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Teaching New Keynesian Open Economy Macroeconomics at the Intermediate Level

Peter Bofinger, Eric Mayer, and
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Abstract: For the open economy, the workhorse model in intermediate textbooks still is the Mundell-Fleming model, which basically extends the investment and savings, liquidity preference and money supply (IS-LM) model to open economy problems. The authors present a simple New Keynesian model of the open economy that introduces open economy considerations into the closed economy consensus version and that still allows for a simple and comprehensible analytical and graphical treatment. Above all, their model provides an efficient tool kit for the discussion of the costs and benefits of fixed and flexible exchange rates, which also was at the core of the Mundell-Fleming model.

Keywords: inflation targeting, monetary policy rules, New Keynesian macroeconomics, open economy
JEL codes: A20, E10, E50, F41

In recent years, a range of papers has been published trying to present an alternative intermediate macroeconomic textbook model to the outdated investment and savings, liquidity preference and money supply, aggregate supply, aggregate demand (IS-LM-AS-AD) model. Among them the most influential have been the monetary policy (IS-MP)-inflation adjustment (IA) model by Romer (2000), the inflation-targeting model by Walsh (2002), the AD-price adjustment (PA) model by Weerapana (2003), the Phillips curve (IS-PC)-monetary-policy rule (MR) model by Carlin and Soskice (2004), and the Bofinger, Mayer, and Wollmershäuser (BMW) model (2006). As is the case for the class of dynamic New Keynesian (NK) macro models popularized by Clarida, Gali, and Gertler (1999), the foundation of each of these models is an IS equation that links the output gap to the real interest rate, a PC that relates the inflation rate to the output gap, and an MR that is evaluated in terms of or derived from a social loss function. Although the IS equation has survived the NK revolution (even though it is now derived from solid micro foundations), the

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major innovations with respect to the IS-LM-AS-AD model are that (a) monetary policy is described by an interest-rate rule (instead of a money-supply rule), (b) inflation enters the model (instead of the price level), and (c) the supply side of the economy is summarized by a PC (instead of the inconsistent AS apparatus).

For the open economy, the workhorse model in intermediate textbooks is still the Mundell-Fleming (MF) model, which basically extends the IS-LM model to open economy problems. Our purpose is to present a simple NK model of the open economy that introduces open economy considerations into the closed economy consensus version and that still allows for a simple and comprehensible analytical and graphical treatment. Typically, NK Open Economy Macroeconomics (NOEM) is based on dynamic micro-founded models that feature rational expectations, optimizing agents, and sticky price adjustment. Obstfeld and Rogoff (1995, 1996) have published pioneering work in the area, and other contributions include those by McCallum and Nelson (1999, 2000), Betts and Devereux (2000, 2001), Corsetti and Pesenti (2001), Kollmann (2001), Smets and Wouters (2002), and Galí and Monacelli (2005). We try to carry over the major innovations of these models into a simple static framework that enables us to discuss modern monetary policy issues. Above all, our model provides an efficient tool kit for the discussion of the costs and benefits of fixed and flexible exchange rates, which is also at the core of the MF model.

BASIC NEW KEYNESIAN OPEN ECONOMY MODEL

The demand side of the model is described by the IS equation. It relates the output gap (y) to the real interest rate (r), which is under the control of the central bank, and to (the log of) the real exchange rate q:[1]

$$y = a - br + cq + \varepsilon_1, \tag{1}$$

where a, b, and c are positive structural parameters of the open economy, and ε_1 is a demand shock. The parameter a reflects the fact that there may be positive neutral values of r. The interest rate elasticity b and the exchange rate elasticity c take values smaller than one. Equation (1) corresponds to the reduced form of the resource constraint in an open economy with a fixed capital stock of the NOEM model laid out by McCallum and Nelson (1999, 2000). A specific feature of their model is that output is only consumed or exported, whereas imports are not treated as finished consumer goods but as material inputs to the production process for domestically produced goods.[2] Consumption is defined by a dynamic and forward-looking log-linearized first-order condition of the household sector, which—under the assumption of uncorrelated preference shocks ε_1—can be approximated by a static and linear relationship between consumption and the real interest rate (Bofinger, Mayer, and Wollmershäuser 2003). Exports depend linearly on the real exchange rate and the foreign output gap. Because the economy under consideration is modeled as a small open economy, it is assumed to have no impact on the rest of the world. Thus, the foreign output gap is exogenous and, for simplicity, equal to zero. The latter implies that foreign real interest rates vary over time; they are assumed to capture all foreign shocks. Note that when c is equal to zero, equation (1) corresponds to the closed economy version of the IS curve, which is identical with a static approximation of the consumption Euler equation.

The second building block of the open economy macro model is the uncovered interest parity condition (UIP):

$$\Delta s^e + \alpha = i - i^*, \tag{2}$$

which can be regarded as the optimizing households' consolidated first-order condition, with respect to domestic and foreign bonds (McCallum and Nelson 1999, 2000). According to equation (2), the differential between domestic i and foreign i^* nominal interest rates has to be equal to the expected percentage rate of nominal depreciation Δs^e and a stochastic risk premium α. If UIP holds, households are indifferent between investing in domestic and foreign assets.

The third building block encompasses the supply side of the model and determines the open economy's inflation rate. Here we differentiate between two polar cases. In the first case, which represents a long-run perspective, the domestic inflation rate is completely determined by the foreign inflation rate expressed in domestic currency terms π^f, and hence by relative purchasing power parity (PPP):

$$\pi = \pi^f = \pi^* + \Delta s. \tag{3}$$

Because it is a long-run perspective, we do not include a shock term. Thus, the domestic inflation rate equals the foreign inflation rate π^* plus the nominal depreciation of the domestic currency Δs. In other words, we assume that the real exchange rate remains constant at its long-run level ($q_0 = 0$) as changes in the real exchange rate, which are defined by $\Delta q \equiv \Delta s + \pi^* - \pi$, are equal to zero.[3]

In the second case, we adopt a short-run perspective. The domestic inflation rate is assumed to fluctuate around the central bank's (credible) inflation target π_0 in response to cyclical movements y and supply shocks ε_2:

$$\pi = \pi_0 + dy + \varepsilon_2, \tag{4}$$

where $d > 0$. This PC relationship results from the solution to the inter-temporal profit maximization problem of firms that are monopolistically competitive and that set prices in a staggered fashion. McCallum and Nelson (1999, 2000) showed that under the assumption that imports do not enter consumption but are used entirely as intermediate inputs, there is no distinction between domestic inflation and consumer price inflation, and no direct exchange rate channel into consumer prices. Thus, the PC is identical with that in a closed economy model. For the static approximation, we assumed that markup shocks ε_2 are uncorrelated, which implies that the expected inflation rate equals the central bank's (credible) inflation target.[4]

MONETARY POLICY UNDER FLEXIBLE EXCHANGE RATES

For a discussion of MP under flexible exchange rates, it is important to decide how the flexible exchange rate is determined. In this section, we discuss three different variants: (a) PPP and UIP hold simultaneously; (b) UIP holds, but deviations from PPP are possible; (c) both UIP and PPP do not hold, and the exchange rate is a pure random variable.

