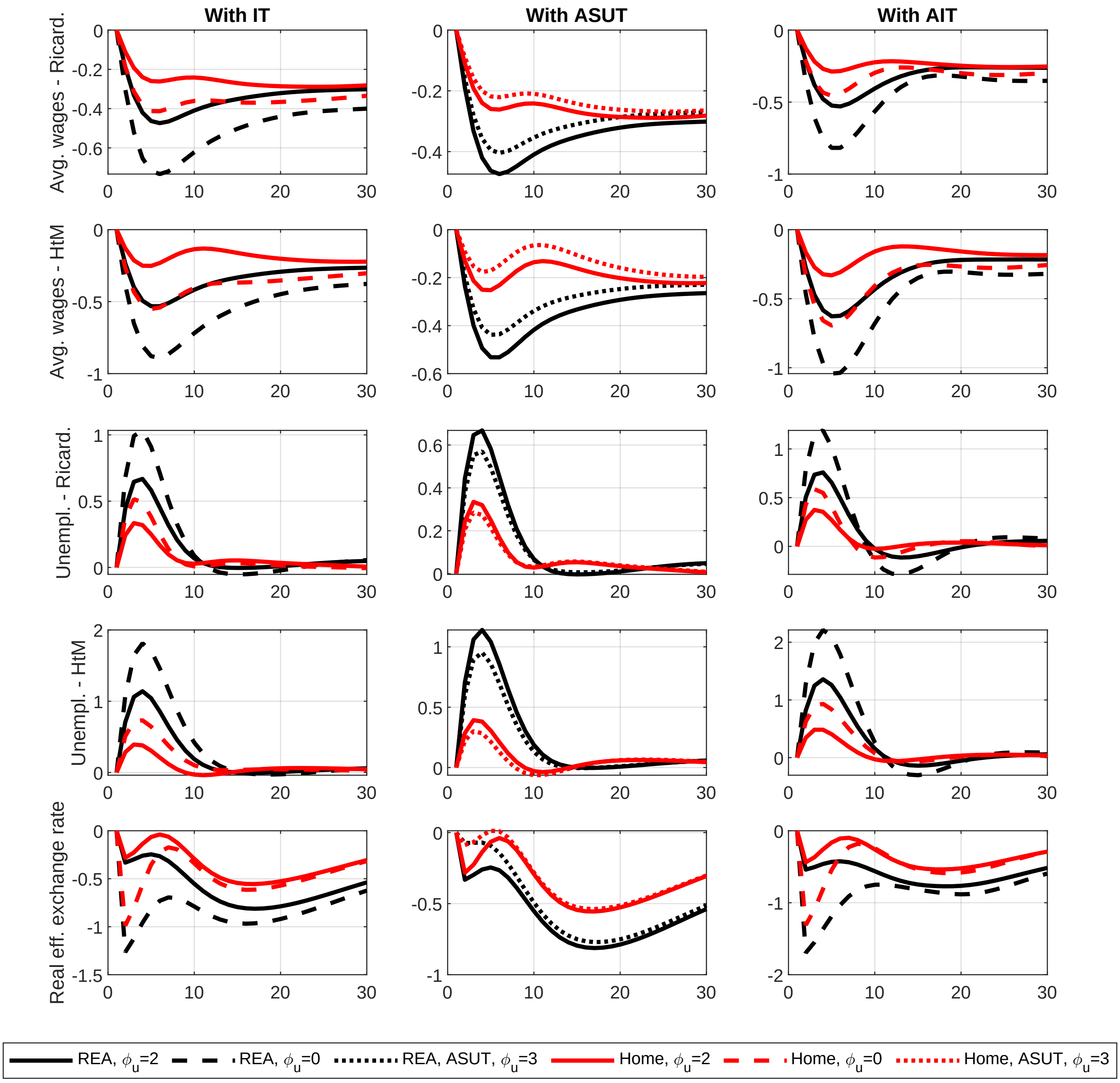
Horizontal axes: quarters; vertical axes: percentage point deviations from the steady state, except wages, which are in precent deviations. Interest rates and inflation are annualised.

