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Optimal Monetary Policy in a Currency Union: The Role of the Cost Channel *

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Abstract

In this paper we introduce the cost channel of monetary policy (e.g., Ravenna and Walsh, 2006) into an otherwise standard New Keynesian model of a two-country monetary union, which is being hit by aggregate, asymmetric and idiosyncratic shocks. The single central bank implements the optimal discretionary monetary policy by setting the union interest rate.The cost channel makes monetary policy less effective in combatting inflation, but it is shown that the optimal response to the decline in effectiveness is a stronger use of the instrument. Moreover, we show how the sign of the spillover effects of idiosyncratic shocks depends on the strength of the cost channel. If the cost channel exceeds a well-defined threshold, then the interest rate turns into a supply-side instrument.

JEL-Classification: E 31, E 52, F 41

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1 Introduction

New Keynesian models have been extensively used to study the transmission of monetary impulses to business cycles fluctuations. It is common to assume that monetary policy affects the real economy and the inflation rate primarily via the demand side. A higher interest rate causes a decline in aggregate demand, output and employment, and, eventually, in wages and prices. Growing empirical evidence, however, suggests that the interest rate also enters into the marginal costs of production (see, for instance, Barth and Ramey, 2001; Ravenna and Walsh, 2006; Chowdhury et al., 2006; Tillmann, 2008). A higher interest rate matters for the pricing decision of firms and thus for inflation and output dynamics. Ignoring the cost channel skews the real picture of the monetary transmission process and distorts the guidelines for the design of optimal policy rules. This paper carefully models both the demand and the supply side effects of monetary policy. We will introduce the cost channel into an otherwise standard New Keynesian model of a two-country monetary union, which is being hit by aggregate, asymmetric and/or idiosyncratic shocks. Our focus will be on the question how the optimal discretionary monetary policy response depends on the strength of the cost channel.

The microeconomic rationale for the cost channel is the existence of liquidity constraints for firms in the factor markets (see Christiano et al., 2005; and Chowdhury et al., 2006). Firms have to pay for production inputs before they receive revenues from selling their products. They borrow funds from financial intermediaries to finance the outlays for the inputs. A rise in the interest rate translates into a rise in marginal costs and product prices.

The conduct of monetary stabilisation policy in the presence of a cost channel has not received much research attention. This is surprising, since the design of optimal monetary policy in a currency union has been studied extensively. Lane (2000) shows that the optimal response to perfectly asymmetric shocks is to "do nothing". Benigno (2004) studies the implications of different degrees of price stickiness among member countries for the optimal target of inflation. Only if the member countries share the same degree of nominal rigidity, it is optimal to stabilise the price level for the union as a whole. Lombardo (2006) emphasises the importance of country-specific degrees of product market competition for the design of optimal monetary policy. If the currency union has a trade linkage with the rest of the world, the strict inflation stabilisation is no longer the first best policy and a partial stabilisation of the exchange rate is desirable (de Paoli, 2009; Cecioni, 2010). Gali and Monacelli (2008) and Beetsma and Jensen (2005) focus on the optimal mix of monetary and fiscal policy. From the viewpoint of the union the optimal policy plan requires that union inflation is stabilised by the single central bank, whereas fiscal policy, implemented at the country-level, should stabilise idiosyncratic shocks. Ferrero (2009) moves one step further by introducing a government budget constraint. He shows that a balanced budget rule generates first-order welfare losses, allowing for variations in government debt is superior.

In a seminal paper, Ravenna and Walsh (2006) investigate the role of the cost channel for the design of optimal monetary policy. They show that, under optimal monetary policy, the output gap and inflation are allowed to fluctuate in response to both productivity and demand shocks. However, they restrict their analysis to the case of a closed economy and ignore all international linkages. Tillmann (2009a) introduces uncertainty about the true size of the cost channel into the model of Ravenna and Walsh. Since an uncertain monetary authority tends to overestimate the price effect of an interest rate hike, the interest rate response to inflation is smaller, uncertainty makes the central bank less aggressive.

This paper contributes to these two strands of literature by the incorporation of a cost channel into a two-country model of a monetary union. The cost channel makes monetary policy less effective in combatting inflation, but, as we will show, the optimal response to the decline in effectiveness is a stronger use of the instrument. In the presence of a cost channel, policymakers are generally more aggressive. This result complements Tillmann (2009a). Moreover, we show that the spillover effects of idiosyncratic shocks very much depend on the strength of the cost channel.

The remainder of the paper is structured as follows. Section 2 develops the basic structure of the model, the building blocks are the IS relation, the Phillips curve and the interest rate rule. In Section 3 we present the solution of the model, Section 4 discusses the optimal monetary policy, along with the inflation and output dynamics of different shocks. Section 5 concludes.

2 Basic Structure of the Model

We consider a world of two countries, (H)ome and (F)oreign. The countries form a monetary union with a single central bank. Countries produce differentiated commodities, all goods are traded. Labour and product markets are imperfectly competitive, and firms set prices subject to a Calvo (1983) scheme of staggered price adjustments. Labour serves as the only input. Following Barth and Ramey (2001), Christiano et al. (2005), and Ravenna and Walsh (2006), we introduce a cost channel by assuming that (a fraction of) firms have to pay their wage bill before they sell their product. Firms borrow at the riskless nominal interest rate set by the central bank.

2.1 The IS Relation

The population of the union is a continuum of households on the interval $[0, 1]$. The population of the segment $[0, n)$ belongs to Home, while the population of $[n, 1]$ belongs to Foreign. All households have identical preferences defined over consumption C_t and total hours worked L_t. The utility of a representative household[1] is given by

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{(C_s)^{1-\sigma}}{1-\sigma} - \frac{(L_s)^{1+\gamma}}{1+\gamma} \right], \tag{1}$$

where $\beta \in [0,1]$ is the discount factor, σ is the inverse of the intertemporal elasticity of substitution, and γ is the inverse Frisch elasticity of labour supply. The consumption index C_t is defined as

$$C_t = \left(\frac{C_t^H}{n} \right)^n \left(\frac{C_t^F}{1-n} \right)^{1-n}, \tag{2}$$

where C_t^H and C_t^F are the consumption baskets of Home and Foreign goods, respectively. These baskets are themselves CES aggregates across Home and Foreign brands. The elasticity of substitution between the two bundles of goods is restricted to unity. Empirically, the unitary assumption seems warranted (see Bergin, 2006).