Monetary Policy under Flexible Exchange Rates if PPP and UIP Hold Simultaneously (Long-Run Scenario)

As it is well known that PPP does not hold in the short term, the first case can mainly be regarded as a long-run perspective. Relative PPP implies that the real exchange remains constant by definition:

$$\Delta q = \Delta s + \pi^* - \pi = 0. \tag{5}$$

For the sake of simplicity, we assume a UIP condition that is perfectly fulfilled and, thus, without a risk premium:

$$\Delta s^e = i - i^*. \tag{6}$$

This expression can be transformed with the help of the Fisher equation:

$$i = r + \pi^e \text{ and } i^* = r^* + \pi^{e*}, \tag{7}$$

and an expectational version of equation (5), $\Delta q^e = \Delta s^e + \pi^{e*} - \pi^e$, into real UIP:

$$\Delta q^e = r - r^*. \tag{8}$$

If relative PPP is fulfilled (and hence, $\Delta q^e = 0$), equation (8) simplifies to

$$r = r^*. \tag{9}$$

Thus, in a world where PPP and UIP hold simultaneously, there is no room for an independent real interest rate policy, even under flexible exchange rates. As the domestic real interest rate has to equal the real interest rate of the foreign (world) economy, the central bank cannot target aggregate demand by means of the real rate.

This does not imply that MP is completely powerless. As equation (7) shows, the central bank can achieve a given real rate (which is determined according to equation [9] by the foreign real interest rate) with different nominal interest rates. Changing nominal interest rates in turn goes along with varying rates of expected nominal depreciation or appreciation of the domestic currency Δs^e, for a given nominal foreign interest rate, equation (6). If i^* and r^* are exogenous, then π^{e*} is exogenous as well, and the chosen (long run) nominal interest rate finally determines the domestic inflation rate via the related expected nominal depreciation and the expectational PPP equation (5). If MP is credible, the expected domestic inflation rate should, on average, be equal to the inflation target set by the central bank.

Thus, the long-run scenario with valid UIP and valid PPP leads to the conclusion that MP has (a) no real interest rate autonomy for targeting aggregate demand, but it has (b) a nominal interest rate autonomy for targeting the inflation rate. This comes rather close to the vision of the proponents of flexible exchange rates in the 1960s, who argued that this arrangement would allow each country an autonomous choice of its inflation rate (Johnson 1972). It can be regarded as an open economy version of the classical dichotomy according to which monetary policy can affect nominal variables only without having an impact on real variables.

Monetary Policy under Flexible Exchange Rates if UIP Holds but Not PPP (Short-Run Scenario)

In our second scenario for flexible exchange rates, we assume that the domestic inflation rate is not affected by the exchange rate. This assumption corresponds with empirical evidence that in the short run the real exchange is rather unstable and mainly determined by the nominal exchange rate (see Figure 1).

Optimal monetary policy under flexible exchange rates. As in the closed economy models, it is assumed that the ultimate goal of MP is to promote welfare. In systems of flexible exchange rates, this goal is usually interpreted in terms of keeping the inflation rate close to the inflation target π_0, which can be freely determined by the central bank or the government, and stabilizing output around its potential. In the literature, it is common practice to summarize these goals by a quadratic loss function:[5]

$$L = (\pi - \pi_0)^2 + \lambda y^2, \tag{10}$$

where λ denotes the central bank's preferences. The intuition behind the quadratic loss function is that positive and negative deviations of target values impose an identical loss on economic agents. Large deviations from target values generate a more than proportional loss. The popularity of the linear quadratic framework also stems from the fact that it is able to deal with different notions of inflation targeting. If the parameter λ, which depicts the weight policymakers attach to stabilizing the output gap compared to stabilizing the inflation rate, is equal

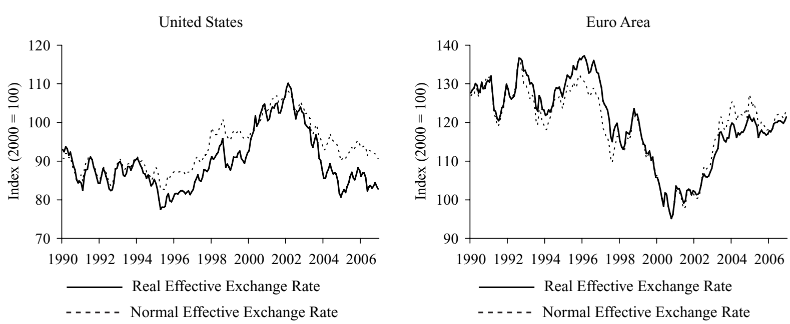

FIGURE 1. Nominal and real exchange rate.
***Source:* International Financial Statistics database of the International Monetary Fund.**

to zero, policymakers only care about inflation. This type of inflation targeting is called strict inflation targeting. If λ is greater than zero, the strategy is called flexible inflation targeting. At the limit, if λ goes to infinity, policymakers only care about output. This preference type is typically referred to as an output junkie.

