Macroeconomic stabilisation and intervention policy under an exchange rate band
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MACROECONOMIC STABILISATION AND INTERVENTION POLICY
UNDER AN EXCHANGE RATE BAND

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ABSTRACT

Macroeconomic stabilisation and foreign exchange market interventions are investigated within the context of a stochastic small open economy. With money demand shocks a peg is optimal, but with goods demand shocks a nominal income target is best. With supply shocks the optimal degree of monetary accommodation rises with the welfare weight attached to output rather than to price stability. A nominal exchange rate band is not advisable from a stabilisation point of view, albeit that with money demand shocks no welfare losses are incurred. With goods demand shocks, narrowing the band affects the optimal coefficient of intramarginal monetary accommodation. With supply shocks and no intramarginal interventions, it is desirable to have a wider band if there is a relatively large weight on price rather than output stability.

Keywords: Exchange rate bands, multiple shocks, stabilisation, monetary accommodation, intramarginal intervention, wage and price sluggishness, unrestricted dirty float, exchange rate peg, PPP exchange rate rule, Ornstein-Uhlenbeck process, stochastic simulation.

JEL code: E0, F3, F4

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1 Introduction

The by now classic Krugman (1991) model of nominal exchange rate bands has been overwhelmingly rejected by the data - see Svensson (1992) for a review. One of the reasons being that the model predicts that exchange rate distributions should be U-shaped with most of the probability mass close to the edges of the band, while empirical exchange rate distributions are hump-shaped with most of the mass near the middle of the band. The Krugman (1991) model has been extended to allow for mean reversion in the fundamental process by Froot and Obstfeld (1991) and Delgado and Dumas (1992). Mean reversion and thus the hump-shaped feature of the empirical exchange rate distributions can be explained by intramarginal interventions which attempt to keep the exchange rate near the middle of the band - see Lindberg and Söderlind (1991) and Beetsma and van der Ploeg (1993). However, to make the macroeconomic analysis of stabilisation policy more realistic, we need to abandon the strict monetary framework and consider extensions that allow for sticky prices and transitory unemployment. In fact, these latter extensions are essential if one seriously wants to discuss the welfare properties of exchange rate bands.

Although the implications of the standard Krugman model have been thoroughly analysed, the question what the stabilisation properties of exchange rate bands are on output, employment and prices has largely remained unanswered. An exception is Klein (1990), who introduces shocks to aggregate demand for goods and money supply in a classical model, and shows that a narrower band on the nominal exchange rate leads to greater stabilisation of nominal and real exchange rates and output. Gros (1990) studies optimal stabilisation in a one-period model with a standard surprise supply function, imperfect substitution between domestic and foreign goods, fully flexible prices and a variety of real and monetary shocks. Authorities use fiscal and monetary policy to stabilise output and to keep the exchange rate in a band. A band is defined in a 'probabilistic' sense, namely that the probability that the exchange rate should be kept between its boundaries is above a certain threshold level. This implies a 'soft' target zone, with

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1 Another reason is that the Krugman (1991) model does not allow for realignment risk. See Bertola and Caballero (1992), and Bertola and Svensson (1993).

2 See also Miller and Weller (1991), Klein (1990), and Beetsman and van der Ploeg (1993).

3 For example, Svensson (1991) shows that for narrow exchange rate bands, the asymptotic or unconditional variance of the interest rate differential (between two countries and at instantaneous maturity) increases in the bandwidth, but for wide bands it decreases in the bandwidth. The instantaneous interest rate differential variability is perfectly negatively correlated with the instantaneous exchange rate variability and increases monotonically when the exchange rate band is narrowed, which is in sharp contrast with a fixed exchange rate regime and, therefore, zero interest rate differential.
intramarginal interventions only. Unfortunately, no case can be made for an exchange rate band, because imposing a band involves an additional restriction under which the stabilisation problem is to be solved. If authorities can make unrestricted use of both monetary and fiscal policy, an exchange rate band does not induce any welfare losses so that both the income and exchange rate target can be met (in the sense that income is stabilised to the maximum possible extent, while at the same time the exchange rate restriction is fulfilled). However, if fiscal policy is restricted, then it might be the case that imposing a band involves welfare losses. Sutherland (1993) uses a similar model to address the question of the optimal width of a target zone. He defines a target zone in the 'conventional' way, as a hard band on the nominal exchange rate with the necessary interventions at the boundaries. From the point of view of macroeconomic stabilisation, he finds that with only money demand or goods demand shocks a target zone cannot be optimal. However, with a combination of these two types of shocks, a target zone may be preferred to both a fixed exchange rate and a free float. The same is true for aggregate supply shocks if authorities care both about output and price stability. Svensson (1992b) also uses a classical monetary model with purchasing power parity and an exogenously determined output level to study the trade-off between various objectives, such as exchange rate and interest rate variability around certain target levels and smoothing short-run exchange rate and interest rate movements. Given these objectives, authorities choose the optimal (time-consistent) path for the nominal money supply in response to a variety of shocks. The optimal width of the exchange rate band, which is informally defined as a range of ±3 standard deviations around the unconditional mean of the exchange rate, follows implicitly from the optimal stabilisation policy.

