Monetary Policy and Unemployment in Open Economies (Draft)

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Abstract

In the welfare analysis of monetary policy shocks in open economies in the tradition of the redux model of Obstfeld and Rogoff, unemployment plays no role. An expansionary shock simply leads to an increase in hours worked reducing welfare because disutility of labour increases while the increase in consumption increases welfare. In one such model with complete pass-through from exchange rates to prices this results in a short-run negative welfare effect and a long-run positive welfare effect (Engler and Tervala, 2011). In the present paper I allow for an explicit role of unemployment in the same vein as in Galí's (2010) closed economy model. Variations in total hours are due to changes in employment and unemployment rather than changes in hours per worker and an expansionary monetary policy reduces unemployment. If, in contrast to previous studies, I allow for factors like fiscal costs of unemployment or a preference for high levels of employment, the result of Engler and Tervala (2011) can be modified considerably in that welfare can increase even in the short-run.

Keywords: Open economy macroeconomics, monetary policy, unemployment

JEL classification: E24, E52, F32, F41

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1 Introduction

When a central bank embarks on an expansionary monetary policy, it does so to stimulate the domestic economy and reduce unemployment: A reduced real rate of interest and a depreciated nominal exchange rate results in an increase in output and employment while unemployment falls. The motivation to reduce unemployment could be, inter alia, to reduce the fiscal costs involved by unemployment.[1] These costs can be sizable fractions of GDP and, more importantly, dependent on the unemployment rate. As the German data of the last twenty years in Figure 1 indicate, the unempoyment rate and the Social Security Expenditures as a fraction of GDP co-move with a correlation coefficient of 0.57. A reduction of the rate of unemployment thus increases the resources available for other purposes like private consumption, investment or leisure that all increase the representative household's utility.

The size of the first two effects of an expansionary monetary policy (the increase in output and employment) has traditionally been at the core of the academic literature while the third (the reduction in unemployment) is, surprisingly, rarely discussed, at least not explicitly. What is usually looked at is the increase in total hours hours worked which can be split up into changes in the number of hours worked per worker, the intensive margin, and the number of workers, the extensive margin. At business cycle frequencies, the later clearly dominates the first as was pointed out by Hansen (1985) for US data and more recently by Merkl and Wesselbaum (2011) for US and German data. It is thus rather people moving out of leisure or unemployment into employment than workers changing their number of hours that drive (as in real business cycle models) or go along with (as in Keynesian models) the business cycle. But the link towards unemployment has only recently been established in the theoretical literature on closed economies, most notably Christiano, Trabandt and Walentin (2010) and Galí (2010).

In Galí's (2010) model, an increase in hours results in a reduction in unemployment so that an expansionary monetary policy stance is likely to be successful in that respect. But a standard normative analysis would not necessarily come to this conclusion (at least not when looking at the effects of unemployment and employment in isolation) as total hours worked enter negatively into the representative household's utility function as they represent foregone leisure. However, the increase in consumption will more than offset this negative effect in a closed economy because of the distorted steady

[1] Other reasons could be social preferences for a low level of unemployment; individual preferences for being in the labour force rather than unemployed in an environment of demand determined employment, to avoid a stigma attached to the unemployed; or because of incomplete insurance of consumption risk.

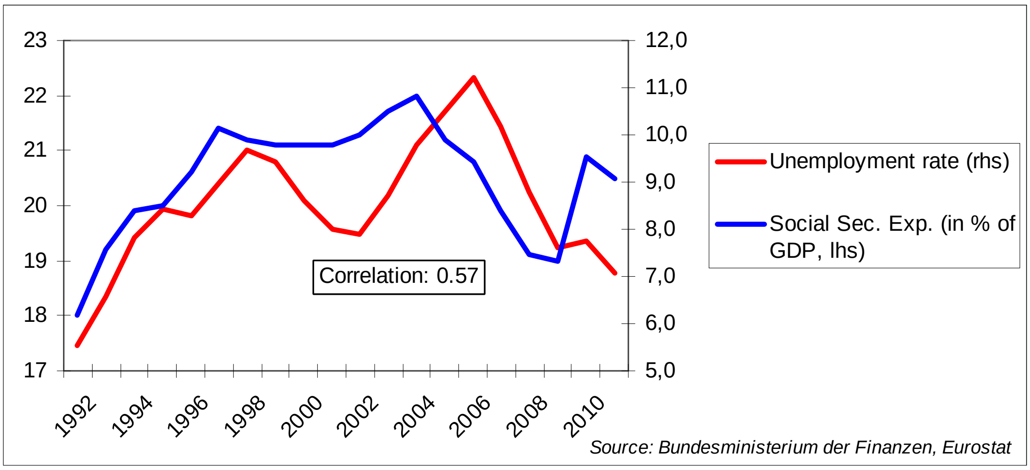

Figure 1: German Social Security Expenditure and the Unemployment Rate (1991-2010)

state in standard DSGE models. But the counterintuitive result here is that a reduction in unemployment per se is bad for welfare because unemployment is the almost exact mirror image of employment with opposite sign. This may not matter much because overall welfare effect is positive so that the sign is correct (i.e. an expansionary monetary policy increases welfare), although the dimension of the effect may be biased downward in light of the reasons mentioned above.

In an open economy things are different, however, as an expansionary monetary policy shock reduces welfare in the short run and only turns positive after several quarters as was demonstrated by Engler and Tervala (2011) in a framework in the tradition of the redux model (Obstfeld and Rogoff, 1995)[2]. The deterioration of the terms of trade implies that the negative welfare effect of the increase in hours is large enough to dominate the positive effect of the increase in consumption. But these models possess the downward bias of underestimating the welfare implications of a reduction in unemployment, too, as they do not consider unemployment. This implies that a removal of this bias could well turn the short-run negative welfare effect of an expansionary monetary policy stance into a positive one. Neglecting the bias seriously impairs the validity of a welfare analysis in an open economy setting.

This paper tries to fill exactly this gap and correct for this bias. In sec-

[2]Further contributions to that large literature are, among many others, Corsetti and Pesenti (2001) and Tille (2001).

tion 2 I present a New Keynesian two-country model with price and wage rigidities that incorporates unemployment as in Galí (2010). Within this framework I discusses the positive and normative implications of an expansionary monetary policy shock and propose a welfare function that simply adds unemployment as an additional argument (section 3). This modelling strategy could be understood as a stand-in for several reasons for which unemployment could matter for welfare. In an extension to the baseline model I show that the introduction of fiscal costs of unemployment could be one such reason for which the simple modification could be representative.

2 The Model

The model is a New-Keynesian, two-country open economy model as in Engler and Tervala (2011) but with monopolistic competition in both the goods and the labour market as in Erceg et al. (2000) and price and wage rigidities à la Calvo (1983). Furthermore, unemployment is taken account of explicitly and determined by the mark-up prevailing in the labour market, i.e. the degree of monopolistic competition as in Galí (2010). Capital markets are fully integrated but this market is incomplete as there is only trade in a riskless bond. Monetary policy is modelled as a standard Taylor rule.

2.1 Households

2.1.1 Preferences and goods demand

The world economy is populated by a continuum of households which in turn consist of a continuum of members. The fraction $1 - n$ of these households lives in the domestic economy while the remaining fraction n lives in the foreign country, so the size of the world economy is normalized to 1. Following Galí (2010), household members are represented by the pairs $(i, j) \in [0, 1] * [0, 1]$ where index i represents the type of work an individual is specialized in and j represents the disutility from work. Each individual either works or is unemployed. When working, the disutility of work is j^{φ} with $\varphi > 0$ and zero when he is out of work.