Given the MP transmission structure of the model, which runs from the real interest rate over economic activity to the inflation rate, optimal monetary policy can be derived by applying the following two-step procedure. First, we insert the PC (4) into the loss function (10). Second, we minimize the modified loss function with respect to y. The solution gives an optimal value of the output gap:

$$y = -\frac{d}{(d^2 + \lambda)}\varepsilon_2. \tag{11}$$

Using a strategy of inflation targeting, one way to conduct MP is to follow an instrument rule (Svensson and Woodford 2005). Such a rule makes the reaction of the instrument of MP depend on all the information available at the time the instrument is set and the structure of the economy. In our framework, the instrument rule can be derived by inserting equation (11) into the IS equation (1) and by solving the resulting expression for r:

$$r^{opt} = \frac{a}{b} + \frac{1}{b}\varepsilon_1 + \frac{d}{b(d^2 + \lambda)}\varepsilon_2 + \frac{c}{b}q. \tag{12}$$

According to this reaction function, the central bank responds to demand and supply shocks (ε_1 and ε_2), which are exogenous to the MP decision as well as to the real exchange rate. In contrast to the domestic shocks, however, the real exchange rate is dependent on the domestic real interest rate. This relationship is given by real UIP, equation (8). Thus, for the case of flexible exchange rates where UIP holds, the real exchange rate in equation (12) has to be substituted.

However, the major problem is to approximate UIP, which prescribes a dynamic and forward-looking law of motion of the exchange rate in a comparative-static model. In accordance with Dornbusch (1986, Part I), we assume that the real exchange rate adjusts to its long-run level q_0 asymptotically, so we write

$$q_{+1} = q_0 + g\,(q - q_0)\,, \quad 0 < g < 1, \tag{13}$$

where q_{+1} is the real exchange rate in the next period and g is a key parameter determining the average speed of adjustment.[6] Combining equation (13) and the real UIP condition (8) (augmented for risk premium shocks α) yields an equation for the real exchange rate in terms of the current real interest rate differential and the risk premium shock:

$$q = q_0 - \frac{1}{1-g}(r - r^* - \alpha). \tag{14}$$

Note that we assumed $\Delta q^e = q_{+1} - q$. Equation (14) shows that a rise in the domestic real interest rate leads to an immediate real appreciation, which then is followed by a gradual depreciation to the initial long-run equilibrium. The higher

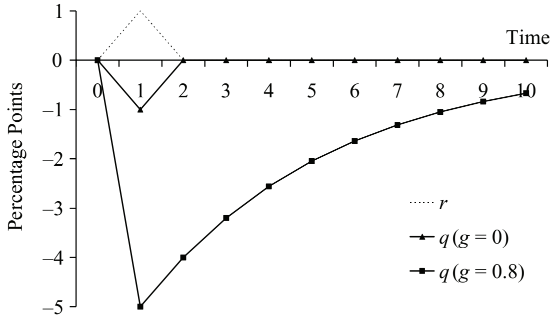

FIGURE 2. The dynamics of the real exchange rate after an increase of the domestic real interest rate. r = real interest rate; q = real exchange rate; g = speed of adjustment.

the parameter g, the lower the speed of adjustment of the real exchange rate and the larger the impact of real interest rate changes on the current real exchange rate. Figure 2 shows the adjustment of the real exchange rate after an increase of the domestic real interest rate by 1 percent for $g = 0$ and $g = 0.8$. In the long run, the real exchange rate is pinned down by absolute PPP, and therefore $q_0 = 0$.

For a comparative-static model, such as the one presented here, it is convenient to set $g = 0$. Equation (14) then simplifies to

$$q = r^* - r + \alpha. \tag{15}$$

Thus, the real exchange rate appreciates in a one-to-one relationship with the domestic real interest rate.

To calculate the optimal interest rate rule of a central bank in a system of flexible exchange rates where UIP holds (with the possibility of risk-premium shocks) while PPP does not hold, we have to insert equation (15) into (12) and solve the resulting equation for r (by assuming that $r = r^{opt}$):

$$r^{opt} = \frac{a}{b+c} + \frac{1}{b+c}\varepsilon_1 + \frac{d}{(b+c)(d^2+\lambda)}\varepsilon_2 + \frac{c}{b+c}(r^* + \alpha). \tag{16}$$

Equation (16) shows that real interest rate has to respond to the following types of shocks: (a) domestic shocks (supply and demand shocks) and (b) international shocks (foreign real interest rate shocks and risk premium shocks). The optimal interest rate response to shocks affecting the demand side (ε_1, α, r^*) does not depend on the central bank's preferences λ. In the case of these shocks, the central bank changes the interest rate in a way that guarantees that the output gap remains closed and that inflation remains at its target level, irrespective of the preference type, equation (11). Thus, as long as shocks solely hit the demand side of the economy, they do not inflict any costs on the society. The reaction of the central

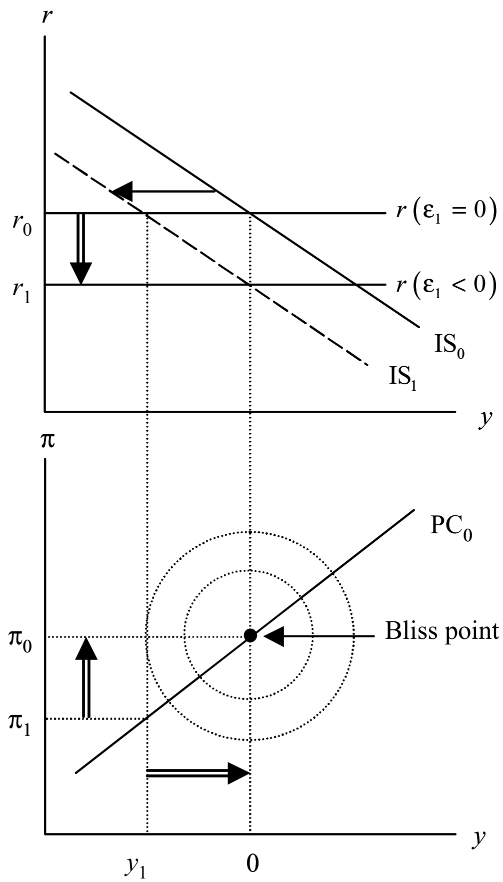

FIGURE 3. Interest rate policy in the case of shocks affecting the demand side. r = real interest rate; y = output gap; π = inflation rate; IS = investment and saving curve; PC = Phillips curve.

bank to supply shocks ε_2 depends on its preferences λ. A central bank that only cares about inflation ($\lambda = 0$) requires a strong real rate response and, accordingly, a large output gap. With an increase in λ, the real interest rate response declines. In equilibrium ($\varepsilon_1 = \varepsilon_2 = \alpha = r^* = 0$) the real interest rate will be given by the neutral real short-term interest rate, $r_0 = a/(b + c)$.