One reason that the stabilising properties of exchange rate bands are largely unexplored is that usually full price flexibility, purchasing power parity and full employment are assumed. Hence, for macroeconomic stabilisation, one may as well have a peg or one currency and reap all the benefits of an optimum currency area. Miller and Weller (1991) extend the analysis to allow

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4 Because accumulated shocks follow a Brownian motion and there is a band on the fundamental of which the unregulated part is a linear combination of accumulated shocks, the money supply becomes non-stationary. Moreover, output and prices are non-stationary so that their asymptotic variances do not exist and, therefore, cannot be used as a criterion for policy optimisation. As an alternative criterion, Sutherland (1992) uses unconditional (on the position in the band) expectations of instantaneous variances. He does not consider stabilisation policy if the exchange rate is in the interior of its band, i.e. intramarginal interventions.

5 To avoid analytical complications, it is necessary to abstract from an explicit band on the exchange rate. Svensson (1992) conjectures that this simplification does not dramatically affect the results, because in the presence of intramarginal interventions the nonlinearity of the exchange rate solution is only significant close to the boundaries and this is precisely where the unconditional exchange rate distribution has relatively little probability mass.
for sluggish nominal wage dynamics and transitory unemployment. Within this richer environment, one is able to distinguish between real and nominal exchange rates. Moreover, in the presence of nominal wage sluggishness and transitory unemployment, the central bank may be interested in the accommodation of shocks. Dornbusch (1982) and Alogoskoufis (1989) examine the effects of monetary accommodation, and of PPP exchange rate rules in particular, on macroeconomic stability in a framework of dirty floating. Frenkel and Aizenman (1982), Aizenman and Frenkel (1985) and others discuss the optimal degree of monetary accommodation and fixity of exchange rates if there is a variety of shocks. However, no work has been done on the effects of monetary accommodation with a nominal exchange rate band.

Hence, the main objective of this paper is to relax the assumptions of purchasing power parity and full employment prevalent in most of the literature on exchange rate bands, by allowing for imperfect substitutability between home and foreign goods and introducing wage and price sluggishness, and to study for various sources of shocks the variability of output and prices under different exchange rate regimes. In particular, a comparison will be made between stabilisation policy under an exchange rate band versus under an unrestricted dirty float, which is the limiting case when the bandwidth goes to infinity. We investigate for which sources of shocks it is desirable, from a stabilisation perspective, to have a band on the exchange rate.

We extend Sutherland (1993) by allowing for wage-price sluggishness and studying the effects of monetary accommodation and the combination of infra- and intramarginal interventions. The objective of stabilisation policy is to minimise the variance of temporary deviations of, for example, output/employment (and prices) from long-run equilibrium. However, most existing models of exchange rate bands imply a non-stationary fundamental so that, with a limited amount of foreign exchange reserves in the world, the exchange rate band collapses sooner or later anyway. Depending on the source of the shocks, output might become non-stationary (as in Sutherland, 1993), thus making it difficult to rationalise stabilisation policy with a band. The point is that stabilisation via a credible band on the nominal exchange rate only makes sense in a

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6 Increased nominal exchange rate indexation ensures more stability in the real exchange rate and the levels of demand and employment, but on the other hand it amplifies the effects of wage disturbances on prices. Alogoskoufis (1991) extends Dornbusch (1982) by highlighting the effects of monetary accommodation and exchange rate accommodation on the forward-looking behaviour of wage-setters and price-setters, and suggests that the higher degree of persistence in inflation arises from a higher degree of accommodation in floating exchange rate regimes. In our model, the PPP exchange rate rule corresponds to 100% monetary accommodation of price and wage shocks.

7 Of course, in 'traditional' exchange rate band models, one can introduce mean-reversion exogenously by simply adopting a mean reverting component in the shocks to the economy. However, we think that this is less appealing than having endogenous mean reversion based on wage/price sluggishness.
stationary stochastic environment (unless one allows for a crawling peg as a potential instrument for macroeconomic stabilisation). Allowing for (intramarginal) monetary accommodation, enables us to make a more consistent comparison between a band regime and an unrestricted dirty float. Sutherland (1993) only compares a band against two special cases, namely a free float and a peg.