I assume full risk sharing across individuals and households within countries so that the work status does not affect the level of consumption. An implication of this is that I abstract from any effects of unemployment on utility beyond its effect of reducing the disutility from working.[3]

[3]This assumption is, of course, anything but innocuous as documented by Sen (1997), and could, in principle, be addressed by assuming incomplete risk sharing in consumption

The representative domestic household's objective function is the discounted present value of the infinite sequence of period utility functions

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, \{N_t(i)\}\right) \tag{1}$$

with discount factor β and rational expectations operator E and period utility function

$$\begin{aligned} U\left(C_t, \{N_t(i)\}\right) &= \log C_t - \int_0^1 \int_0^{N_t(i)} j^{\varphi} dj di \\ &= \log C_t - \int_0^1 \frac{N_t(i)^{1+\varphi}}{1+\varphi} di \end{aligned}$$

where $N_t(i)$ is the fraction of household members with specilization i that is employed in period t, and where C_t is the consumption index

$$C_t = \left[(1-n)^{\frac{1}{\rho}} \left(C_t^h\right)^{\frac{\rho-1}{\rho}} + n^{\frac{1}{\rho}} \left(C_t^f\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}$$

with

$$C_t^h = \left[(1-n)^{-\frac{1}{\theta}} \int_n^1 \left(C_t^h(z)\right)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}}, \; C_t^f = \left[n^{-\frac{1}{\theta}} \int_0^n \left(C_t^f(z)\right)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}},$$

where $C_t^h(z)$ and $C_t^f(z)$ are domestically or foreign produced goods z. I assume no home bias in consumption so that according indexes apply for foreign. These equations, as most other foreign equations, will not be shown, however. A standard expenditure-minimization procedure produces demand functions for the continuum of goods,

$$C_t^h(z) = \left(\frac{P_t^h(z)}{P_t^h}\right)^{-\theta} \left(\frac{P_t^h}{P_t}\right)^{-\rho} C_t$$

$$C_t^f(z) = \left(\frac{P_t^f(z)}{P_t^f}\right)^{-\theta} \left(\frac{P_t^f}{P_t}\right)^{-\rho} C_t$$

as in Christiano et al. (2010), some form of disutility of unemployment in the household's utility function (see Clark and Oswald (1994) for empirical evidence) or some productivity decreasing effect for long spells of unemployment (Sen, 1997). However, in this paper I deal with this issue in a somewhat different way as will become apparent below.

with the aggregate consumption price index defined as

$$P_t \equiv \left[(1-n)(P_t^h)^{1-\rho} + n(P_t^f)^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{2}$$

and the price index of domestically and foreign prodced goods defined as $P_t^h \equiv \left((1-n)^{-1}\int_n^1 \left(P_t^h(z)\right)^{1-\theta} dz\right)^{\frac{1}{1-\theta}}$ and $P_t^f \equiv \left(n^{-1}\int_0^n \left(P_t^f(z)\right)^{1-\theta} dz\right)^{\frac{1}{1-\theta}}$ respectively, where $P_t^h(z)$ and $P_t^f(z)$ are the prices corresponding to $C_t^h(z)$ and $C_t^f(z)$.

The law of one price is assumed to hold, so we have

$$P_t^h(z) = S_t P_t^{*h}(z), \quad P_t^f(z) = S_t P_t^{*f}(z),$$

for foreign currency price $P_t^{*h}(z)$ of a domestically produced good and $P_t^{*f}(z)$ as the foreign currency price of a foreign produced good and nominal exchange rate S_t expressing the domestic currency in terms of the foreign currency. Because all goods are tradable and because of the absence of any home bias in consumption, purchasing power parity holds, i.e. $P_t = S_t P_t^*$ for the foreign consumption price index P_t^*.

As there are $(1-n)$ households in the home and n households in the foreign country, world demand for domestic and foreign goods then is given by

$$Y_t^d(z) = \left(\frac{P_t^h(z)}{P_t^h}\right)^{-\theta}\left(\frac{P_t^h}{P_t}\right)^{-\rho} C_t^W \tag{3}$$

where $Y_t^d(z) \equiv (1-n)C_t^h(z) + nC_t^{*h}(z)$ is world aggregate demand for good z with $C_t^{*h}(z)$ denoting foreign demand for the domestic good and where $C_t^W \equiv ((1-n)C_t + nC_t^*)$ is world aggregate consumption. The representative household's total spending on consumption in period t can be shown to be

$$\int_n^1 P_t^h(z)C_t^h(z)dz + \int_0^n P_t^f(z)C_t^f(z)dz = P_t C_t$$

2.1.2 The terms of trade and the nominal exchange rate

World demand for good z (equation 3) is a function of the relative price $\frac{P_t^h}{P_t}$. When approximated around the steady state, this term is proportional to the terms of trade T_t, defined as

$$T_t \equiv \frac{P_t^h}{P_t^f}$$

as an approximation of the consumer price index (2) around a symetric steady state in which $P^h = P^f$ can be shown to yield[4]

$$\widehat{p}_t^h - \widehat{p}_t = n\widehat{\tau}_t$$

Hats over lower case variables denote percent deviations from the respective steady state values. The link between the terms of trade and the nominal exchange rate can be established by using the law of one price so that

$$\widehat{\tau}_t = \widehat{p}_t^h - \widehat{p}_t^{*f} - \widehat{s}_t \tag{4}$$

To the extent that prices are sticky, a depreciation of the nominal exchange rate, i.e. $\widehat{s}_t > 0$, implies a deterioration of the terms of trade, i.e. $\widehat{\tau}_t < 0$.

2.1.3 Budget Constraints, Euler Equations and interest rate parity

When maximising (1), the household faces the flow budget constraint

$$D_t = (1 + i_t)D_{t-1} + \int_0^1 W_t(i)N_t(i)di - P_tC_t + \Pi_t \tag{5}$$

where i_t is the riskless non-state-contingent nominal interest rate of the domestic bond D_t, where Π_t is the household's share in firms‘ profits and where $W_t(i)$ is the nominal wage that type i workers receive when they are employed. The domestic bond is assumed to be traded internationally in a frictionless market. Foreign households' holdings of these bonds are D_t^* so that the market for the bond clears when

$$(1 - n)D_t + nD_t^* = 0$$

The resulting home Euler equation of the domestic household is

$$\frac{1}{1 + i_t} = \beta E_t \left\{ \frac{C_t}{C_{t+1}} \frac{P_t}{P_{t+1}} \right\}$$

while for the foreign household, when maximising with respect to a foreign bond that is not traded internationally and paying interest i_t^*, the Euler equation is

$$\frac{1}{1 + i_t^*} = \beta E_t \left\{ \frac{C_t^*}{C_{t+1}^*} \frac{P_t^*}{P_{t+1}^*} \right\}$$

[4] The corresponding equation for the foreign economy is $\widehat{p}_t^* = \widehat{p}_t^{*f} + (1 - n)\widehat{\tau}_t$.

Because of the integrated market for domestic bonds, domestic and foreign nominal interest rates are linked through an interest parity condition into which a risk premium is incorporated[5],

$$1 + i_t = (1 + i_t^*) E_t \left\{ \frac{S_{t+1}}{S_t} \right\} - \psi \left(e^{d_t} - 1 \right)$$

where d_t is the domestic net asset position relative to steady state GDP. I assume that in the steady state $D = 0$ so that the risk premium is zero in the steady state, too. The risk premium is introduced because otherwise there would not be a unique steady state. The reason for this can be seen when log-linearizing the two Euler equations, subtracting one from the other, taking account of the purchasing power parity and the interest parity condition:

$$\widehat{c}_t - \widehat{c}_t^* = E_t \left\{ \widehat{c}_{t+1} - \widehat{c}_{t+1}^* \right\} + \psi d_t$$

where hats over lower case letters denote log deviations from the steady state of the respective variables. Without a risk-premium (i.e. $\psi = 0$), temporary changes to the difference between domestic and foreign consumption, due to a re-allocation of wealth, would become permanent. Consumption and other variables would thus follow a random walk, a property that the new open economy models in the tradition of Obstfeld and Rogoff (1995) possess. A net asset position and a corresponding risk premium that return to their original steady states allow the difference in consumption to fade over time. The main advantage of the absence of the random walk property is that it allows the computation of unconditional moments.