The strategy of inflation targeting under flexible exchange rates can also be presented graphically. In the spirit of the IS-LM-AS-AD approach, the graphical treatment requires two diagrams (see Figure 3). The IS curve and the representation of MP are depicted in the $y - r$ space. The IS curve relates the output gap to the real interest rate and the exogenous shocks affecting the demand side of the economy.

Thus, we have to replace q in equation (1) with equation (15), which leads to a downward sloping curve in the $y - r$ space:

$$y = a - (b + c)r + c(r^* + \alpha) + \varepsilon_1. \tag{17}$$

Note that the slope of the IS curve is flatter in an open economy, $1/(b + c)$, compared with a closed economy $(1/b)$ in which $c = 0$. This implies that an identical increase of the real interest rate has a weaker effect on aggregate demand in a closed economy than in an open economy because, in the latter, interest rate changes are accompanied by an appreciation of the real exchange rate. The instrument rule enters as a horizontal line in the $y - r$ space (marked by $r(\cdot)$, where the dot indicates the shift parameters of the MP line $\varepsilon_1, \varepsilon_2, \alpha$, and r^*). In equilibrium, at the intersection of $r(\varepsilon_1 = \varepsilon_2 = \alpha = r^* = 0) = r_0$ and IS_0, the output gap y is closed. The PC is depicted as an upward-sloping curve in the $y - \pi$ space. If $y = 0$, then inflation is at its target level. For $\lambda = 1$, the loss function of the central bank can be illustrated by circles around a bliss point in the $y - \pi$ space. The bliss point that represents the first best outcome with a loss of zero is defined by an inflation rate π equal to the inflation target π_0 and an output gap of zero. We can derive the geometric form of the circle by transforming the loss function (10) into

$$1 = \left.\frac{(\pi - \pi_0)^2}{(\sqrt{L})^2} + \frac{(y - 0)^2}{(\sqrt{L})^2}\right|_{\lambda=1}, \tag{18}$$

where $(0, \pi_0)$ is the center of the circle and the radius is given by $\sqrt{L}$.[7]

Figure 3 illustrates the interest rate reaction of the central bank in the presence of a negative shock affecting the demand side of the economy. From equation 17, we can see that such shocks have their origin either in the behavior of domestic actors such as the government or consumers ($\varepsilon_1 < 0$), or in the international environment in the form of a change in the foreign real interest rate ($r^* < 0$) or the risk premium ($\alpha < 0$). The latter group of shocks affects domestic demand via the real exchange rate. In the case of a negative shock, the IS curve shifts to the left, resulting in a negative output gap y_1 and a decrease of the inflation rate π_1. As a consequence, the central bank lowers the real interest rate from r_0 to r_1 so that the output gap disappears and, hence, the deviation of the inflation rate from its target.

For the case of a supply shock, Figure 4 shows that the central bank is confronted with a tradeoff between output and inflation stabilization. A positive supply shock ($\varepsilon_2 > 0$) shifts the PC upward. If there is no MP reaction (the real interest rate remains at r_0), the output gap is unaffected, but the inflation rate rises to π_1 (Point B). If, however, the central bank tightens MP by raising the real interest rate to r_1, the output gap becomes negative, and the inflation rate falls back to its target level π_0 (Point A). The optimum combination of y and π depends on the preferences λ of the central bank. If π and y are equally weighted in the loss function, the iso-loss locus is a circle and PC_1 touches the circle at (y_2, π_2). In any case, there is a social cost represented by the positive radius of the iso-loss circle.[8]

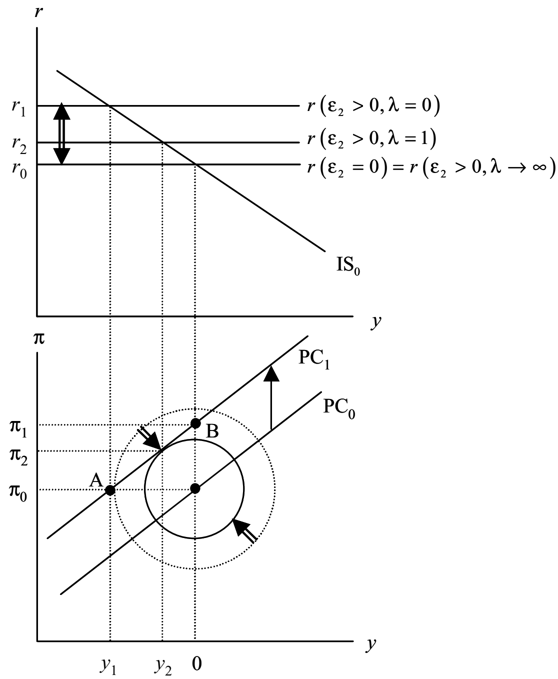

FIGURE 4. Interest rate policy in the case of a supply shock. r = real interest rate; y = output gap; π = inflation rate; IS = investment and saving curve; PC = Phillips curve; ε_2 = supply shock; λ = central bank's preferences for output gap stabilization.

Simple interest rate rules under flexible exchange rates. Instead of relying on all available information, a central bank can also restrict its information to a small subset of directly observable variables. At the heart of simple interest rate rules lies the notion that they are not derived from an optimization problem. Instead, the coefficients are chosen ad hoc, based on the experiences and skills of the monetary policymakers.[9] The most prominent version of a simple rule is the Taylor (1993) rule. According to this rule, the actual real interest rate is defined as the sum of the equilibrium real interest rate r_0 and two additional factors accounting for the actual economic situation that is assumed to be observable by movements in the inflation rate and in the output gap:

$$r = r_0 + e(\pi - \pi_0) + fy. \tag{19}$$

As the two reaction coefficients e and f are assumed to be greater than zero, the Taylor rule can be represented by an upward-sloping MP line in the $y - r$ space (see Figure 5). Although variations of the output gap lead to changes in the