Figure 13. Contractionary demand shock: country-specific demand components



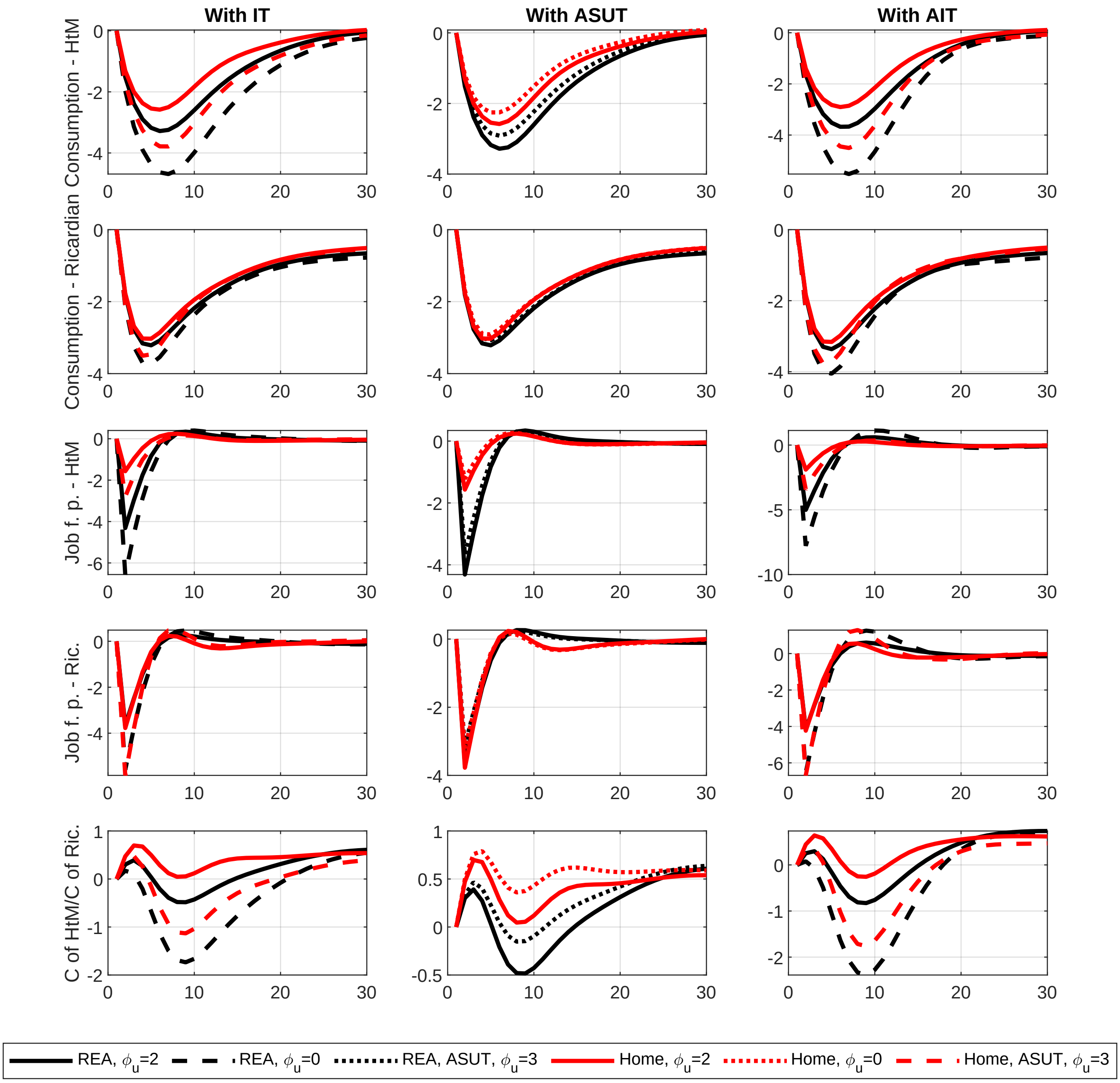
Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

Figure 14. Contractionary demand shock: country-specific variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

Figure 15. Contractionary demand shock: country-specific variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except job finding rates and relative consumption, which are in p.p. deviations. All variables are in real terms.

Acknowledgements

The authors would like to thank the co-leads of the Strategy Review Workstream on Employment (Claus Brand, Günter Coenen, Reamonn Lydon, Meri Obstbaum and David Sondermann), Jelena Zivanovic, the participants of 2022 Dynare Conference, the 2022 Computing in Economics and Finance conference, and the participants of the Strategy Review Workstream on Employment.
The opinions expressed are those of the authors and do not reflect views of the Bank of Portugal, the Central Bank of Ireland, or the European Central Bank. This paper has been written while Matija was at the European Central Bank. Any remaining errors are the sole responsibility of the authors.

Sandra Gomes
Bank of Portugal, Lisbon, Portugal; UECE/REM, Lisbon, Portugal; email: sgomes@bportugal.pt

Pascal Jacquinot
European Central Bank, Frankfurt am Main, Germany; email: pascal.jacquinot@ecb.europa.eu

Matija Lozej
Central Bank of Ireland, Dublin, Ireland; email: matija.lozej@centralbank.ie

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

This paper can be downloaded without charge from www.ecb.europa.eu, from the Social Science Research Network electronic library or from RePEc: Research Papers in Economics. Information on all of the papers published in the ECB Working Paper Series can be found on the ECB's website.

PDF ISBN 978-92-899-5511-9 ISSN 1725-2806 doi:10.2866/67943 QB-AR-23-006-EN-N