The consumer price index for Home, p_t^{cH}, is given by $p_t^{cH} = np_t^H + (1-n)p_t^F$. Here p_t^H is the producer price index for Home goods, and p_t^F is the producer price index for Foreign goods (variables written in lower case letters are log deviations from the deterministic steady state of that variable). Let $q_t \equiv p_t^F - p_t^H$ represent the terms of trade. Then the Home (Foreign) consumer price index can be written as

$$p_t^{cH} = p_t^H + (1-n)q_t; \qquad p_t^{cF} = p_t^F - nq_t. \tag{3}$$

There are no impediments to trade, so the law of price holds for each brand. And since preferences are assumed to be identical in the entire union, absolute purchasing power parity holds: $p_t^{cH} = p_t^{cF}$. Relative purchasing power parity states $\pi_t^{cH} = \pi_t^{cF}$ with $\pi_t^{cH} \equiv p_t^{cH} - p_{t-1}^{cH}$ as Home and $\pi_t^{cF} \equiv p_t^{cF} - p_{t-1}^{cF}$ as the Foreign rate of consumer price inflation. The Home and Foreign rates of producer price inflation, however, defined as $\pi_t^H \equiv p_t^H - p_{t-1}^H$ and $\pi_t^F \equiv p_t^F - p_{t-1}^F$, respectively, differ across countries.

The allocation of resources encompasses three choices: the choice between consumption today and consumption in the future (savings), the choice between the baskets of Home and Foreign goods, and the choice between brands. The solution of the intertemporal utility maximisation problem is given by the standard Euler equation

$$c_t^w = E_t c_{t+1}^w - \sigma^{-1}(R_t - E_t \pi_{t+1}^w). \tag{4}$$

Here c_t^w is aggregate consumption in the union, R_t is the nominal interest rate, and $E_t \pi_{t+1}^w$ is the expected consumer (and producer) price inflation in the union. In a next step, households split consumption expenditure into purchases of

[1] For convenience, we omit any household index and interpret all variables in both per-capita and aggregate terms.

Home and Foreign goods. Aggregate demand for Home and Foreign goods, c_t^H and c_t^F, respectively, can be expressed as

$$c_t^H = (1-n)q_t + c_t^w \; ; \qquad c_t^F = -nq_t + c_t^w. \tag{5}$$

The demand for Home (Foreign) goods is increasing (decreasing) in the terms of trade q_t. This is the well-known open economy expenditure-switching effect. The strength of the terms-of-trade effect is increasing in $1-n$, the weight of Foreign goods in the consumption index (2). The goods market equilibrium in Home and Foreign requires $c_t^H = y_t^H$ and $c_t^F = y_t^F$, where y_t^H and y_t^F are the real output gaps in Home and Foreign, respectively. At the union level, we have $c_t^w = y_t^w$ with y_t^w as aggregate (union) output gap. With this at hand, the demand side of the economies can be stated as

$$y_t^H = (1-n)q_t + E_t y_{t+1}^w - \sigma^{-1}(R_t - E_t \pi_{t+1}^w) + u_t^H \tag{6}$$

$$y_t^F = -nq_t + E_t y_{t+1}^w - \sigma^{-1}(R_t - E_t \pi_{t+1}^w) + u_t^F. \tag{7}$$

In (6) and (7), we have added the demand shocks u_t^H and u_t^F, which are assumed to follow an AR(1) process:

$$u_t^H = \rho_u u_{t-1}^H + \xi_{u,t}^H; \qquad u_t^F = \rho_u u_{t-1}^F + \xi_{u,t}^F \tag{8}$$

where $\xi_{u,t}^H$ and $\xi_{u,t}^F$ are zero mean white noise processes, and $\rho_u \in [0,1]$. These equations represent the IS relations in our two-country model of a currency union.

2.2 The Phillips Curve

Monopolistically competitive firms aim to maximise the current value of profits. Each firm chooses the optimal price subject to three constraints: a downward sloped demand schedule for its product, a production function describing the technology, and a Calvo (1983) scheme of price adjustment where each firm may reset its price with probability δ in any given period. Assuming that the steady state is characterised by zero inflation in both countries, the evolution of the Home and Foreign producer inflation rates are given by marginal cost based (log-linearised) Phillips curves:

$$\pi_t^H = \beta E_t \pi_{t+1}^H + \theta \cdot mc_t^H + \varepsilon_t^H; \qquad \pi_t^F = \beta E_t \pi_{t+1}^F + \theta \cdot mc_t^F + \varepsilon_t^F \tag{9}$$

where $\theta \equiv \frac{\delta(1-\beta(1-\delta))}{1-\delta}$ (see, e.g, Gali, 2008). In analogy to the assumption on the properties of the demand shocks the exogenous supply shocks, ε_t^H and ε_t^F, are assumed to be AR(1) processes:

$$\varepsilon_t^H = \rho_\varepsilon \varepsilon_{t-1}^H + \xi_{\varepsilon,t}^H; \qquad \varepsilon_t^F = \rho_\varepsilon \varepsilon_{t-1}^F + \xi_{\varepsilon,t}^F \tag{10}$$

where $\xi_{\varepsilon,t}^H$ and $\xi_{\varepsilon,t}^F$ are zero mean white noise processes, and $\rho_\varepsilon \in [0,1]$.

Firms produce output by means of labour according to

$$y_t^H = l_t^H; \qquad\qquad y_t^F = l_t^F. \tag{11}$$

Real marginal costs, mc_t^H and mc_t^F, are linear in the real wage,

$$mc_t^H = w_t^H - p_t^H + zR_t; \qquad\qquad mc_t^F = w_t^F - p_t^F + zR_t, \tag{12}$$

and, due to the cost channel, increasing in the nominal interest rate set by the central bank. Firms are assumed to face a liquidity constraint in the factor markets. Factors of production have to be paid before goods markets open and firms can sell their products. Here, labour is the only factor of production. Thus the wage bill is the maximum amount firms must borrow at the beginning of a period from financial intermediaries. Financial intermediaries receive deposits from households and supply loans to firms at the nominal interest rate R_t^l. For simplicity we can approximate the lending rate R_t^l by the policy-controlled risk-free interest rate R_t. Any wedge between these two interest rates will be captured by the parameter $z \geq 0$, which measures the strength of the cost channel. Note that it is the nominal interest rate, which enters into the firms' real marginal costs. The expected inflation rate does not matter, since loans are assumed to be supplied and repaid within a period. After goods have been produced and sold in the goods market, firms repay loans at the end of the period. There is no accumulation of debt.