Section 2 presents our model of a small open economy. Section 3 discusses the regimes of managed exchange rates without a band, paying particular attention to a peg, a clean float, a PPP rule and a nominal income target. A peg is the best regime for money demand shocks, while a nominal income target is optimal for goods demand shocks. With supply shocks the optimal degree of monetary accommodation rises with the weight attached to output stability rather than to price stability. Section 4 studies the stability of output/employment and prices for different degrees of intramarginal intervention and various bandwidths under a variety of shocks. Section 4 also investigates stabilisation policy under an exchange rate band and addresses whether a band is desirable from a stabilisation perspective. Section 5 concludes.

2 Transitory Unemployment in a Small Open Economy

Most models of exchange rate bands are based on the seminal work of Krugman (1991), and adopt the unrealistic assumptions of fully flexible wages and prices, and, therefore, purchasing power parity and full employment. However, for policy purposes it is essential to allow for sticky nominal wages and transitory unemployment. Otherwise, it would be difficult to make a case for monetary accommodation or to provide a rationale for exchange rate bands. It is also important to allow for imperfect substitution between home and foreign goods, so that one can allow for the effects of the real exchange rate on aggregate demand. Miller and Weller (1991) therefore apply the analysis of Krugman (1991) to the familiar exchange rate overshooting model of Dornbusch (1976). In order to study the case of an exchange rate band against other exchange rate regimes, we extend Miller and Weller (1991) by allowing for a variety of demand and supply shocks and also for intramarginal interventions. We assume that the only available policy instrument is the money supply, but it is straightforward to introduce fiscal policy (see Appendix 1). However, monetary policy seems a more realistic instrument for the day-to-day management of the exchange rate, while the effects of fiscal policy only become visible with some lag in time. Thus, our model reads as follows:

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8 In addition, it is possible to explain the stylised fact that a reduction in nominal exchange rate variability goes together with a fall in real exchange rate variability (e.g., Mussa, 1986).

9 Lewis (1990) and Lindberg and Söderlind (1992) also allow for intramarginal interventions.
\[ y = -\eta (\tilde{i} - \pi) + \delta (e + p^* - p) + \nu, \eta > 0, 0 < \delta < 1 \]  
(1)

\[ m - p = y - \lambda i + w, \lambda > 0 \]  
(2)

\[ dp = \phi_p (y - y^*) dt + \pi dt + \sigma_p dz_p, dz_p \sim \text{IN}(0, dt), \phi_p > 0 \]  
(3)

\[ E_e(de) = (i - \tilde{i}) dt \]  
(4)

\[ dv = -\phi_v v dt + \sigma_v dz_v, dz_v \sim \text{IN}(0, dt), \phi_v > 0 \]  
(5a)

\[ dw = -\phi_w w dt + \sigma_w dz_w, dz_w \sim \text{IN}(0, dt), \phi_w > 0 \]  
(5b)

where \( m, y, y^*, p, p^*, e, i, \tilde{i} \) and \( \pi \) denote the logarithms of nominal money supply, aggregate demand, full-employment level of output, home price level, foreign price level, nominal exchange rate (the price of one unit of foreign currency in terms of domestic currency units), domestic interest rate, foreign interest rate and core inflation, respectively. Furthermore, \( dz_p, dz_v, \) and \( dz_w \) denote shocks to supply, demand for domestic goods and money demand, respectively. These shocks are independent of each other.

The IS-curve (1) says that aggregate demand increases when the real interest rate declines or the real exchange rate depreciates. The real interest rate is simply the nominal interest rate minus core inflation. Variable \( v \) is the accumulation of shocks to the demand for domestically produced goods and follows the Ornstein-Uhlenbeck process (5a) with mean-reversion parameter \( \phi_v \) and instantaneous standard deviation \( \sigma_v \) (e.g. Karlin and Taylor, 1981, p.172). The LM-curve (2) says that the velocity of circulation increases with the nominal interest rate. Variable \( w \) is the accumulation of velocity shocks and follows the process (5b). The Phillips-curve (3) indicates that inflation occurs if there is a shortage of labour, and that deflation occurs when there is unemployment. The degree of labour market flexibility is determined by the parameter \( \phi_p \). Supply shocks \( z_p \) follow a Brownian motion and represent positive shocks to nominal wages. Producer prices are a constant mark-up on unit labour costs, so that supply shocks may also be interpreted as negative shocks to labour productivity. The money supply is stable in steady state, so core inflation \( \pi \) being the expected steady-state rate of inflation is assumed to be zero.\(^{10}\) The uncovered interest parity condition (4) says that an interest rate differential in favour of the domestic country can only be sustained if the currency is expected to depreciate in the future, i.e. if the currency is currently over-valued.