2.1.4 Wage setting

As workers are specialized in certain types of work in this model, it is reasonable to assume that they are not exposed to perfect competition in the labor market. Following Erceg et al. (2000) and Galí (2010), wage $W_t(i)$ is set by a labor union representing sector i workers in an environment of monopolistic competition. Labor input $N_t(i)$, on the other hand, is determined by firms' aggregate labor demand decisions and allocated equally across households within a country. Furthermore, a mechanism à la Calvo (1983) is assumed according to which wages in a sector can only be reset in a given period with probability $1 - \theta_w$ that is independent of the time since the last resetting occurred. This implies that it is optimal for the unions to set wages in a

[5] A risk premium of this kind was proposed by Schmitt-Grohé and Uribe (2003) to induce stationarity in a small-open economy model. See also Bergin (2006) for an empirical assessment and Tervala (2011) for a theoretical application.

forward looking manner as they know that with a positive probability they will have to leave their wage unchanged in a changed future environment.

When deciding about the optimal wage W_t^o in period t, unions take the aggregate wage index $W_t = \left(\int_0^1 W_t(i)^{1-\epsilon_w} di \right)^{\frac{1}{1-\epsilon_w}}$ and domestic labor demand for period $t+k$, $N_{t+k|t}$,

$$N_{t+k|t} = \left(\frac{W_t^o}{W_{t+k}} \right)^{-\epsilon_w} \int_n^1 N_{t+k}(z) dz$$

which is conditional on the wage decision in period t, as given. $N_{t+k}(z)$ is firm z's labor input introduced below. The first order conditions for optimal wages is thus

$$\sum_{k=0}^{\infty} (\beta\theta_w)^k E_t \left\{ \frac{N_{t+k|t}}{C_{t+k}} \left(\frac{W_t^o}{P_{t+k}} - \frac{\epsilon_w}{\epsilon_w - 1} MRS_{t+k|t} \right) \right\} = 0$$

where $MRS_{t+k|t} = C_t N_{t+k|t}^{\varphi}$ is the marginal rate of substitution between consumption and employment in $t+k$ for workers whose wages were reset in period t. Log-linearizing around the deterministic zero inflation steady state, we get

$$w_t^o = \mu^w + (1 - \beta\theta_w) \sum_{k=0}^{\infty} (\beta\theta_w)^k E_t \left\{ mrs_{t+k|t} + p_{t+k} \right\} \tag{6}$$

where $\mu^w = \log \frac{\epsilon_w}{\epsilon_w - 1}$ is the log steady state (and frictionless) wage markup. In order to relate the wage setting decision in sector i to aggregate developments one can define $MRS_t = C_t N_t^{\varphi}$ as the average marginal rate of substitution with aggregate employment $N_t = \int_0^1 N_t(i) di$ and gets

$$\begin{aligned} mrs_{t+k|t} &= mrs_{t+k} + \varphi \left(n_{t+k|t} - n_{t+k} \right) \\ &= mrs_{t+k} - \epsilon_w \varphi \left(w_t^o - w_{t+k} \right) \end{aligned} \tag{7}$$

Combining (6) and (7) with the linearized wage index $w_t = \theta_w w_{t-1} + (1 - \theta_w) w_t^o$ one gets the wage inflation equation

$$\pi_t^w = \beta E_t \left\{ \pi_{t+1}^w \right\} - \lambda_w \left(\mu_t^w - \mu^w \right)$$

where $\pi_t^w = w_t - w_{t-1}$ and where $\mu_t^w = w_t - p_t - mrs_t$ is the average wage markup and $\lambda_w = \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w\varphi)}$.

Defining log the real wage $\omega_t = w_t - p_t$ the following identity linking the real wage and wage and CPI inflation holds:

$$\widehat{\omega}_t = \widehat{\omega}_{t-1} + \pi_t^w - \pi_t$$

2.1.5 Unemployment

Following Galí (2010), I now relate the inefficiently low level of employment that is due to the monopolistic labour market structure to the unemployment rate. This is done by determining the actual level employment and the level of employment that would be observed in a world without monopolistic competition in the labour market. The later of the two constitutes the aggregate labour force and the difference between the two the level of unemployment.

A worker with specilization i will be willing to work as long as

$$\frac{W_t(i)}{P_t} \geqslant C_t j^{\varphi}$$

is fulfilled. For the "marginal supplier" in sector i, denoted as $L_t(i)$, this condition holds with equality:

$$\frac{W_t(i)}{P_t} = C_t L_t(i)^{\varphi}$$

Defining the aggregate labor force as $L_t = \int_0^1 L_t(i)di$, taking logs and integrating, we get the aggregate labor supply relation

$$w_t - p_t = c_t + \varphi l_t$$

where $w_t = \int_0^1 w_t(i)di$, $l_t = \int_0^1 l_t(i)di$.

Defining the unemployment rate u_t as the (log) difference between the aggregate labor force and employment,

$$u_t = l_t - n_t$$

and using the wage markup equation,

$$\mu_t^w = w_t - p_t - (c_t + \varphi n_t)$$

we get

$$\mu_t^w = \varphi u_t$$

The unemployment rate in period t is thus proportional to the wage markup. Any decline in the markup, due to decline in the real wage or an increase in consumption or employment, will result in a decline in the unemployment rate as people move out of unemployment into work and out of the labor force into inactivity. The strength of this effect is determined inversely by the parameter φ which determines the degree of disutility of work. Employment fluctuations, i.e. the extensive margin, rather than changes in hours worked per worker, the intensive margin, as in models without a labour market inefficiency are thus the driving force of ouput fluctuations in this model. The utility cost of an increase in output is determined by the disutility of being in work rather than out of work and not the disutility of reducing leisure to work more hours of an already employed worker.

2.2 Supply Side: Firms

2.2.1 Profits and Demand

The continuum of domestic firms is indexed by $z \epsilon [n, 1]$, and produces output $Y_t(z)$ with production function

$$Y_t(z) = N_t(z)^{1-\alpha} \tag{8}$$

where $N_t(z) = \left(\int_0^1 N_t(i, z)^{1-\frac{1}{\epsilon_w}} di \right)^{\frac{\epsilon_w}{\epsilon_w - 1}}$ is the employment index of firm z. The firm's demand for labour input of type i, $N_t(i, z)$, is

$$N_t(i, z) = \left(\frac{W_t(i)}{W_t} \right)^{-\epsilon_w} N_t(z)$$

for all $i \epsilon [0, 1]$ and $z \epsilon [n, 1]$

Firm z period t profits are

$$\Pi_t(z) = P_t^h(z) Y_t(z) - W_t N_t(z), \tag{9}$$

which take account of world demand function (3) and production function (8).

2.2.2 Price Setting

Under flexible prices, home firm z's first order condition is

$$P_t^{ho}(z) = \frac{\theta}{\theta - 1} \frac{W_t}{(1-\alpha) N_t(z)^{-\alpha}}$$

where $P_t^{ho}(z)$ is the optimal price. As this is the same for all firms resetting prices in t, we can write

$$P_t^{ho} = \frac{\theta}{\theta - 1} \Psi_t$$

with average marginal cost function $\Psi_t = \frac{W_t}{(1-\alpha) A_t N_t{}^{-\alpha}}$.

If, instead, price setting is à la Calvo, with price stickiness parameter θ_p, the objective is $V_t(z)$,

$$\max_{P_t(z)} V_t(z) = \sum_{k=0}^{\infty} \theta_p^k E_t \left\{ Q_{t,t+k} \Pi_{t+k}(z) \right\}$$

where $Q_{t,t+k} \equiv \beta E_t \left\{ \frac{C_t}{C_{t+1}} \frac{P_t}{P_{t+1}} \right\}$ is the household's discount factor and the linearized optimality condition can be shown to be:

$$p_t^{ho} = \mu^p + (1 - \beta\theta_p) \sum_{k=0}^{\infty} (\beta\theta_p)^k E_t \left\{ \psi_{t+k|t} \right\} \tag{10}$$

where $\psi_{t+k|t} = \log \Psi_{t+k|t}$ is the log marginal cost function in period $t + k$ of those firms that reset their price in period t and that have not reset the price between t and $t + k$ and where $\mu^p \equiv \log \frac{\theta}{\theta - 1}$ is the optimal log price markup.