Let us take a closer look at some features of the economy determining the strength of the cost channel. According to Rabanal (2007), the larger the fraction of firms facing a liquidity constraint, the higher z is. This line of reasoning rests on the assumption that only the interest rate on external funds raise the marginal costs of production. Barth and Ramey (2001), and Chowdhury et al. (2006), however, argue that all firms are affected by the cost channel. The concept of opportunity costs implies that the logic of the effects of interest rates on firms' costs also applies when firms are primarily financed by internal funds. A less controversial feature detemining z is the degree of interest rate pass-through. In imperfect financial markets the change in the lending rate may even exceed the change in the central bank rate, i.e. financial market restrictions amplify the effects of the cost channel. The parameter z is thus not restricted to lie between zero and one (see de Bondt, 2005; Chowdhury et al., 2006; Ravenna and Walsh, 2006; and Tillmann, 2009a). And finally, we can refer to almost all the factors put forward in the literature on the balance-sheet channel and the financial accelerator in order to substantiate the supply-side effects of monetary policy (see e.g. Bernanke and Gertler, 1995; and Bernanke et al., 1999).

The empirical evidence about the importance of the cost channel varies across countries and over time. Ravenna and Walsh (2006) find a cost channel coefficient of about unity for the U.S. Tillmann (2008) provides supportive evidence for a significant cost channel for the Euro area. This result is confirmed by Henzel et al. (2009). The study of Chowdhury et al. (2006) suggests that the strength of the cost channel varies in accordance with differences in financial systems. For countries with a highly regulated financial sector such as Germany or Japan, they do not find a significant cost channel. However, for countries with a more market-based system such as in the UK or in the U.S., the authors estimate a coefficient of about unity. Tillmann (2009b) argues that the coefficient for the U.S. follows a U-shaped pattern. The cost channel was most important in the pre-Volcker era and less important in the Volcker-Greenspan period. Recently, due to Tillmann, the cost channel regained quantitative importance. This in turn conflicts with Gabriel and Martins (2010), who claim that the cost channel is poorly identified for the U.S.

With regard of the model, nominal wages are set either by individual households (see e.g. Blanchard and Gali, 2010) or by non-atomistic trade unions (see Gnocchi, 2009). In all labour market settings the wage setting institution is interested in the real wage in terms of the consumer price index. We can thus proceed by assuming that the real consumer wage is a0 constant markup over the marginal rate of substitution between consumption and leisure. Observing the period utility function in (1) we get

$$w_t^H = p_t^{cH} + \sigma\ c_t(H) + \gamma\ l_t^H; \qquad w_t^F = p_t^{cF} + \sigma\ c_t(F) + \gamma\ l_t^F, \tag{13}$$

where $c_t(H)$ is the consumption of a Home household and $c_t(F)$ is the consumption of a Foreign household, respectively. Notice that the inverse of the Frisch elasticity of labour supply γ turns out to be the employment elasticity of wages.

Next we rewrite the Phillips curve (9). We insert the wage (13) into (12) and substitute the result into the inflation equation (9). Then, by observing technology (11), the definition of the consumer price index (3), product market equilibrium, and aggregate demand (5), we yield for Home inflation: $\pi_t^H = \beta E_t \pi_{t+1}^H + \theta(1-n)(1+\gamma)q_t + \theta\sigma\ c_t(H) + \theta\gamma c_t^w + \theta z R_t + \varepsilon_t^H$. Note that Home inflation is increasing in the terms of trade. If the (relative) price of Foreign goods increases, the Home consumer price index increases, and so does Home wages, Home marginal costs, and Home inflation.

Assuming that households have access to a complete set of state contingent securities (complete asset markets), the marginal utility of consumption and thus (per-capita) consumption itself is equalised across countries, $c_t(H) = c_t(F) = c_t^w$.[2] Subsequently we use $c_t^w = y_t^w = y_t^H - (1-n)q_t$ to arrive at the following Home Phillips curve:

$$\pi_t^H = \beta E_t \pi_{t+1}^H + \theta(1-n)(1-\sigma)q_t + \theta(\sigma+\gamma)y_t^H + \theta z R_t + \varepsilon_t^H. \tag{14}$$

The Foreign Phillips curve is given by

$$\pi_t^F = \beta E_t \pi_{t+1}^F - \theta n(1-\sigma)q_t + \theta(\sigma+\gamma)y_t^F + \theta z R_t + \varepsilon_t^F. \tag{15}$$

Real marginal costs and thus product prices and current inflation will be increasing in the central bank interest rate. Since the demand effect of a higher interest rate - consumption, production, employment, wages, real marginal costs and thus prices decline - works in the opposite direction, the overall effect of a higher interest rate on current inflation is a priori ambiguous.

[2] If asset markets are incomplete and/or purchasing power parity does not hold, a risk sharing condition is needed to ensure an optimal risk allocation (see De Paoli, 2009).

2.3 The Welfare Objective

The common central bank chooses the union-wide nominal interest rate R_t to maximise the utility of the representative household given by (1). As this optimal policy problem is non-linear, a closed form solution cannot be derived. Hence we are restricted to an approximation of the welfare objective. In the literature it is by now fairly standard to use the linear-quadratic approach developed by Sutherland (2002) and Benigno and Woodford (2012). We obtain the objective function from a second-order Taylor series expansion of (1) around the deterministic steady state[3]:

$$-E_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} D_s \right\} + t.i.p. + o\left(\| \xi \|^3\right), \tag{16}$$

where $t.i.p.$ stands for terms independent of policy and $o\left(\| \xi \|^3\right)$ represents terms of order three and higher. The per-period deadweight loss function D_t is given by

$$D_t = \phi_y (y_t^w)^2 + \phi_\pi (\pi_t^w)^2 \tag{17}$$

where the ϕ-weights are combinations of the structural parameters of the model. Note that the derivation of (16) and (17) rests on the assumption that Home and Foreign do not differ with respect to the structural parameters. In particular, the degree of price stickiness and the strength of the cost channel are assumed to be identical across countries. If there were differences in these parameters, the per-period deadweight loss function would also include the terms of trade and the inflation differential between Home and Foreign (see e.g. Benigno, 2004; Ferrero, 2009, and Cecioni, 2010). In our model, however, influencing national differences is not at the disposal of the central bank. Neither the terms of trade nor the inflation differential are affected by monetary policy directly, so that these terms are part of $t.i.p.$

3 Solution of the Model

The derivation of the optimal monetary policy assumes the following sequence of events. First, households set their inflation expectation, $E_t\pi_{t+1}^H$ and $E_t\pi_{t+1}^F$, then period t demand and supply shocks are revealed. Given the realisations of the shocks, the central bank sets the nominal interest rate. Next, wage setters decide on the wage, and firms decide on the product price and take up a loan to finance the wage bill. Employment is pinned down, and production takes place. After selling the products on the goods market firms repay the loan.

[3]We follow (large parts of) the literature in assuming that steady state distortions are eliminated by appropriate fiscal subsidies.