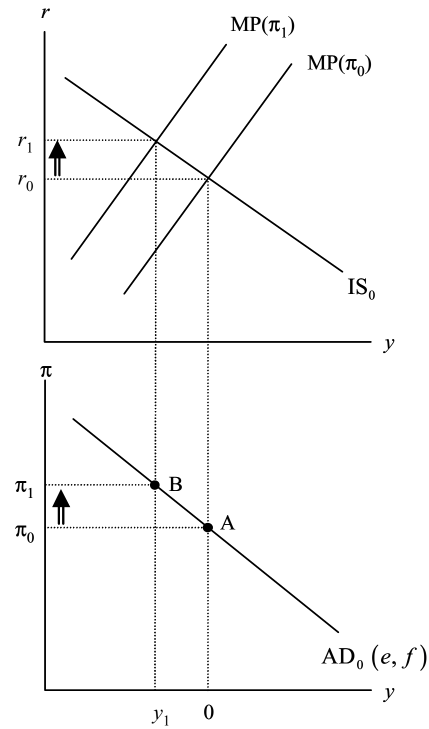

FIGURE 5. Simple instrument rules and the aggregate demand curve. r = real interest rate; y = output gap; π = inflation rate; IS = investment and savings curve; AD = aggregate demand curve; MP = monetary policy line; e, f = parameters of the central bank's reaction function.

real interest rate, which constitute movements along the MP line, the inflation rate represents a shift parameter.

The IS curve is derived in the same way as in the previous section:

$$y = a - (b + c)r + c(r^* + \alpha) + \varepsilon_1. \tag{20}$$

In contrast to the previous section, under simple interest rate rules an explicit construction of an AD curve in the $y - \pi$ space is required, which depends on the simple interest rate rule that is implemented by the central bank. Algebraically, the AD curve can be easily derived by inserting the Taylor rule (19) into the IS curve (20), by replacing r_0 with $a/(b + c)$, and by solving the resulting equation for π:

$$\pi = \pi_0 - \frac{1 + (b + c)f}{(b + c)e} y + \frac{c(r^* + \alpha) + \varepsilon_1}{(b + c)e}. \tag{21}$$

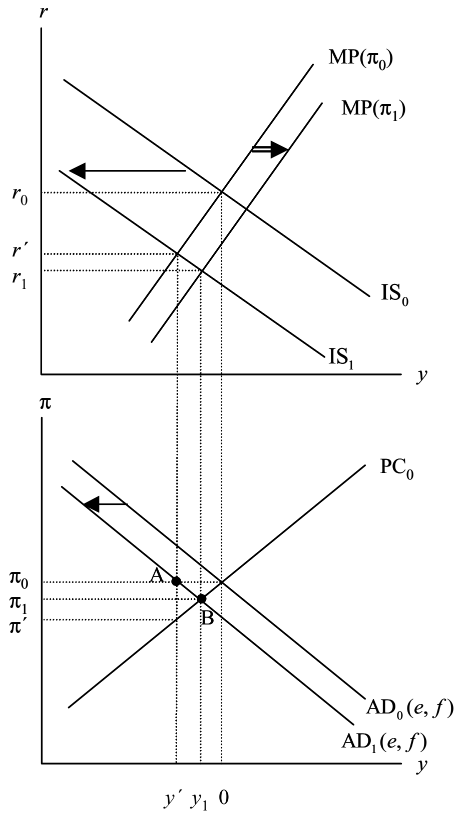

FIGURE 6. Simple rules and shocks affecting the demand side. r = real interest rate; y = output gap; π = inflation rate; IS = investment and saving curve; AD = aggregate demand curve; MP = monetary policy line; PC = Phillips curve; e, f = parameters of the central bank's reaction function.

Graphically, it can be constructed in the same spirit as the aggregate demand curve in the AS-AD model. We start with an MP line for an inflation rate equal to π_0 and an output gap of zero (see Figure 6). This combination of output and inflation gives Point A in the lower panel. Then we derive an MP line for an inflation rate $\pi_1 > \pi_0$. According to the Taylor principle (Taylor 1999), which states that real interest rates should be raised in response to an increase in the inflation rate, this line is associated with higher real interest rates than MP (π_0). Hence, the new equilibrium is characterized by a negative output gap y_1. The combination of y_1 and π_1 gives the Point B in the lower panel. Connecting Point A with Point B results in a downward-sloping aggregate demand curve AD_0.

Because of the downward-sloping AD curve, the graphical analysis of shocks under a Taylor rule is more complex than under optimal MP. If the economy is hit by a negative demand shock, the IS curve in the upper panel of Figure 6 shifts leftward. In response to the decrease of the output gap from 0 to y', the central bank lowers real interest rates—by moving along the MP (π_0) line—from r_0 to r', which leads to the output gap y'. In the lower panel, the AD curve has to shift. Its new locus is determined by the fact that it has to go through a point (A), which is defined by the new output gap y' and the (so far) unchanged inflation rate π_0. The new equilibrium is reached by the intersection of the shifted AD curve with the unchanged PC in Point B. It is characterized by an output decline to y_1 (which is less than y') and an inflation rate π_1. The decline of the output gap from y' to y_1 and the inflation rate to π_1 (instead of π') happens because the central bank additionally reduces the real interest rate, because the Taylor rule requires a lower real rate as a consequence of the decline in the inflation rate.

In the upper panel of Figure 6, this is reflected by a shift of the MP line to the right, which intersects with the IS_1 line at the same output level that results from the intersection of the AD_1 line with the PC in the lower panel. This may sound somewhat difficult, but the mechanics of the shifts are completely identical with the shifts in the IS-LM-AS-AD model in the case of the same shock. Although in our model the decline in inflation implies an expansionary monetary impulse because it lowers the real interest rate, in the IS-LM-AS-AD model the decrease in the price level increases the real money stock, which also has an expansionary effect because it lowers the nominal interest rate.

For a graphical discussion of a supply shock, we only need to consider the $y - \pi$ space (see Figure 7). The PC is shifted upward, which increases the inflation rate to π'. In this case, the Taylor rule requires a higher real interest rate, which leads

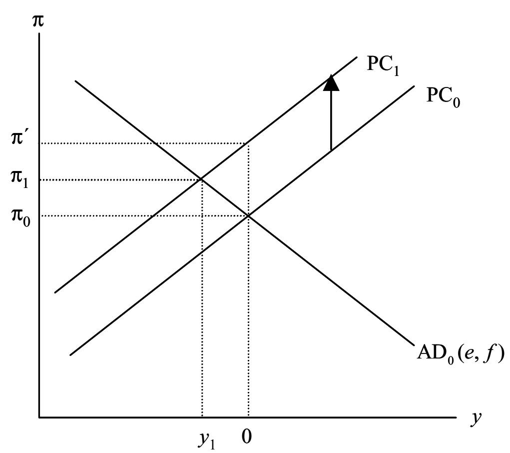

FIGURE 7. Simple rules and supply shocks. y = output gap; π = inflation rate; AD = aggregate demand curve; PC = Phillips curve; e, f = parameters of the central bank's reaction function.

to a negative output gap y_1. The reduced economic activity finally dampens the increase of the inflation rate to π_1.