2.2.3 Aggregate prices

Next we want to relate firm specific marginal costs $\psi_{t+k|t}$ to average marginal costs in order to derive an aggregate inflation equation. Using the approximate production relationship $y_t = (1 - \alpha)n_t$, that will be derived below, we can write

$$\psi_{t+k|t} = \psi_{t+k} + \alpha(n_{t+k|t} - n_{t+k})$$

and because

$$y_{t+k|t} - y_{t+k} = (1 - \alpha)(n_{t+k|t} - n_{t+k})$$

we get

$$\psi_{t+k|t} = \psi_{t+k} + \frac{\alpha}{(1 - \alpha)} (y_{t+k|t} - y_{t+k})$$

The term in brackets can be related to the relative price of the non-adjusting firm prices and average domestic prices (the derivation is presented in the appendix),

$$y_{t+k|t} - y_{t+k} = -\theta \left(p_t^{ho} - p_{t+k}^h \right)$$

so we get

$$\psi_{t+k|t} = \psi_{t+k} + \frac{\alpha\theta}{(1 - \alpha)} \left(p_t^{ho} - p_{t+k}^h \right)$$

From this, (10), and the evolution of the aggregate domestic price index,

$$p_t^h = \theta_p p_{t-1}^h + (1-\theta_p) p_t^{ho}$$

the aggregate domestic price inflation equation

$$\pi_t^h = \beta E_t \left\{ \pi_{t+1}^h \right\} - \lambda_p \left(\mu_t^h - \mu^p \right)$$

can be derived, with domestic inflation $\pi_t^h \equiv p_t^h - p_{t-1}^h$, average price markup $\mu_t^h \equiv p_t^h - \psi_t$ and $\lambda_p \equiv \frac{(1-\theta_p)(1-\beta\theta_p)}{\theta_p} \frac{1-\alpha}{1-\alpha+\alpha\theta}$.

2.3 Monetary Policy

Central bank behaviour is described by the following Taylor-type rule

$$\widehat{1+i_t} = \rho_i \widehat{1+i_{t-1}} + \phi_\pi \pi_t^h + \phi_y \widehat{y}_t + \phi_w \pi_t^w + \varepsilon_t$$

with monetary policy shock ε_t that follows a white noise process. The reason for choosing the domestic inflation rate rather than the CPI-inflation is that in an open economy, the output dispersion due to staggered wage setting is proportional to domestic prices rather than the CPI so that the implied inefficiency will be reduced when the central bank reacts to changes in π_t^h rather than in π_t. This rule abstracts, however, from any reactions to fluctuations in the exchange rate or the terms of trade. The reaction to wage inflation is motivated by the improved stabilization performance as highlighted by Erceg et al. (2000).

2.4 Symmetric Equilibrium

2.4.1 Aggregate demand

Defining aggregate output per household as

$$Y_t \equiv \left[(1-n)^{-\frac{1}{\theta}} \int_n^1 \left(\frac{Y_t(z)}{1-n} \right)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}$$

we get an aggregate demand relationship by plugging in the aggregate good specific demand functions (3) (re-scaled to denote per household values):

$$Y_t = \left(\frac{P_t^h}{P_t} \right)^{-\rho} C_t^W$$

This implies that in a symmetric steady state with $C = C^*$ we have $Y = C$ so that around the steady state, the aggregate demand relationship approximately

$$\begin{aligned}\widehat{y}_t &= \widehat{c}_t^W - \rho\left(\widehat{p}_t^h - \widehat{p}_t\right)\\ \widehat{y}_t &= \widehat{c}_t^W - \rho n \widehat{\tau}_t\end{aligned}$$

Because for the foreign country the corresponding equation is

$$\widehat{y}_t^* = \widehat{c}_t^W + \rho\left(1-n\right)\widehat{\tau}_t$$

the difference between domestic and foreign output is proportional to the terms of trade:

$$\widehat{y}_t - \widehat{y}_t^* = -\rho\widehat{\tau}_t$$

A deterioration of the domestic terms of trade, i.e. $\widehat{\tau}_t < 0$, results in a positive output differential vis-à-vis the foreign country so that an expansionary monetary policy shock that depreciates the domestic exchange rate reallocates production towards the domestic economy as it induces a consumption switching effect, the size of which is determined by the cross-country elasticity of substitution ρ.

2.4.2 Aggregate production and markups

Aggregation of labour input $N_t(i,z)$ over all firms and types results in the following aggregate labour input N_t:

$$\begin{aligned}N_t &= \int_n^1\int_0^1 N_t(i,z)didz\\ &= \int_n^1 N_t(z)\int_0^1 \frac{N_t(i,z)}{N_t(z)}didz\\ &= \Delta_t^w\int_n^1 N_t(z)dz\\ &= \Delta_t^w Y_t^{\frac{1}{1-\alpha}}\int_n^1\left(\frac{Y_t(z)}{Y_t}\right)^{\frac{1}{1-\alpha}}dz\\ &= \Delta_t^w\Delta_t^p Y_t^{\frac{1}{1-\alpha}}\end{aligned}$$

with $\Delta_t^w \equiv \int_0^1\left(\frac{W_t(i)}{W_t}\right)^{-\epsilon_w}di$ and $\Delta_t^p \equiv \int_n^1\left(\frac{Y_t(z)}{Y_t}\right)^{\frac{1}{1-\alpha}}dz$ denoting employment and output dispersion that are due to the wage and price rigidities.[6]

[6] For the fourth equality note that the production function can be re-arranged to get $N_t(z) = Y_t(z)^{1/(1-\alpha)} = (Y_t(z)Y_t/Y_t)^{1/(1-\alpha)}$.

Galí (2010) showed that fluctuations of Δ_t^w are of second order, i.e. that up to a first order approximation this term is zero. The same is shown for Δ_t^p in the appendix. So we can derive the approximate aggregate production function:

$$y_t = (1-\alpha)n_t$$

The price markup is approximately

$$\begin{aligned}
\widehat{\mu}_t^p &= p_t^h - \psi_t - \mu^p \\
&= p_t^h - w_t + \log(1-\alpha) - \alpha n_t - \mu^p \\
&= (p_t^h - p_t) - (w_t - p_t) - \alpha n_t + \log(1-\alpha) - \mu^p \\
&= n\tau_t - \omega_t - \alpha n_t + \log(1-\alpha) - \mu^p
\end{aligned}$$

Noting that $\log(1-\alpha) - \mu^p$ equals $\omega_t + \alpha n_t$ in the steady state, we get

$$\widehat{\mu}_t^p = n\widehat{\tau}_t - \widehat{\omega}_t - \frac{\alpha}{1-\alpha}\widehat{y}_t$$

For the wage mark-up we have accordingly

$$\begin{aligned}
\widehat{\mu}_t^w &= \widehat{w}_t - \widehat{p}_t - \widehat{mrs}_t \\
&= \widehat{\omega}_t - \widehat{c}_t - \varphi\widehat{n}_t
\end{aligned}$$