3.1 The Aggregate Bloc

For a variable X, an aggregate (union) variable X^w is defined as weighted average of the national variables, $X_t^w \equiv nX_t^H + (1-n)X_t^F$. The relative variable X^R is defined as $X^R \equiv X^H - X^F$. From aggregation of (6) and (7) we get

$$y_t^w = E_t y_{t+1}^w - \sigma^{-1}(R_t - E_t \pi_{t+1}^w) + u_t^w, \tag{18}$$

where u_t^w denotes the aggregate demand shock. For union inflation we obtain from (14) and (15):

$$\pi_t^w = \beta E_t \pi_{t+1}^w + \theta(\sigma + \gamma) y_t^w + \theta z R_t + \varepsilon_t^w. \tag{19}$$

In the presence of a cost channel monetary policy shifts both the IS curve and the PC curve. Inserting the IS into the PC curve delivers union inflation as function of the interest rate:

$$\pi_t^w = -\frac{\theta(\sigma + \gamma)}{\sigma} R_t + \theta z R_t + ...$$

The first term is the demand effect, whereas the second term is the cost effect of a change in the interest rate. An increase in R_t lowers current consumption by σ^{-1} times the change in R_t. As a consequence, the marginal rate of substitution between consumption and leisure declines, and wage setters reduce their wage claim by σ times the change in consumption. Since lower consumption corresponds to lower output and employment, the marginal rate of substitution declines even more, reinforcing the wage decline by γ times the decline in employment. Firms face a decline in their marginal costs. The lower the degree of price stickiness (high θ), the higher the pass-through to producer price inflation. The cost channel, on the other hand, equals z times the change in R_t, and the impact on inflation also depends on θ. To summarise, if the cost channel is very strong, that is, if $z > \frac{\sigma+\gamma}{\sigma}$, then the cost channel outweighs the demand channel. An increase in R_t pushes inflation up. In such a scenario the interest rate turns into a supply-side instrument. Note that $z > 1$ is necessary but not sufficient for a dominant supply-side effect. For a similar result see Schmitz (2011).

Combining the IS and the PC curve in a slightly different manner leads to the Monetary Policy Curve MPC. By substituting (18) into (19) to eliminate the interest rate, we get:

$$\pi_t^w = \theta(\sigma + \gamma - \sigma z)\ y_t^w + (\beta + \theta z) E_t \pi_{t+1}^w + \theta z \sigma E_t y_{t+1}^w + \theta z \sigma u_t^w + \varepsilon_t^w. \tag{20}$$

The MPC curve depicts all combinations of inflation and output, which can be chosen by the central bank by varying the interest rate. The MPC curve is positively sloped for a dominant demand channel, $\sigma + \gamma - \sigma z > 0$, and negatively sloped for a dominant cost channel (see Figure 1 below). If there is no cost channel ($z = 0$), the MPC curve coincides with the PC curve. For $z > 0$, MPC is flatter than PC.

The optimal policy plan consists of maximising (16) with respect to y_t^w, π_t^w and the interest rate R_t, subject to the sequence of constraints given by the aggregate demand curve (18) and the aggregate Phillips curve (19). Rearranging the first-order conditions gives the inflation targeting rule:

$$\pi_t^w = -\frac{\phi_y}{\theta\phi_\pi(\sigma + \gamma - \sigma z)} y_t^w. \tag{21}$$

Depending on the strength of the cost channel, the optimal policy ends up with inflation and output gaps which are of equal sign (dominant cost channel, $\sigma + \gamma - \sigma z < 0$) or of different sign (dominant demand channel, $\sigma + \gamma - \sigma z > 0$). We will pick up this result in section 4, where the optimal policy plan will be discussed in more detail.

In the presence of a cost channel, the determinacy (and stability) of the equilibrium deserves particular attention, see Surico (2008). In order to describe the behaviour of the union inflation gap, we write (21) at period $t+1$, take expectations and substitute into (20) to eliminate current and expected output. The path of π_t^w is then given by the following expectational difference equation:

$$\pi_t^w = \frac{(\beta + \theta z)\phi_y - \sigma\theta z A}{N_0} E_t \pi_{t+1}^w + \frac{\phi_y \theta z \sigma}{N_0} u_t^w + \frac{\phi_y}{N_0} \varepsilon_t^w, \tag{22}$$

with $A \equiv \theta\phi_\pi(\sigma + \gamma - \sigma z)$ and $N_0 \equiv \phi_y + \theta^2\phi_\pi(\sigma + \gamma - \sigma z)^2 > 0$. Equilibrium determinacy requires the coefficient $\left[(\beta + \theta z)\phi_y - \sigma\theta z A\right]/N_0$ to be less than one. As necessary and sufficient condition for a unique rational expectations equilibrium we get

$$z < \frac{(1-\beta)\phi_y + \theta^2\phi_\pi(\sigma + \gamma)^2}{\theta\left[\phi_y + \sigma\theta\phi_\pi(\sigma + \gamma)\right]}. \tag{23}$$

If the parameter z is smaller than the threshold (23), the union inflation gap returns to its pre-shock steady state value. If the strength of the cost channel, however, exceeds the threshold (23), a demand and/or supply shock sets into motion an unstable process for the union inflation and output gap. In the absence of a cost channel ($z = 0$), the determinacy condition is unambigously fulfilled.

A dominant cost channel is consistent with equilibrium determinacy, if the parameter for the strength of the cost channel lies within the following interval:

$$\frac{\sigma + \gamma}{\sigma} < z < \frac{(1-\beta)\phi_y + \theta^2\phi_\pi(\sigma + \gamma)^2}{\theta\left[\phi_y + \sigma\theta\phi_\pi(\sigma + \gamma)\right]}.$$

If the degree of price stickiness is high, that is, if $\theta < \frac{\sigma(1-\beta)}{\sigma+\gamma}$, then the interval is not empty.

3.2 The Difference Bloc

In this subsection, the analysis is focussed on the differential behaviour of the two countries which make up the monetary union. In particular, output and inflation differentials are considered to measure relative macroeconomic performance. From (6) and (7), we can write relative output as

$$y_t^R = q_t + u_t^R. \tag{24}$$

The nominal interest rate vanishes, i.e. a change in R_t affects aggregate demand but not the distribution of demand between Home and Foreign. Exactly the opposite is true for the terms of trade, a change in q_t does affect only the output differential but not the aggregate. In particular, the larger is q_t, the larger is the expenditure effect towards Home goods, and thus the larger is the output differential.

Using the Phillips curves (14) and (15), we obtain for the inflation differential

$$\pi_t^R = \beta E_t \pi_{t+1}^R + \theta(1-\sigma)q_t + \theta(\sigma+\gamma)y_t^R + \varepsilon_t^R. \tag{25}$$

The current inflation differential depends on its expected value next period and the current output differential. Moreover, a rise in the terms of trade causes the rate of Home consumer inflation to rise. To avoid an erosion of the real wage in terms of consumer prices, wage setters raise the wage. Home firms respond with an increase in the price of their output generating a positive inflation differential. The interest rate does not matter, relative output and relative inflation are insulated from monetary policy.