Monetary Policy under Flexible Exchange Rates that Behave like a Random Walk

One of the main empirical findings on the determinants of exchange rates is that in a system of flexible exchange rates no macroeconomic variable is able to explain exchange rate movements (especially for the short and medium run, which are the only relevant time horizons for MP) and that a simple random walk out-performs the predictions of the existing models of exchange rate determination (Meese and Rogoff 1983). In a simple way, such random walk behavior can be described by

$$q = q_0 + \eta, \tag{22}$$

where η is a random white-noise variable. Inserting equation (22), instead of real UIP, into equation (12) yields the following optimum interest rate:

$$r^{opt} = \frac{a}{b} + \frac{1}{b}\varepsilon_1 + \frac{d}{b(d^2 + \lambda)}\varepsilon_2 + \frac{c}{b}\eta. \tag{23}$$

Random exchange rate movements constitute an additional shock to which the central bank has to respond with its interest rate policy. At first sight, even under this scenario, MP autonomy is still preserved. However, there are limitations, which depend on (a) the size and the persistence of such shocks and (b) the impact of real exchange rate changes on AD, which is determined by the coefficient c in equation (1).

Empirical evidence shows that the variance of real exchange rates greatly exceeds the variance of underlying economic variables such as money and output. This so-called *excess volatility puzzle* of the exchange rate is documented well in the studies of Baxter and Stockman (1989) and Flood and Rose (1995). On the basis of these results, we assume that $Var[\eta] \gg Var[\varepsilon_1]$. Thus, if a central bank would try to compensate the demand shocks created by changes in the real exchange rate, it could generate highly unstable real interest rates. Although this causes no problems in our purely macroeconomic framework, there is no doubt that most central banks try to avoid an excessive instability of short-term interest rates (i.e., interest rate smoothing) to maintain sound conditions in domestic financial markets.[10] If this has the consequence that the central bank does not sufficiently react to a real exchange rate shock, the economy is confronted with a suboptimal outcome for the final targets y and π.

For the graphical solution, the IS curve is simply derived by inserting equation (22) into (1), which eliminates q:

$$y = a - br + c\eta + \varepsilon_1. \tag{24}$$

Exchange rate shocks η lead to a shift of the IS curve, similar to what happens in the case of a demand shock. In Figure 8, we introduce a smoothing band that limits the room of maneuver of the central bank's interest rate policy. To avoid undue

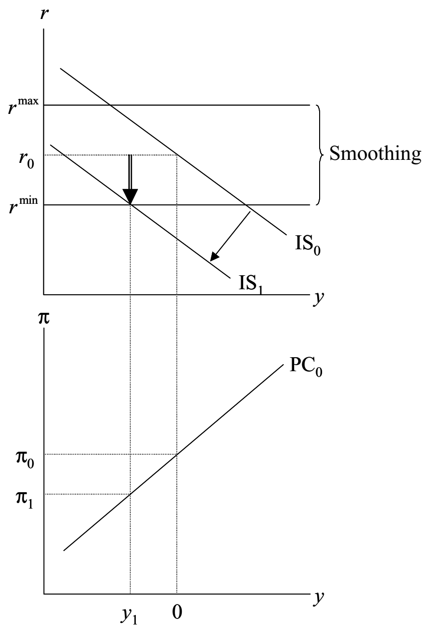

FIGURE 8. Interest rate smoothing and exchange rates that behave like a random walk. r = real interest rate; y = output gap; π = inflation rate; IS = investment and saving curve; PC = Phillips curve.

fluctuations of the interest rate, the central bank refrains from a full and optimal interest rate reaction in response to a random real appreciation ($\eta < 0$) that shifts the IS curve to the left. As a result, the shock is only partially compensated so that the output gap and the inflation rate remain below their target levels.

MONETARY POLICY UNDER FIXED EXCHANGE RATES

With fixed exchange rates a central bank completely loses its leeway for a domestically oriented interest rate policy. In order to avoid destabilizing short-term capital inflows or outflows, the central bank has to follow UIP in a very strict way. If the fixed-rate system is credible, $\Delta s^e = 0$ and the UIP condition simplifies to

$$i = i^* + \alpha. \tag{25}$$

Inserting equation (25) into (7) shows how the real interest rate is determined under fixed exchange rates:

$$r = i^* + \alpha - \pi. \tag{26}$$

Fixed Exchange Rates as a Destabilizing Policy Rule

As the real interest rate is only determined by foreign variables and as it depends negatively on the domestic inflation rate, the central bank can no longer pursue an autonomous real interest rate policy. In principle, this interest rate rule can be interpreted as a special case of a simple interest rate rule. Equation (26) can easily be transformed into

$$r = (i^* + \alpha - \pi_0) + (-1)(\pi - \pi_0) + 0 \cdot y, \tag{27}$$

that is, a specific simple rule with $e = -1$ and $f = 0$. See equation (19) for a general definition of simple rules. It is interesting to see that under fixed exchange rates real interest rates have to fall when the domestic inflation rate rises. Thus, MP becomes more expansive in situations of accelerating price increases, which questions the stabilizing properties of fixed exchange rates in times of shocks.

This can also be shown with our graphical analysis. Because the real rate is not affected by the domestic output gap, the MP line enters the $y - r$ space as a horizontal line. The IS curve is given by

$$y = a - (b + c)r + c(r^* + \alpha) + \varepsilon_1, \tag{28}$$

which is equal to the IS curve under flexible exchange rates. The corresponding interest-rate-rule-dependent AD curve in the $y - \pi$ space is derived in a similar way as in the case of simple interest rate rules. By inserting the interest rate rule (26) in equation (28), we get

$$\pi = \pi^* + \frac{1}{b + c}[y - a + b(r^* + \alpha) - \varepsilon_1]. \tag{29}$$

This implies that the AD curve has a positive slope. Compared with the negative slope of the AD curve under a Taylor rule, the positive slope reveals again the destabilizing property of the *interest rate rule* generated by fixed exchange rates. For the graphical analysis, it is important to see that (a) the slopes of the IS curve and the AD curve have the same absolute value, but the opposite sign; (b) the slope of the AD curve $1/(b + c)$ is greater than one as $0 < (b + c) < 1$. Thus, the AD curve is steeper than the PC, which has a slope of d that is assumed to be positive and less than one.