2.4.3 International Investment Position

The aggregate resource constraint determines the domestic economy's international investment position D_t. It can be derived by combining (5) and (9):

$$D_t = (1+i_t)D_{t-1} + P_t^h Y_t - P_t C_t$$

In an initial steady state that is symmetric across countries with $D = 0$, we have $Y = C$, and accordingly for the foreign country $Y^* = C^*$. Setting $Y = Y^*$ and normalizing the initial price level such that it equals one, around the steady state we have approximately

$$\widehat{c}_t = -d_t + \beta^{-1}d_{t-1} + \widehat{y}_t + n\widehat{\tau}_t$$

For the foreign country the corresponding equation is

$$\widehat{c}_t^* = \frac{1-n}{n}d_t - \beta^{-1}\frac{1-n}{n}d_{t-1} + \widehat{y}_t^* - (1-n)\widehat{\tau}_t$$

Combing the domestic and foreign equations we get the international aggregate resource constraint:

$$(1-n)\,\widehat{c}_t + n\widehat{c}_t^* = (1-n)\widehat{y}_t + n\widehat{y}_t^*$$

2.4.4 Steady state

From the price and wage setting equations and the aggregate resource constraint $Y = C$ follows the steady state output and employment levels

$$Y = \left((1-\alpha) \left(\frac{\theta}{\theta - 1} \right)^{-1} \left(\frac{\epsilon_w}{\epsilon_w - 1} \right)^{-1} \right)^{\frac{1-\alpha}{1+\varphi}}$$

and

$$N = Y^{\frac{1}{1-\alpha}}$$

The volumes of output and employment in the steady state are thus an inverse function of the degree of monopolistic distortion in the goods and the labour market and the concavity of the production function. These inefficiencies in the steady state will drive the welfare implications of monetary policy shocks as discussed below.

2.5 Calibration

The calibration follows mainly that of Engler and Tervala (2011) for the open economy variables and Galí (2010) for the domestic variables. β is set to 0.99 implying a steady state annual interest rate of roughly 4 percent when regarding periods as quarters. For θ and α I choose a value of nine and 0.25, respectively, so that the steady state labour share, $\frac{W}{P}\frac{N}{Y} = (1-\alpha)\left(\frac{\theta}{\theta-1}\right)^{-1}$, equals 67 percent and the markup 12.5 percent. The degree of price and wage rigidity, θ_p and θ_w, is 0.75 implying price and wage adjustments after four quarters on average. Setting the steady state unemployment rate to 5 percent and the Frisch elasticity, i.e. φ^{-1} to 0.2 implicitly determines the degree of the monopolistic distortion on the labour market (because $\mu^w = \varphi u$) for which $\epsilon_w = 4.52$ follows. ρ, the cross-country substitution elasticity, is set to 2 which is within the range of variables chosen by Engler and Tervala (2011). The coefficients of the Taylor rule are $\rho_i = 0.9$, $\phi_\pi = 1.5$ and $\phi_y = \phi_w = 0.125$. The coefficient determining the risk premium, ψ, is set to 0.003, which is roughly in line with the value reported by Bergin (2006).

3 Welfare Effects of Monetary Policy

With the model at hand, we can now turn to the analysis of monetary policy shocks. For that purpose a standard welfare metric is introduced (section 3.1), which is first applied to a closed economy (section 3.2) in order to build an intuition for that metric. In the next step, the analysis is extended to the open economy (section 3.3), starting with an in-depth description of the positive effects of the monetary policy shock that determine the welfare dynamics of the model economy. Finally, the special implications that unemployment could have for welfare are discussed and a modification of the standard welfare function is proposed (section 3.4).

3.1 The Welfare Metric

In order to analyze the welfare implications of the monetary policy shock, I apply a first order Taylor expansion to the representative household's utility function to get the following welfare metric W^{1}[7]:

$$\begin{aligned} W_t^1 &\equiv dU_t^1 \\ &= \widehat{c}_t - N^{1+\varphi}\int_0^1 \widehat{n}_t(i)di \\ &= \widehat{c}_t - N^{1+\varphi}\widehat{n}_t \end{aligned} \tag{11}$$

This perspective thus tracks the effects of a shock on period-by-period utility allowing an assessment of the evolution of these effects over time. The new open economy macroeconomic literature in the tradition of Obstfeld and Rogoff (1995) employed a different, but closely related welfare metric. There the discounted present value of the period utility changes as displayed in (11) is observed,

$$dU_t^{DPV} = \sum_{t=0}^{\infty} \beta^t \left\{ \widehat{c}_t - N^{1+\varphi}\widehat{n}_t \right\}$$

which simply describes the total effect of a shock on welfare. Both concepts are reasonable for policy analysis and they should be regarded as complements rather than substitutes as they highlight two important dimensions of welfare effects of policy shocks. In the present analysis, however, I focus on the first welfare metric, as the evolution of welfare over time is the subject of analysis.

3.2 The Closed Economy

To get an intuition for this measure, an application to a closed economy is insightful. The welfare implication of an increase in domestic production that follows a shock to aggregate demand can easily be derived as in that

[7]This approach has been followed by Ganelli and Tervala (2010) and Tervala (2010) and Engler and Tervala (2011).

case $\widehat{n}_t = \frac{1}{1-\alpha}\widehat{y}_t$ and $\widehat{y}_t = \widehat{c}_t$, so that we have

$$W_t^{1,\text{closed}} = \left(1 - \left(\frac{\theta}{\theta-1}\right)^{-1}\left(\frac{\epsilon_w}{\epsilon_w - 1}\right)^{-1}\right)\widehat{y}_t$$

where the term in brackets is clearly positive and an increasing function of the degree of the monopolistic distortions in both the goods and the labor markets. The inefficiency of the steady state allows a monetary policy shock (or any other demand shock) to increase welfare as the degree of underemployment and underproduction is reduced while marginal utility of the additional consumption exceeds the implied increased disutility from labor effort (see Blanchard and Kiyotaki, 1987).

3.3 The Open Economy

In an open economy additional effects are at play, induced by the changed terms of trade. A change in the terms of trade re-shuffles demand across countries, thereby inducing deviations from the equality between $\widehat{y}_t$ and $\widehat{c}_t$. For some parameterizations this is supported by means of a re-allocation of wealth through the current account. These effects are best illustrated through impulse responses to an expansionary shock to the monetary policy rule which are presented in Figure 2. The shock ceteris paribus pushes the domestic interest rate below its steady state value reducing the real rate of interest both domestically and abroad because domestic and foreign rates are linked through the uncovered interest parity condition and because goods price are sticky. Aggregate demand *for both home and foreign firms* increases after the decrease of the real interest rates as households substitute tomorrow's for today's consumption and firms hire more workers to meet this extra demand. They accomplish this by offering higher wages, boosting both wage inflation (π_t^w) and domestic price inflation (π_t^h) to the extent that this is possible, given the assumed price rigidity. This, in turn, partially reverses the reduction of the interest rate as the central bank endogenously reacts to price and wage inflation.

Up to now the discussion resembled much the discussion of a closed economy. However, in an open economy the exchange rate and the terms of trade are affected too, as can be seen when we log-linearize the uncovered interest rate condition, solve forward and note that $\widehat{s}_\infty = 0$. Then we get

$$\widehat{s}_t = -\sum_{i=0}^{\infty}\left(\widehat{1+i_{t+i}} - \widehat{1+i_{t+i}^*} + \psi d_{t+i}\right)$$