The terms of trade evolve according to

$$q_t = q_{t-1} - \pi_t^R. \tag{26}$$

The current period terms of trade is a function of its past value, thus the past level of the terms of trade is a state variable. As a consequence, neither the inflation rates nor output jump to their new steady state level after a shock, but converge gradually to the new equilibrium.

Using (24), (25) and (26), the relative bloc can be written as expectational difference equation :

$$y_t^R = a_0\left[E_t y_{t+1}^R - E_t u_{t+1}^R\right] + a_1\left[y_{t-1}^R - u_{t-1}^R - \varepsilon_t^R\right] + a_2 u_t^R,$$

where a_0, a_1 and a_2 are positive constants as defined in the Appendix. The difference bloc is stable. Neither the output nor the inflation differential explodes.

4 Optimal Monetary Policy

In this section, we investigate the optimal monetary response to demand and supply shocks. We will distinguish between aggregate shocks, (perfectly) asymmetric shocks and idiosyncratic shocks.

4.1 Demand Shocks

In this subsection our focus will be on shocks in product demand. The aggregate and the difference bloc can be solved separately. Setting $\varepsilon_t^H = \varepsilon_t^F = 0$, that is, turning off supply shocks, the solution is summarised in Table 1.

Table 1

$$y_t^w = -\frac{z\sigma\theta^2\phi_\pi(\sigma+\gamma-\sigma z)}{N_1}u_t^w \tag{T1}$$

$$\pi_t^w = \frac{z\sigma\theta\phi_y}{N_1}u_t^w \tag{T2}$$

$$R_t = \frac{\sigma}{N_1}\left[\phi_y(1-\beta\rho_u)+\theta(\sigma+\gamma)A\right]u_t^w \tag{T3}$$

$$y_t^R = \lambda_1(y_{t-1}^R - u_{t-1}^R) + Bu_t^R \tag{T4}$$

$$\pi_t^R = (1-\lambda_1)q_{t-1} + Cu_t^R \tag{T5}$$

$$q_t = \lambda_1 q_{t-1} - Cu_t^R \tag{T6}$$

$$y_t^H = (1-n)\lambda_1(y_{t-1}^R - u_{t-1}^R) + \left[(1-n)B - n\frac{z\sigma\theta A}{N_1}\right]u_t^H - (1-n)\left[B + \frac{z\sigma\theta A}{N_1}\right]u_t^F \tag{T7}$$

$$\pi_t^H = (1-n)\left[\lambda_1\pi_{t-1}^R - Cu_{t-1}^R\right] + \left[nzG + (1-n)C\right]u_t^H + (1-n)\left[zG - C\right]u_t^F \tag{T8}$$

$$y_t^F = -n\lambda_1(y_{t-1}^R - u_{t-1}^R) - n\left[B + \frac{z\sigma\theta A}{N_1}\right]u_t^H + \left[nB - (1-n)\frac{z\sigma\theta A}{N_1}\right]u_t^F \tag{T9}$$

$$\pi_t^F = -n\lambda_1\pi_{t-1}^R + nCu_{t-1}^R + n\left[zG - C\right]u_t^H + \left[(1-n)zG + nC\right]u_t^F \tag{T10}$$

The coefficients are defined in the Appendix. Note that the derivation of the

national variables (T7) - (T10) makes use of the fact that Home and Foreign variables can be expressed as $X_t^H = X_t^w + (1-n)X_t^R$ and $X_t^F = X_t^w - nX_t^R$, respectively.

Aggregate Shocks

Assume a positive aggregate demand shock: $u_t^H = u_t^F > 0$. For $z = 0$, our model replicates a well-known result: $y_t^w = \pi_t^w = 0$. An aggregate demand shock will be offset by varying the interest rate. The interest rate necessary to bring back inflation to target is identical with the interest rate necessary to close the output gap. There is no trade-off between the inflation and the output target (see Clarida et al., 1999). This "textbook" solution, however, does not hold in the presence of a cost channel. The cost channel drives a wedge between the output and the inflation target.

For $z > 0$, the sign of the output gap depends on the strength of the cost channel. If the demand channel dominates, $\sigma+\gamma-\sigma z > 0$, we have $y_t^w < 0$; if the cost channel dominates, $\sigma+\gamma-\sigma z < 0$, we have $y_t^w > 0$, see (T1). The inflation gap does not switch the sign, π_t^w will be positive for all parameter constellations, see (T2). Figure 1 illustrates. The demand and the supply side are captured by the vertical IS-curve and the positively sloped PC-curve, respectively. Point A is the deterministic (pre-shock) steady state with $y_t^w = 0$ and $\pi_t^w = 0$. Point A also represents the welfare-maximising (loss-minimising) combination of y_t^w and π_t^w. The indifference curves (combinations of y_t^w and π_t^w with equal loss) are ellipses with the centerpoint A. The smaller the distance to point A, the smaller is the loss.

Figure 1 about here

The aggregate demand shock shifts the IS-curve to the right (point B). Thus, positive output and inflation gaps emerge, and welfare declines. The optimal response of the central bank depends on z. We assume that, at first, the demand channel will dominate. To improve welfare, the central bank raises the interest rate, see (T3). Contrary to a world without a cost channel, where the central bank can choose between all points on the PC curve, the monetary authority is now confronted with a Monetary Policy Curve MPC. As mentioned above, the MPC curve depicts all combinations of inflation gap and output gap, which are feasible for the central bank. For a low value of z, the MPC curve is positively sloped. Starting from point B, the increase in the interest rate moves the economy along the MPC (z low) curve. Closing the output gap leads to point C, while closing the inflation gap leads to point D. But neither C nor D are optimal. The optimal monetary policy plan is given by point E, where an indifference curve is tangent to MPC. Since the cost channel makes monetary policy less effective in combating inflation, the central bank accepts a positive inflation gap. The optimal inflation rate is lower than the inflation rate at point C, so that the increase in the interest rate is larger than the increase necessary to close the output gap. Consequently, a negative output gap emerges as part of the optimal policy plan. The welfare-maximising increase in the interest rate is magnified by the cost channel, so that the cost channel will make the optimal monetary policy more aggressive.

Supposing that the cost channel dominates, the interest rate will turn from a demand into a supply side instrument. Graphically, the MPC curve exhibits a negative slope. The sign of the change in the interest rate is ambiguous now. If point B is the point of tangency between an indifference curve and MPC (z high), the optimal monetary response is to do nothing. If the tangent point lies to the northwest of point B, it is optimal to increase the interest rate. This lowers the output gap, but widens the inflation gap. Point F is the most "unorthodox", as this is where the optimal inflation-output combination lies to the southeast of point B. Then it is optimal to reduce the interest rate. The positive demand shock will be reinforced, but due to the strong cost effect, it is most effective to reduce inflation via a lower interest rate.