Impact of Demand and Supply Shocks

In Figure 9, we use this framework to discuss the consequences of a negative shock that affects the demand side of the domestic economy ($\varepsilon_1, r^*, \alpha$). The result is a shift of the IS curve to the left. Without repercussions on the real interest rate, the output gap would fall to y' and the inflation rate to π'. However, in a system of fixed exchange rates, the initial fall in π increases the domestic real interest rates because the nominal interest rate is kept unchanged on the level of the foreign nominal interest rate. Thus, in a first step, we use the new output gap y' and an unchanged inflation rate π_0 to construct the new location of the AD curve

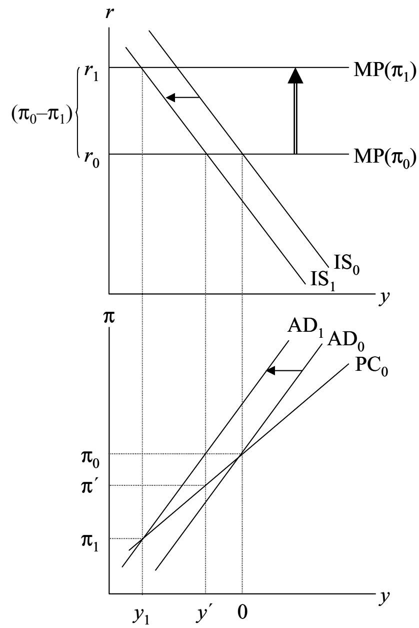

FIGURE 9. Fixed exchange rates and shocks affecting the demand side. r = real interest rate; y = output gap; π = inflation rate; IS = investment and saving curve; AD = aggregate demand curve; MP = monetary policy line; PC = Phillips curve.

in the $y - \pi$ space. It also shifts to the left to AD_1.[11] This finally leads to the new equilibrium combination (y_1, π_1), which is the intersection between the PC and the new AD curve. This equilibrium goes along with a rise of the real interest rate from r_0 to r_1, which is equal to the fall of the inflation rate from π_0 to π_1. It is obvious from Figure 9 that the MP reaction in a system of fixed exchange rates is destabilizing because $\pi_1 < \pi'$ and $y_1 < y'$.

In Figure 10, we show the effects of a supply shock. Initially, the shock shifts the PC upward, which leads to a higher inflation rate π' with an unchanged output gap. Because the rise in inflation lowers the real interest rate, a positive output gap emerges, which leads to a further rise of π. The final equilibrium is the combination (y_1, π_1). Again, we see that the policy rule of fixed exchange rates has a destabilizing effect as it increases the effects of the shock compared to a situation in which there would have been no MP reaction (0, π').

Figure 11 shows that this combination is also suboptimal compared with the outcome a central bank chooses under optimal policy behavior in a system of flexible exchange rates (see Figure 4). Assuming again that the central bank equally weights π and y in its loss function, the dotted circle (y^{flex}, π^{flex}) depicts the loss under flexible exchange rates. If the central bank had followed a policy of constant

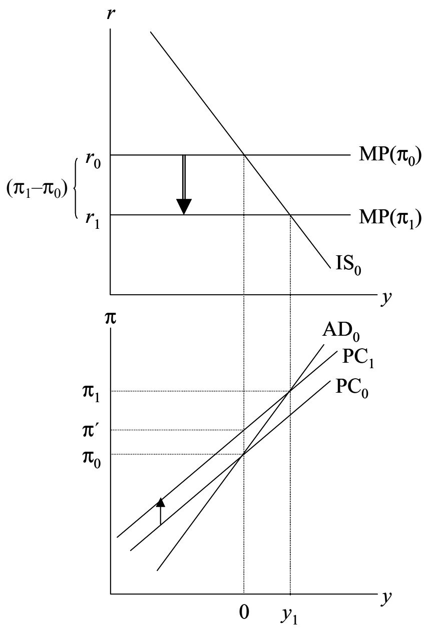

FIGURE 10. Fixed exchange rates and supply shocks. r = real interest rate; y = output gap; π = inflation rate; IS = investment and saving curve; AD = aggregate demand curve; MP = monetary policy line; PC = Phillips curve.

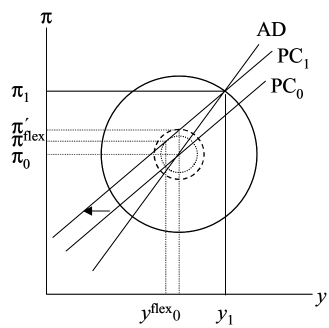

FIGURE 11. Loss under different strategies in an open economy. y = output gap; π = inflation rate; AD = aggregate demand curve; PC = Phillips curve.

real interest rates (that is, absence of any policy reaction), the dashed circle would have been realized with $(0, \pi')$. Under fixed exchange rates, however, the iso-loss circle expands significantly, and the final outcome in terms of the central bank's target variables is (y_1, π_1).

Fixed Rates Can Also Be Stabilizing

From this analysis one would be tempted to draw the conclusion that a system of fixed exchange rates always performs poorly. However, this result is difficult to reconcile with the empirical fact that, for example, countries such as the Netherlands and Austria were able to follow a successful macroeconomic policy under almost absolutely fixed exchange rates in the 1980s and 1990s.

An explanation for this observation is that our analysis leaves open how the foreign real interest rate is determined. A stabilizing movement of the domestic real interest rate can be generated if the foreign central bank is confronted with and reacts to the same demand shocks as the domestic economy. This was certainly the case in the Netherlands and Austria, which pegged its currency to the deutsche mark until 1998. The economies in both countries are very similar to the German economy. Thus, in the literature on optimum currency areas, the correlation of real shocks plays a very important role (e.g., Bayoumi and Eichengreen 1992).