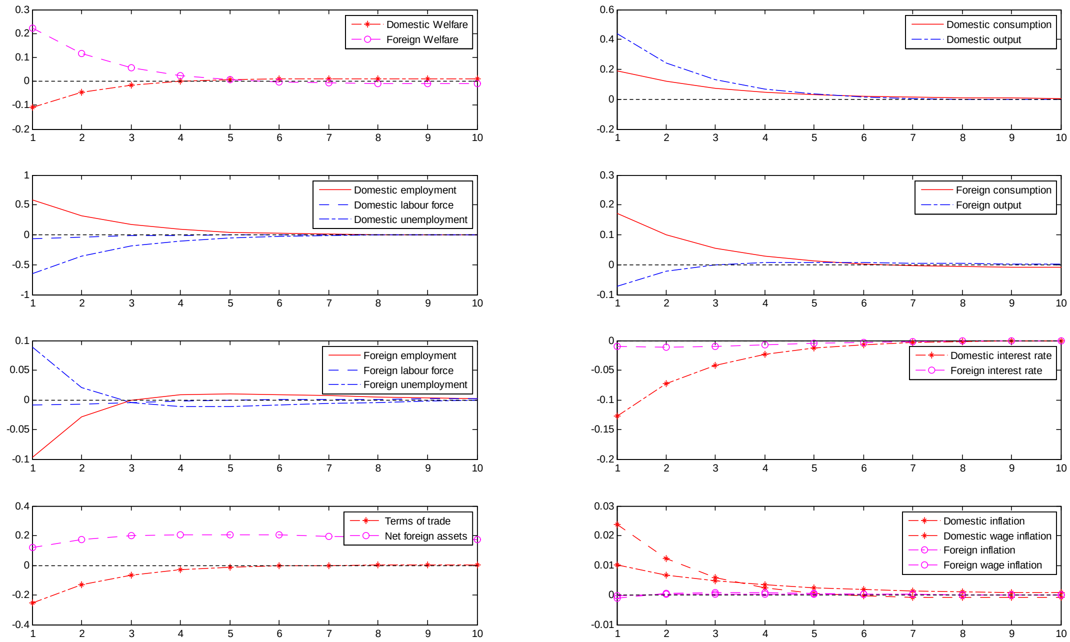

Figure 2: Impulse responses to an expansionary monetary policy shock.

When the monetary policy shock induces a fall of the domestic interest rate below the foreign one for some while and/or improves the international investment position (i.e. $d_t > 0$), this tends to depreciate the nominal exchange rate. This is what happens in the present model. As goods prices are sticky, the terms of trade will deteriorate (in the present model this implies a decline in τ, i.e. $\widehat{\tau}_t < 0$; see equation (4)) and as long as domestic and foreign goods are (imperfect) substitutes, relative demand will shift away from foreign goods and towards domestic goods. This *expenditure switching effect* implies an increase in demand for domestic goods beyond the increase in domestic demand while the opposite occurs abroad.

From this follow mainly two effects: First, the domestic disutility of labor effort increases relative to the closed economy scenario as employment, or total hours worked increase. Exactly the opposite happens in the foreign economy. Second, firms' revenues increase relative to foreign firms' revenues when the Marshall-Lerner-Robinson condition is fulfilled, as this implies that the relative decline in the relative price of domestic firms (the terms of trade) is more than compensated by the increase in relative output. Tille (2001) showed that the Marshall-Lerner-Robinson condition is fulfilled for $\rho > 1$. There is thus a transfer of wealth from the foreign to the domestic economy (the *current account effect*) in that case, d_t increases. After this temporary wealth transfer, households will smooth the additional consumption that the wealth effect affords. As a consequence, the short run relative increase in output and disutility from labour on the one hand and consumption on the other hand increases relative to the closed economy scenario.

Engler and Tervala (2011) show that even for a scenario in which the Marshall-Lerner-Robinson condition is not fulfilled, the *short-run* welfare effect of an expansionary monetary policy shock is negative. i.e. that the increase in disutility from labour is larger than the increase in consumption utility. This means than irrespective of the size of the substitution elasticity between domestically and foreign produced goods, an expansionary monetary policy is beggar-thyself in the short-run.

The short-run beggar-thy-neighbour effect can be seen in Figure 2, where domestic welfare falls immediately after the shock while foreign welfare increases[8]. The increase in domestic employment is larger than the increase in consumption while foreign employment falls. The net effect on domestic welfare is negative, even though the coefficient on the first, $N^{1+\varphi}$, is roughly 0.52, weakening the impact of the increase in employment significantly. The welfare effect for the foreign economy is clearly positive as consumption increases and employment falls. The expenditure-switching effect thus has a powerful implication for welfare in open economies.

In the long run these effects can change, however. In case of a permanent wealth reallocation in favor of the domestic economy, as is the case in the models of Obstfeld and Rogoff (1995) and Engler and Tervala (2011) which possess the random walk property discussed above, households can afford a higher level of consumption and a lower level of hours as they receive a permanent stream of interest payments from the foreign country in the new steady state. Monetary policy is beggar-thy-neighbour in the long run in these models.

Here, however, the long-run equilibrium is the same steady state as the old one, so that we can only look at the "medium run", the time between the quarters immediately after the shock and the new/old steady state. Domestic welfare turns positive in the medium-run because households smooth the reduction of consumption towards the steady state while employment falls. They accomplish this by driving down their international investment position

[8] The beggar-thy-neighbour result of Engler and Tervala (2011) for *any* value of ρ is not shown here but can easily replicated in the current model. Results are available from the author upon request.

that they had built up in the first quarters after the shock. The foreign country pays back its debt by reducing consumption below and increasing employment and the labour force above the steady state levels. So in the medium-run, monetary policy shocks are beggar-thy-neighbour in this model.

Up to now, unemployment played no role in the welfare analysis beyond being almost the mirror image of employment changes. An increase in unemployment is thus good for welfare if taken literally. This counterintuitive result will be discussed and modified in the next section.

3.4 Unemployment

In the present model, the increase in total hours worked comes entirely from newly hired, formerly unemployed workers. At the same time, the increase in income not only increases consumption, but also leisure, as both are normal "goods". Consequently the labour force declines, further contributing to the decline in unemployment (see Figure 2). In the foreign economy where output falls, employment falls and unemployment increases while the income effect reduces the labour force here, too. According to the welfare metric W^1 (equation (11)) this implies that the decrease in domestic unemployment reduces welfare while the reduction in foreign unemployment increases welfare. The ensuing question then is whether there are reasonable welfare implications of unemployment that go beyond the change in employment and that are not yet taken account of.

Unemployment could affect welfare in a number of ways. First, it could reduce utility of the unemployed relative to people in employment through its effect on consumption if there is incomplete risk sharing so that the reduced income reduces consumption. Second, unemployment could have a negative psychological effect because being out of work might reduce self esteem and social status. Third, it might cause disutility because it involves search costs that could be modelled as reduced time available for leisure. Fourth, unemployment causes fiscal costs that are proportional to the level of the rate of unemployment. In countries with elaborate systems to support the unemployed, these costs can be considerable as was exemplified in Figure 1. Fifth, society as a whole could have a preference for a low level of unemployment. Again, this should be of particular relevance in countries with elaborate welfare systems as such systems rely on sizable contributions by employees or tax payers. A reduction in unemployment could make such a system not only more affordable but also more acceptable as a social institution. Any social planner in favor of such institutions should thus be in favor of low levels of unemployment.

These aspects are generally neglected in the literature on the welfare effects of monetary policy shocks in open economies (and, of course, in the closed economy literature as well[9]) and they are, up to now, not tackled directly in the present model. If integrated into the model, they will, however, increase utility if unemployment falls, either because the aggregate level of consumption increases or because social stress or stigma related to unemployment falls, or because more time can be spent on productive purposes or leisure rather than search time; or because resources that are used to support the unemployed are reduced and can be used for other, utility increasing purposes.

These effects will be inconsequential for the sign of the welfare effect in a closed economy, as they will re-inforce the increase in welfare when output increases, but they can potentially change the sign of the short-run welfare effect in an open economy because, as we saw above, welfare falls in the aftermath of the shock. So this issue is of a greater relevance here than for a closed economy.