Asymmetric and Idiosyncratic Shocks

A perfect asymmetric demand shock, defined as $u_t^H = -u_t^F$, maximises the output and the inflation differentials, and thus the sum of national losses. Union output and union inflation, however, remain unaltered. A perfect asymmetric shock does not provoke any policy response, u_t^R does not enter into the optimal interest rate rule (T3). The central bank may recognise the losses at the national level, but due to the assumed symmetry in the transmission process, the central bank can not affect country differentials. The optimal policy is to do nothing (see Lane, 2000). It should be clear that the "do nothing"-result does not hold in a world where the strength of the cost channel is country-specific.

National (idiosyncratic) shocks affect both aggregate and relative demand. Take, for instance, an unexpected increase in Foreign government spending: $u_t^F > 0$ and $u_t^H = 0$. Such a shock will increase aggregate demand ($u_t^w > 0$), whereas relative demand decreases, $u_t^R = u_t^H - u_t^F < 0$. On impact Foreign output as well as Foreign inflation will increase. This in turn will raise demand for Home goods for two reasons. Firstly, a higher Foreign income pushes up demand for Home goods. Secondly, Foreign inflation implies a deterioration of its terms of trade, and demand switches from Foreign to Home. Now the monetary authority comes into action. Let us start with the case $z = 0$. The loss-minimising response to the increase in aggregate demand is a rise in the interest rate causing households to shift consumption from the current period into the future. Current consumption will then fall in Home and Foreign.

For $z = 0$, the decline in aggregate consumption neutralises the positive demand shock, aggregate demand declines to the pre-shock level. From Foreign's point of view, there are three effects, the positive government spending shock, the decline in consumption demand due to the upward shift in the interest rate, and the negative expenditure switching effect due to the deterioration of the terms of trade. As indicated by (T9), the net effect is always positive. In terms of Foreign output, the increase in the interest rate and the worsening of the terms of trade only mitigate the positive government spending shock. The optimal monetary policy does not reverse the sign of the impact effect, the Foreign output gap remains positive. The same holds true for the Foreign inflation gap, see (T10).

In the presence of a cost channel, the results are less clear-cut. Assuming that the demand channel outweighs the cost channel, $\sigma + \gamma - \sigma z > 0$, then, compared to the case $z = 0$, the increase in the interest rate is even stronger, and the optimal policy plan will now require a negative union output gap, see (T1). As a consequence, consumption declines even more, which may turn the response of Foreign output negative. This can be seen from (T9), where the sign of $\left[nB - (1-n)\frac{z\sigma\theta A}{N_1}\right]$ is ambiguous. The cost channel magnifies the pressure on Foreign inflation. As can be seen from (T10), the strength of the inflation effect is increasing in the strength of the cost channel.

How do the spillover effects on Home output and inflation look like? The improvement of Home's terms of trade implies a demand switch from Foreign to Home. On the other hand, the optimal monetary policy requires an increase in the interest rate which will lower consumption demand. The net effect on Home output is unambiguously negative, that is, the increase in the interest rate lowers the demand for Home goods more than the increase in Home exports to Foreign. This result, which holds true even for $z = 0$ (see (T7)), immediately follows from the definition of union output as the weighted average of the national outputs. The optimal monetary policy closes the output gap at the union level ($z = 0$), the Foreign output gap remains positive, therefore the Home output gap must be negative. The Home inflation gap will be negative too, see (T8). If there is a cost channel, the central bank acts even more aggressively, the interest rate hike will be larger, and Home consumption and thus Home output will decline even more, see (T7). An expansionary demand shock in Foreign, combined with the optimal monetary policy, thus generates a negative spillover on Home, Home output goes down. However, due to the inflationary pressure of the cost channel, the sign of the Home inflation gap will now be ambiguous. Depending on the parameter constellation the coefficient $[zG - C]$ may be positive, zero or negative, see (T8).

Finally, let us have a closer look at the case of a dominating cost channel, $\sigma + \gamma - \sigma z < 0$. Depending on the parameter constellation, the optimal monetary policy will be an increase or a cut in the interest rate (see (T3), where A is negative now). Either way, at the union level the output and the inflation gap will remain positive. Since monetary policy is less aggressive, the decline in Foreign consumption does not outweigh the positive demand shock, Foreign output increases unambiguously, see (T9). The spillover on Home output may now become positive, see (T7).

4.2 Supply Shocks

In this subsection we will discuss the optimal monetary response to negative cost-push shocks ($\varepsilon_t^w > 0$) and/or favorable technology shocks ($\varepsilon_t^w < 0$). Again, we distinguish between aggregate shocks, (perfectly) asymmetric shocks and idiosyncratic shocks. The demand shocks are now assumed to be zero: $u_t^H = u_t^F = 0$. Our main results are summarised in Table 2.

Table 2

$$y_t^w = -\frac{A}{N_2(z)}\varepsilon_t^w \tag{T11}$$

$$\pi_t^w = \frac{\phi_y}{N_2(z)}\varepsilon_t^w \tag{T12}$$

$$R_t = \frac{1}{N_2(z)}\left[\phi_y\rho_\varepsilon + \rho A(1-\rho_\varepsilon)\right]\varepsilon_t^w \tag{T13}$$

$$y_t^R = \lambda_1 y_{t-1}^R - K\varepsilon_t^R \tag{T14}$$

$$\pi_t^R = \lambda_1\pi_{t-1}^R - K\varepsilon_{t-1}^R + K\varepsilon_t^R \tag{T15}$$

$$q_t = \lambda_1 q_{t-1} - K\varepsilon_t^R \tag{T16}$$

$$y_t^H = (1-n)\lambda_1 y_{t-1}^R - \left[n\frac{A}{N_2(z)} + (1-n)K\right]\varepsilon_t^H + (1-n)\left[K - \frac{A}{N_2(z)}\right]\varepsilon_t^F \tag{T17}$$

$$\pi_t^H = (1-n)\lambda_1\pi_{t-1}^R + \left[n\frac{\phi_y}{N_2(z)} - (1-n)K\right]\varepsilon_t^H + (1-n)\left[\frac{\phi_y}{N_2(z)} + K\right]\varepsilon_t^F \tag{T18}$$

$$y_t^F = -n\lambda_1 y_{t-1}^R + \left[K - \frac{A}{N_2(z)}\right]\varepsilon_t^H - \left[(1-n)\frac{A}{N_2(z)} + nK\right]\varepsilon_t^F \tag{T19}$$

$$\pi_t^F = -n\lambda_1\pi_{t-1}^R + n\left[\frac{\phi_y}{N_2(z)} + K\right]\varepsilon_t^H + \left[(1-n)\frac{\phi_y}{N_2(z)} - nK\right]\varepsilon_t^F \tag{T20}$$

where K and $N_2(z)$ are defined in the Appendix. Note that $\frac{\partial A}{\partial z} < 0$ and $\frac{\partial N_2}{\partial z} < 0$.