SUMMARY AND COMPARISON WITH THE RESULTS OF THE MUNDELL-FLEMING MODEL

For many central banks, open economy considerations are of major importance for the conduct of MP. Above all, the choice between absolutely fixed exchange rates (like unilateral pegs or monetary unions) and perfectly flexible exchange rates is still a matter of debate. Today the workhorse open economy model in intermediate textbooks is the MF model, even though our understanding of MP has shifted away in recent years from money-supply rules and fixed-price models to interest rate rules and inflation targeting. We present an open economy model that ties in with the tradition of modern NK macro models. It provides students taking an intermediate-level macroeconomics course with a tool that allows a simple analytical and graphical analysis of MP aspects under both fixed and flexible exchange rates.

For a summary of the open economy version of the NK macro model, it seems useful to compare it with the main policy implications of the MF model. Under fixed exchange rates, the MF model comes to the conclusion that (a) MP is completely ineffective, whereas (b) fiscal policy is more effective than in a closed economy setting.

The NK model shows that MP is not only ineffective but rather has a destabilizing effect on the domestic economy. Compared with the MF model, the sources of demand shocks can be made more explicit (above all, the foreign real interest rate and the risk premium), and it is also possible to analyze the effects of supply shocks. As far as the effects of fiscal policy are concerned, the NK model also comes to the conclusion that it is an effective policy tool, and that it is more effective than in a closed economy. A restrictive fiscal policy has similar effects as a negative demand shock, so we can use the results of Figure 9. It is obvious that the initial effect on the output gap is magnified by the destabilizing nature of the fixed-exchange-rate rule.

Under flexible exchange rates, the MF model provides two main results: (a) MP is more effective than in a closed economy setting, whereas (b) fiscal policy becomes completely ineffective. It is important to note that the MF model implicitly assumes that PPP is violated as it assumes absolutely fixed prices. As far as UIP is concerned, the MF model makes the same assumption as the baseline NK model: an increase in domestic interest rates is associated with an appreciation of the domestic currency. For the three versions of flexible exchange rates, the NK models provide results that are partly compatible and partly incompatible with the MF model.

A world where PPP and UIP (long-run perspective) simultaneously hold the NK model produces the contradictory result that there is no MP autonomy with regard to the real interest rate. Thus, the central bank is unable to cope with demand shocks. However, because of its control over the nominal interest rate, it can target the inflation rate and, thus, react to supply shocks. For fiscal policy, the NK model also differs from the MF model. As it assumes an exogenously determined real interest rate, that is, a horizontal MP line, fiscal policy has the same effects as in a closed economy. By shifting the IS curve, it can perfectly control the output gap and, indirectly, the inflation rate.

Under a short-run perspective (UIP holds, PPP does not hold), the results of the NK model are identical with regard to MP. The central bank can control AD and the inflation rate by the real interest rate. Fiscal policy is, again, effective, and if one assumes that the central bank does not react to actions of fiscal policy (constant real rate), it is as effective as in a closed economy.

In the third scenario for flexible exchange rates (random walk), the results of the NK model are, in principle, identical with those of the short-term perspective. However, the ability of MP to react to exchange rate shocks can be limited by the need to follow a policy of interest rate smoothing. Thus, there can be clear limits to the promise of MP autonomy made by the MF model. Again, fiscal policy remains fully effective.

In sum, the NK model shows that for flexible exchange rates a much more differentiated approach is needed than under the MF model. Above all, the results of the MF model, concerning fiscal policy, are no longer valid if MP is conducted in the form of interest rate rule instead of a monetary-targeting rule on which the MF model is based. In the NK model, fiscal policy remains a powerful policy tool in all three versions of flexible exchange rates, provided that the central bank does not instantaneously offset the fiscal impulse.

NOTES

1. Following standard conventions, an increase in q is a real depreciation of the domestic currency.
2. The advantage of this modeling strategy becomes clearer below when the determinants of inflation are discussed.
3. The long-run level of the real exchange rate is given by absolute PPP: $P = SP^*$ or, in logs, $p = s + p^*$. If absolute PPP holds, the level of the real exchange rate, which is defined as $Q = SP^*/P$, or, in logs, $q = s + p^* - p$, is $Q = 1$ or, in logs, $q = 0$.

4. It would be interesting to discuss intermediate cases, in which the real exchange has an impact on the inflation rate. In the open economy model of Galí and Monacelli (2005), for example, imports are treated as finished consumer goods so that consumer price inflation is calculated as a weighted average (by the factor e) of domestic inflation π^d (determined by equation [4]) and imported inflation π^f (determined by equation [3]). However, the problem is that using an equation like $\pi = (1-e)\pi^d + e\pi^f = \pi_0 + dy + e\Delta q + \varepsilon_2$ would make the graphical analysis, which is central to the present article, complex.
5. For a micro-founded derivation of the standard loss function, see Woodford (2003, ch. 6).
6. The speed of adjustment can be expressed in terms of periods for a deviation of the real exchange rate from its long-run level to decay by 50 percent: $g/(1-g)$.
7. For $\lambda \neq 1$, the geometric form of the loss function is an ellipse.
8. Note that current account topics could also be addressed in our framework. Assuming that both exports and imports depend on the real exchange rate and the state of the foreign and domestic cycle, respectively, the following equation for the current account nx can be easily derived: $nx = (y^* - y) + (h^* + h - 1)(r^* - r)$. The first term $y^* - y$ measures current account variations due to output gap differentials, while the second term reflects the influence of movements in the real exchange rate, which can be approximated by $q = r^* - r$ if the risk premium is set to zero. The parameters h and h^* denote the price elasticities of domestic import and foreign export demand, respectively. This representation allows discussing a variety of current account topics both algebraically and graphically.
9. Note that there is also an enormous literature on optimal simple rules that derives the coefficients of the simple rule by minimizing the central bank's loss function (see Rudebusch and Svensson 1999). Although such an approach would also be feasible within our model, we think that optimal simple rules are too complicated to be taught in intermediate macro courses.
10. However, most models, as the one presented here, fail to integrate the variance of interest rate changes and its consequences into a macroeconomic context.
11. In fact, the described shift of the AD curve is only true in the case of ε_1-shocks that affect the AD curve and the IS curve by exactly the same extent (see equations [28] and [29]). If, however, the economy is hit by a α-shock or an r^*-shock, the AD curve shifts by a larger amount than the IS curve, as b is typically greater than c.

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