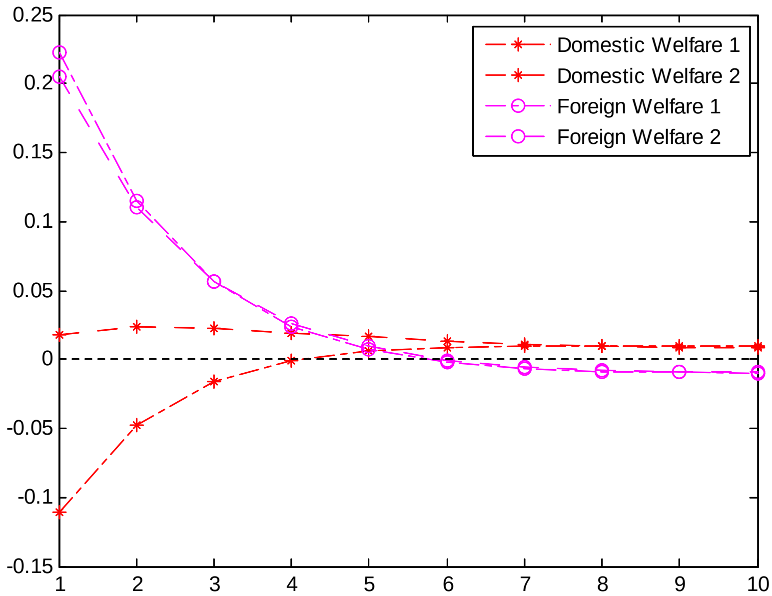

Figure 3: Welfare with and without explicit account of unemployment.

A short-cut to modelling any of these mentioned aspects in detail can be to simply add a term that incorporates unemployment into the utility or

[9] An exception being Christiano et al. (2010).

welfare function so that any reduction in its rate improves welfare[10]. This is the approach I follow in this section, showing the dynamic effects of a monetary policy shock on welfare. In the next section, I will present a sketch of a model of fiscal costs of unemployment that inhibits the same qualitative dynamics of welfare as the basic one.

I define the new welfare metric 2 W^2 as follows:

$$\begin{aligned} W_t^2 &\equiv dU_t^2 \\ &= \widehat{c}_t - N^{1+\varphi}\widehat{n}_t - \upsilon\widehat{u}_t \end{aligned}$$

where υ denotes the utility costs associated with an increase in unemployment. This can be re-written as

$$\begin{aligned} dU_t^2 &= \widehat{c}_t - N^{1+\varphi}\widehat{n}_t - \upsilon\left(\widehat{l}_t - \widehat{n}_t\right) \\ &= \widehat{c}_t - \left(N^{1+\varphi} - \upsilon\right)\widehat{n}_t - \upsilon\widehat{l}_t \end{aligned}$$

indicating that the disutility increasing effect of employment that is realized *at the individual level* is partly or fully compensated by the *aggregate* positive effect that employment has as it reduces unemployment. At the same time, a decrease of the labour force increases welfare ceteris paribus as it decreases unemployment.

The underlying assumption of this approach is thus that at the level of individual, or household optimization, unemployment cannot be affected. The state of unemployment at the individual level can thus regarded as an externality of the household's decision affecting aggregate welfare. This can reasonably be justified as the level of employment is entirely demand determined in this model.

A simple numerical example illustrates that this modification to the welfare function can easily overturn the short-run beggar-thy-neighbour effect. Figure 2 shows the evolution of domestic and foreign welfare according to welfare metrics W^1 and W^2 for the same exercise as presented in Figure 1 for $\upsilon = 0.2$. The monetary policy shock increases domestic welfare because domestic unemployment falls and decreases foreign welfare because foreign unemployment increases. The effect is largest for the immediate reaction after the shock as this is the time when the change in unemployment is largest.

[10] An analogous reasoning justifies the introduction of money into a DSGE framework by means of writing it directly into the utility function as in Sidrauski's (1967) MIU-model. One interpretation of this approach is that it provides a short-cut to motivate a demand for money which ultimately could be related to something else than utility derived from holding money directly. Money could, instead, increase utility indirectly by facilitating transactions (Clower, 1967 and Brock, 1974) and thereby increase overall welfare.

3.5 Costs of unemployment

Next I present a sketch of a variation of the model that incorporates costs that are related to the rate of unemployment. I present only those equations that are changed by this exercise. These costs can be understood as resources needed to re-distribute income from employed to unemployed workers or costs related to measures to bring unemployed workers back to work. More specifically, I assume them to be proportional to the rate of unemployment, denoting them as Bu_t. This functional form of these costs is justified by the German data presented in Figure 1 in the Introduction. They are financed by lump-sum taxes T_t, so that the representative household and the government face the budget constraints

$$D_t = (1 + i_t)D_{t-1} + \int_0^1 W_t(i)N_t(i)di - P_tC_t + \Pi_t - T_t$$

and

$$T_t = Bu_t$$

respectively.

The resources associated with the fiscal costs are in the form of domestically produced goods. They are modelled as a CES-index of these goods allowing a derivation of demand functions for each good z so that aggregate demand for these goods is now

$$Y_t^d(z) = \left(\frac{P_t^h(z)}{P_t^h}\right)^{-\theta} \left(\frac{P_t^h}{P_t}\right)^{-\rho} C_t^W + \left(\frac{P_t^h(z)}{P_t^h}\right)^{-\theta} Bu_t$$

From this follows the aggregate demand function

$$Y_t = \left(\frac{P_t^h}{P_t}\right)^{-\rho} C_t^W + Bu_t$$

which in the symmetric steady state reduces to $Y = C + Bu$. Around this steady state we have

$$\widehat{y}_t = -\rho n \left(1 - Bu/Y\right) \widehat{\tau}_t + \left(1 - Bu/Y\right) \widehat{c}_t^W + (Bu/Y)\widehat{u}_t$$

and, assuming the same costs of unemployment in the steady state in the foreign economy, we can write

$$\widehat{y}_t - \widehat{y}_t^* = -\rho \left(1 - Bu/Y\right) \widehat{\tau}_t + (Bu/Y) \left(\widehat{u}_t - \widehat{u}_t^*\right)$$

The aggregate resource constraint can be shown to be approximately

$$d_t = \beta^{-1} d_{t-1} + \widehat{y}_t - \widehat{c}_t + n\widehat{\tau}_t - (Bu/Y)\widehat{u}_t$$

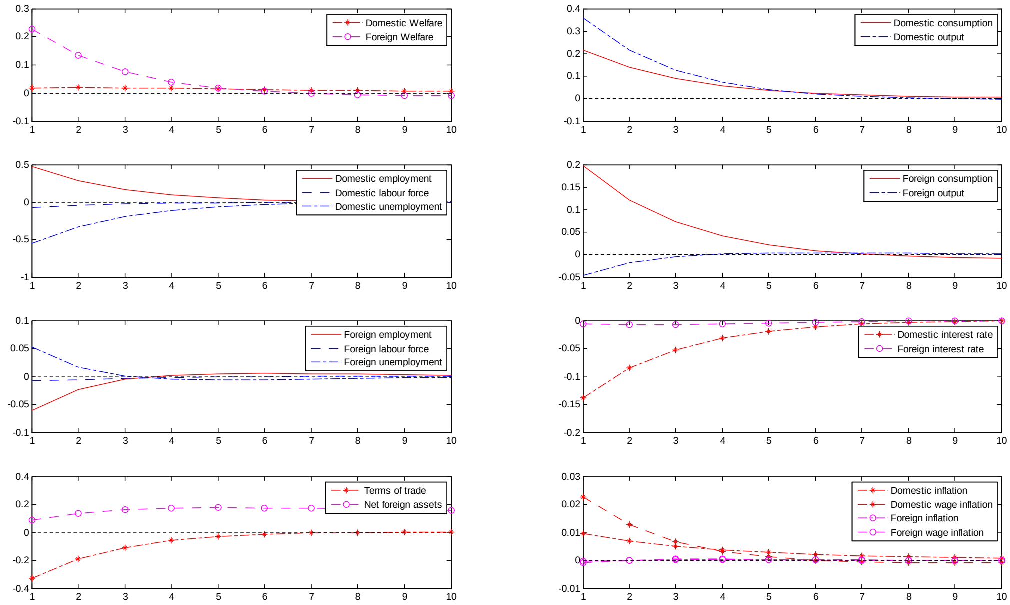

Figure 4: Impulse responses to an expansionary monetary policy shock with fiscal costs of unemployment.

and steady state employment increases relartive to the model without costs of unemployment to

$$N = \left((1-\alpha) \left(\frac{\theta}{\theta - 1} \right)^{-1} \left(\frac{\epsilon_w}{\epsilon_w - 1} \right)^{-1} (1 - Bu/Y)^{-1} \right)^{\frac{1}{1+\varphi}}$$

The introduction of these costs results in a negative wealth effect for households increasing the incentive to work thereby increasing the aggregate labour input and production. The dynamics of the model variables and the impact on welfare according to welfare metric W^1 to the monetary policy shock assuming $Bu/Y = 0.2$ are presented in Figure 4. While the dynamics of most variables are slightly different, it is obvious that the implications for welfare closely resemble those of the basic model evaluated with welfare metric W^2: Welfare increases slightly after the monetary policy shock.