Aggregate Shocks

An aggregate cost-push shock ($\varepsilon_t^H = \varepsilon_t^F = \varepsilon_t^w > 0$) shifts the Phillips curve upwards. On impact, a union inflation gap emerges, whereas union output remains unaltered. In Figure 2, the economy moves from the starting point A to point B with utility level u_B. A cost-push or productivity shock drives a wedge between the output and the inflation target even in the absence of a cost channel. For $z = 0$ the central bank chooses the welfare-maximising point on the shifted PC curve (point C). The optimal policy is an increase in the interest rate, see (T13), so mitigating the inflationary effect of the cost-push. But there will be no full accomodation. Because of a negative output gap (see (T11)) the optimal monetary policy will tolerate an inflation rate above the target, see (T12).

For $0 < z < (\sigma + \gamma)/\sigma$ the trade off between inflation and output worsens. A given increase in the interest rate and thus a given decline in output is now accompanied by a higher inflation rate. In Figure 2 the monetary policy curve MPC, representing all feasible combinations of union inflation and output, is flatter than the PC curve (but still positively sloped). Point C with utility level u_C is no longer available, the new equilibrium point D with $u_D < u_C$ lies to the northwest of point C. The cost channel makes monetary policy less effective in combatting inflation, but the optimal response to the decline in effectiveness is a stronger use of the instrument.

For a strong cost channel, $z > (\sigma+\gamma)/\sigma$, MPC is negatively sloped. Now it is optimal to respond to a cost push with a decline in the interest rate. The IS curve shifts to the right, the PC curve shifts down, the loss-minimising combination of π_t^w and y_t^w lies to the south-east of point B (and to the north-east of the starting point A).

Figure 2 about here

Asymmetric and Idiosyncratic Shocks

A perfect asymmetric cost-push shock ($\varepsilon_t^H = -\varepsilon_t^F$) very much resembles a perfect asymmetric demand shock. The optimal monetary policy is to do nothing, the relative supply shock ε_t^R does not enter into the interest rate rule (T13). As mentioned by Lane (2000), such a policy generates large fluctuations in output and inflation in the member countries, even if union-wide aggregate output and inflation display zero volatility.

A national cost-push shock affects aggregate inflation and the inflation differential. Suppose that Home trade unions successfully bargain for a higher wage ($\varepsilon_t^H > 0$ and $\varepsilon_t^F = 0$). Home producer price inflation goes up, so does union inflation. Since Home's terms of trade deteriorate, consumers switch from Home to Foreign goods, y_t^H decreases, y_t^F increases. The decline in the demand for Home goods mitigates the impact effect of a higher ε_t^H on π_t^H, the higher demand for Foreign goods causes Foreign inflation to rise. The optimal response of the central bank to the idiosyncratic cost shock is parameter dependent, see (T13). A dominating demand channel, $\sigma + \gamma - \sigma z > 0$, is sufficient for a rise in the interest rate lowering the demand for both Home and Foreign goods. The overall effect on Home output is negative (see (T17)), the overall effect on Home inflation is ambiguous (see (T18)). As indicated by (T19), the net effect on Foreign output depends on the parameter constellation, all three signs are possible. Foreign inflation unambiguously increases, see (T20).

For a strong cost channel, the optimal response to the increase in aggregate inflation is a decline in the interest rate. The change in Home output is ambiguous now, the decline in the interest rate countervails the terms of trade effect.

Concerning Foreign output the terms of trade effect and the interest rate decline reinforce each other, Foreign output goes up, see (T19).

5 Conclusions

This paper investigates the conduct of optimal monetary policy in the presence of a cost channel of monetary transmission. The framework is a two-country New Keynesian model, where these countries constitute a currency union with a single central bank. The existence of a cost channel implies that a change in the interest rate now affects both the demand- and the supply-side of the economies. There is now a meaningful trade-off between stabilising union inflation and stabilising the union output gap. It is shown that the optimal response to aggregate, asymmetric and idiosyncratic shocks very much depends on the strength of the cost channel. The cost channel makes monetary policy less effective in combatting inflation, but the optimal response to the decline in effectiveness is a stronger use of the instrument. For a strong cost channel the interest rate turns into a supply-side instrument. In order to reduce inflation, a direct cut in marginal costs is more effective than a decline in marginal costs via lower aggregate demand. An analogous result holds for an aggregate cost-push shock. For perfect asymmetric shocks we replicate the "do nothing"-result of Lane (2000). Despite the distribution of inflation, production and employment varies across countries with the relative strength of the cost channel, the monetary authority does not react to this kind of shocks. Finally, we derive the optimal response to idiosyncratic shocks. We show how the sign and size of the spillover effects depend on the strength of the cost channel.

The model developed in this paper is a very simple one. It can be extended in different directions. These include: (i) allowing for country-specific cost channels; (ii) introducing national fiscal authorities which maximise national welfare; and (iii) modelling the interactions with the rest of the world.

Appendix: Parameter definitions

$$a_0 \equiv \frac{\beta}{1+\beta+\theta(1+\gamma)}, \quad a_1 \equiv \frac{1}{1+\beta+\theta(1+\gamma)}; \quad a_2 \equiv \frac{1+\beta+\theta(1-\sigma)}{1+\beta+\theta(1+\gamma)}$$

$$N_1(z) \equiv \phi_y - \phi_y(\beta+\theta z)\rho_u + \theta A(\sigma+\gamma-\sigma z+\sigma z\rho_u) > 0;$$

$$N_2(z) \equiv \phi_y - \phi_y(\beta+\theta z)\rho_\varepsilon + \theta A(\sigma+\gamma-\sigma z+\sigma z\rho_\varepsilon) > 0$$

$$B \equiv \frac{1+\beta(1-\lambda_1-\rho_u)+\theta(1-\sigma)}{\beta(\lambda_2-\rho_u)} > 0; \qquad C \equiv \frac{\theta(\sigma+\gamma)}{\beta(\lambda_2-\rho_u)} > 0;$$

$$G \equiv \frac{\sigma\theta\phi_y}{N_1} > 0; \qquad K \equiv \frac{1}{\beta(\lambda_2 - \rho_\varepsilon)} > 0.$$

$$0 < \lambda_1 = \frac{1}{2a_0} - \frac{1}{2a_0}\sqrt{1 - 4a_0 a_1} < 1; \qquad \lambda_2 = \frac{1}{2a_0} + \frac{1}{2a_0}\sqrt{1 - 4a_0 a_1} > 1$$