4 Conclusions

This paper introduces unemployment into a standard open economy model with nominal price and wage rigidities and analyses welfare effects of a monetary policy shock by means of a metric that tracks the utility of a representative household over time. As such, the analysis provides no additional information relative to a model where fluctuations of hours worked are due to variations at the intensive margin because hours worked are negative for utility in any case. However, unemployment incurs significant costs, most obviously fiscal costs, but other negative side-effects can easily be imagined. I propose a modified welfare function that captures such additional costs of unemployment in a general way by simply adding an additional term to the welfare function and provide the sketch of a model with explicit costs which generates the same welfare implications as the general extension. It turns out that the introduction of these additional features can change the sign of the welfare impact of monetary policy shocks.

According to this analysis, expansionary monetary policy shocks can be much more beneficial than previously considered and even generate positive welfare effects in the short-run.[11] Unemployment does increase disutility from labour, but this is offset by reductions in costs of unemployment or simply because the social planner has a preference for a low level of unemployment.

What this model does not capture, are different time lags in consumption and employment changes which should have an important influence on the precise evolution of welfare over time. Furthermore, the households'utility functions could tackle the costs of unemployment at the individual level directly as in Christiano et al. (2010), either by introducing incomplete risk sharing across household members or by search costs for unemployed workers when looking for a job. However, in my analysis I show that even without these costs at the individual level, the welfare implications of a monetary policy shock change considerably.

[11] Such shocks remain, however, not an option for systematic reductions in unemployment as such a policy stance would not be time consistent.

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A Appendix

A.1 Fluctuations of Δ_t^p around the symmetric steady state of order 1 are zero.

We need to show that a first order Taylor approximation of Δ_t^p around a symmetric steady state is zero. Up to first order, we have

$$\left(\frac{Y_t(z)}{Y_t}\right)^{\frac{1}{1-\alpha}} - \left(\frac{Y(z)}{Y}\right)^{\frac{1}{1-\alpha}} = \frac{1}{1-\alpha}\left(\frac{Y(z)}{Y}\right)^{\frac{1}{1-\alpha}-1}\left(\frac{1}{Y}dY_t(z) - \frac{Y(z)}{Y^2}dY_t\right)$$
$$\widehat{\left(\frac{Y_t(z)}{Y_t}\right)^{\frac{1}{1-\alpha}}} = \frac{1}{1-\alpha}\left(\widehat{y}_t(z) - \widehat{y}_t\right)$$

and after integrating over all z we have

$$\int_n^1 \widehat{\left(\frac{Y_t(z)}{Y_t}\right)^{\frac{1}{1-\alpha}}} dz = \frac{1}{1-\alpha}\left(\int_n^1 \widehat{y}_t(z)dz - \widehat{y}_t\right)$$

So we need to show that $\int_n^1 \widehat{y}_t(z)dz = \widehat{y}_t$. In order to derive this equality we assume an index for per household consumption Y_t of the form, $Y_t = \left[(1-n)^{-\frac{1}{\theta}} \int_n^1 \left(\frac{Y_t(z)}{1-n}\right)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}}$, which in the steady state reduces to

$$\begin{aligned} Y &= \left[(1-n)^{-\frac{1}{\theta}} \int_n^1 \left(\frac{Y(z)}{1-n}\right)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}} \\ &= \frac{1}{1-n}\left[(1-n)^{-\frac{1}{\theta}}\, Y(z)^{\frac{\theta-1}{\theta}} \int_n^1 dz\right]^{\frac{\theta}{\theta-1}} \\ &= Y(z) \end{aligned}$$

This convenient equality between the level of output at the firm level $Y(z)$ and aggregate per-capita output Y follows because the size of the economy measured in terms of the number of firms equals the size of the economy measured in terms of households. As a consequence, aggregation over all firms and normalization by households exactly cancel. Around this steady state we have

$$\begin{aligned}
Y_t &= \left[(1-n)^{-\frac{1}{\theta}} \int_n^1 \left(\frac{Y_t(z)}{1-n}\right)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}} \\
Y_t - Y &\approx \frac{1}{1-n}\frac{\theta}{\theta-1}\underbrace{\left[(1-n)^{1-\frac{1}{\theta}}\, Y^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}-1}(1-n)^{-\frac{1}{\theta}}}_{Y^{\frac{1}{\theta}}} \\
&\quad *(1-n)\frac{\theta-1}{\theta}Y(z)^{-\frac{1}{\theta}}\int_n^1 \left(Y_t(z)-Y(z)\right) dz \\
\widehat{y}_t &\approx \int_n^1 \widehat{y}_t(z)dz \qquad (12)
\end{aligned}$$

This verifies the claim stated above.

A.2 $y_{t+k|t} - y_{t+k} = -\theta\left(p_t^{ho} - p_{t+k}^h\right)$

First we approximate the demand function of firm z:

$$\begin{aligned}
Y^d_{t+k|t}(z) &= \left(\frac{P_t^{ho}(z)}{P^h_{t+k|t}}\right)^{-\theta}\left(\frac{P^h_{t+k}}{P_{t+k}}\right)^{-\rho} C^W_{t+k} \\
\widehat{y}_{t+k|t}(z) &\approx -\theta\left(p_t^{ho}(z) - p^h_{t+k}\right) - \rho\left(p^h_{t+k} - p_{t+k}\right) + \widehat{c}^W_{t+k}
\end{aligned}$$

Subtracting (12) and plugging $\widehat{y}_{t+k|t}(z)$ into $\widehat{y}_{t+k}$, we get

$$\begin{aligned}
\widehat{y}_{t+k|t}(z) - \widehat{y}_{t+k} &\approx -\theta\left(p_t^{ho}(z) - p^h_{t+k}\right) - \rho\left(p^h_{t+k} - p_{t+k}\right) + \widehat{c}^W_{t+k} \\
&\quad - \int_n^1 \left(-\theta\left(p^h_{t+k}(z) - p^h_{t+k}\right) - \rho\left(p^h_{t+k} - p_{t+k}\right) + \widehat{c}^W_{t+k}\right) dz \\
&= -\theta p_t^{ho}(z) + \int_n^1 \theta p^h_{t+k}(z) dz
\end{aligned}$$

Noting that

$$P^h_{t+k} \equiv \left((1-n)^{-1}\int_n^1 \left(P^h_{t+k}(z)\right)^{1-\theta} dz\right)^{\frac{1}{1-\theta}}$$

can be approximated by

$$\widehat{p}_{t+k}^{h} \approx \int_{n}^{1} \widehat{p}_{t+k}^{h}(z)dz$$

we get

$$\widehat{y}_{t+k|t}(z) - \widehat{y}_{t+k} = -\theta \left(\widehat{p}_{t}^{h}(z) - \widehat{p}_{t+k}^{h}\right)$$

As this relation is valid for all firms having re-set their price in t and because the the steady state $y(z) = y$ and $p^h(z) = p^h$ we can write

$$y_{t+k|t} - y_{t+k} = -\theta \left(p_{t}^{ho} - p_{t+k}^{h}\right)$$