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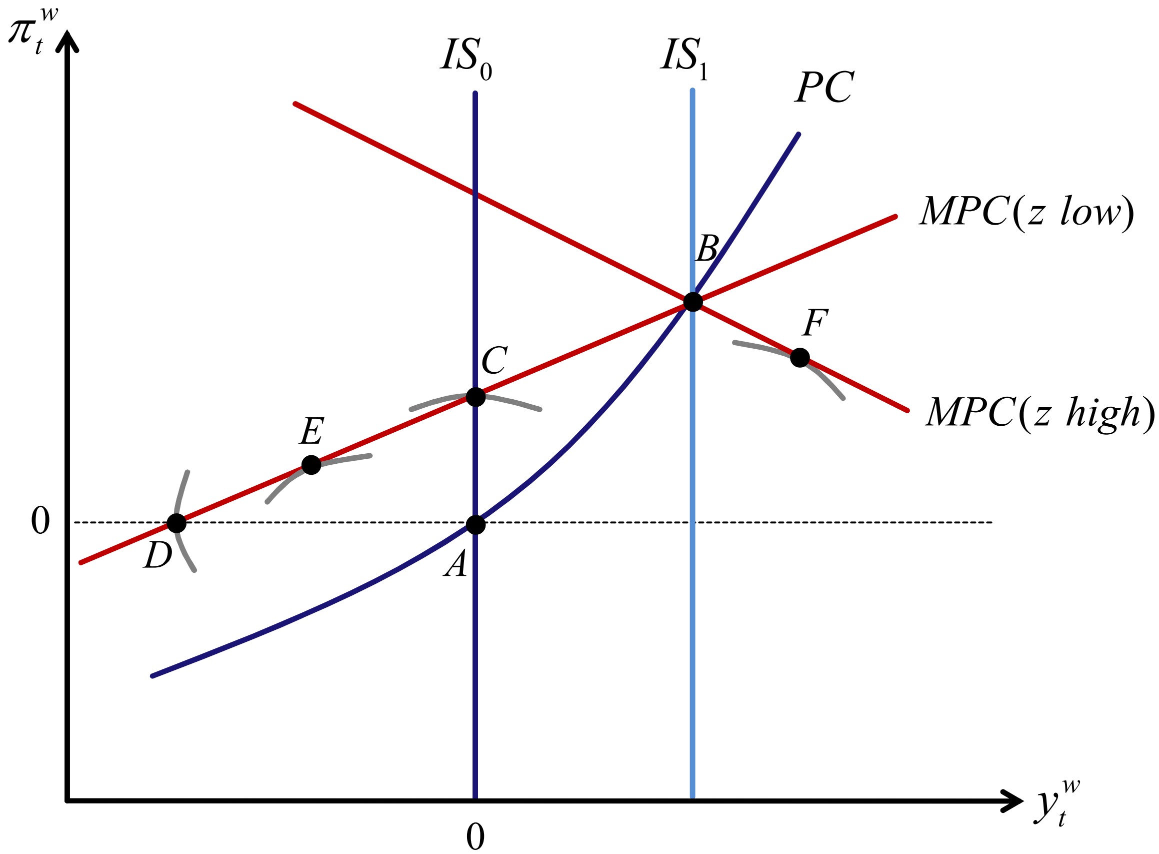

Figure 1

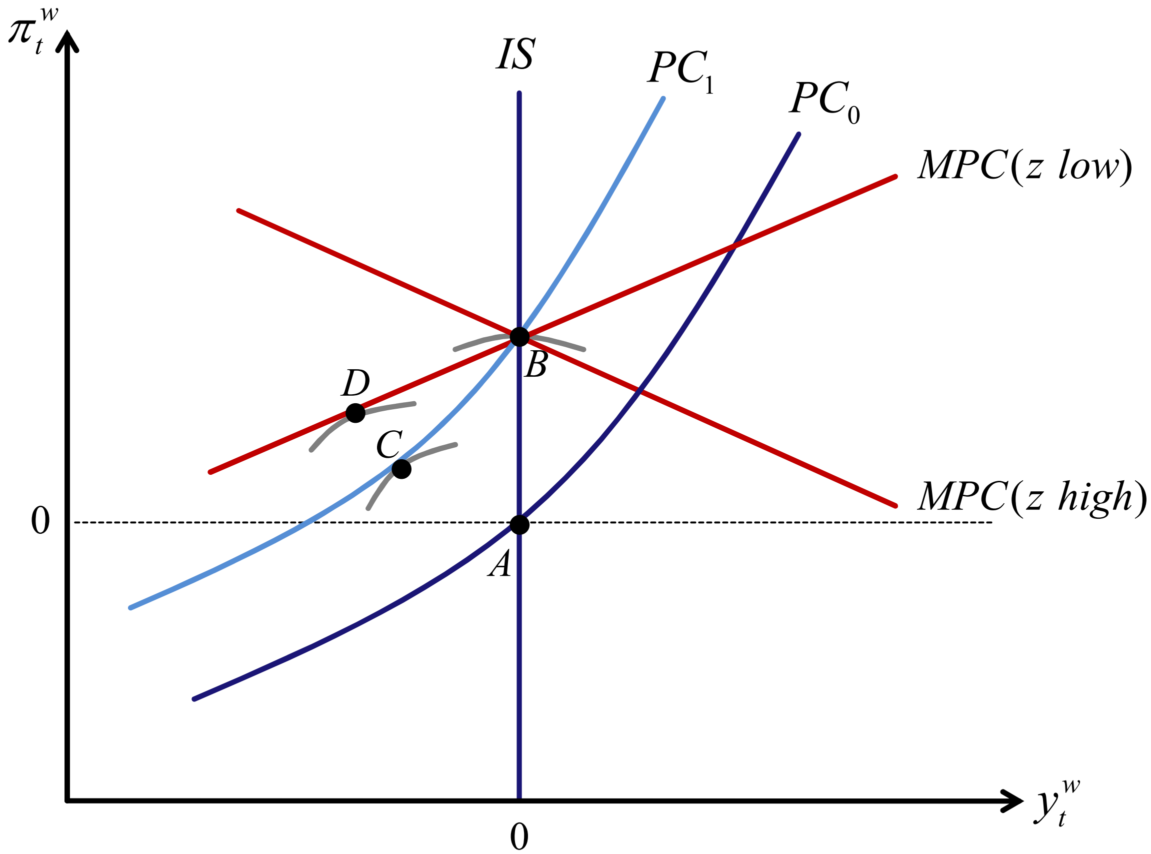

Figure 2