Shocks to the foreign price level correspond to shocks to domestic demand (\( v = \delta p^* \)), so

\(^{10}\) This implies that the economy is always saddlepath stable. If aggregate demand depends, in contrast, on the real consumption interest rate, i.e. the nominal interest rate minus the rationally expected change in the price level, an unstable spiral may result for higher inflation depresses the real interest rate, boosts aggregate demand and thus induces even higher inflation. The use of core inflation in the definition of the real interest rate avoids such a spiral and simplifies the algebra.
that without loss of generality we set $p^* = 0$. Furthermore, shocks to the foreign interest rate correspond to a combination of goods and money demand shocks and we thus set $\tau^* = 0$. We also normalise full-employment output to unity, so that $y^F = 0$. The dynamics are thus given by

$$
\begin{aligned}
\begin{bmatrix}
dp \\
dv \\
dw \\
dE/dt
\end{bmatrix}
&=
\begin{bmatrix}
-\phi_p(\eta+\delta) & \phi_p \lambda & -\phi_p \eta & \phi_p \delta \\
0 & -\phi_v(\eta+\lambda) & 0 & 0 \\
0 & 0 & -\phi_w(\eta+\lambda) & 0 \\
1-\delta & 1 & 1 & \delta
\end{bmatrix}
\begin{bmatrix}
p \\
v \\
w \\
e
\end{bmatrix}
dt
+
\begin{bmatrix}
\phi_p \eta \\
0 \\
0 \\
-1
\end{bmatrix}
m dt
+
\begin{bmatrix}
\sigma_p dz_p \\
\sigma_v dz_v \\
\sigma_w dz_w \\
0
\end{bmatrix},
\end{aligned}
$$

(6)

where output follows from the reduced-form IS-LM model

$$
y = (\eta+\lambda)^{-1}[-(\eta+\delta)\mu + \lambda \nu + \eta(m-w) + \delta \lambda e],
$$

(7)

and the interest rate follows from $\mu = \frac{E}{dE}$. Adverse supply shocks (higher $p$) cause stagflation, while adverse demand shocks (lower $\nu$, $m$ or $e$ and higher $w$) cause unemployment and deflation.

3 Managed Exchange Rates without a Band

3.1 Composite fundamental and the reduced form

Exchange rate regimes can be characterised by money supply rules which react to fundamentals. The latter are a time-invariant function of the predetermined part of the state vector. If we impose $\phi_v = \phi_p = \phi$ and $\phi_w = \phi \delta$ on the mean reversion parameters, the money supply rule and the fundamental are given by:

$$
m = \mu + \beta (f-\mu) \quad \text{with} \quad f = p + (1-\delta)^{-1}(\nu+w).
$$

(8)

where $\mu$ is the long-run component of the money supply, $f$ denotes the fundamental and $\beta$ stands

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11 If $f$ depends on any other linear combination of $p$, $\nu$ and $w$, the exchange rate cannot be uniquely determined from the fundamental alone, but depends also on the values of the individual components of the fundamental.
for the coefficient of monetary accommodation. Monetary policy can be conducted in this way if, for example, the central bank has more information than private agents. If the private sector does not observe shocks to the individual stochastic components of the fundamental itself, the private sector can from the money supply rule (8) unambiguously infer the change in the fundamental and thus the way in which the exchange rate should go (given intervention policy and excluding bubbles). However, if authorities respond to individual shocks in a way which does not correspond to (8), the private sector cannot infer how the exchange rate is supposed to change from observing a given change in the money supply for it does not know the type of shock that authorities are reacting to. Substituting (8) into (1)-(5), we obtain the reduced form:

\[
\begin{align*}
\left( \begin{array}{c}
\frac{df}{E_d e} \\
\end{array} \right) &= \frac{1}{\eta + \lambda} \left( \begin{array}{c}
-\phi \delta + \phi \eta (\beta - 1) \\
1 - \beta - \delta \\
\end{array} \right) \left( \begin{array}{c}
f \\
e \\
\end{array} \right) dt + \frac{1}{\eta + \lambda} \left( \begin{array}{c}
\phi \eta \\
1 - \beta \\
\end{array} \right) (1 - \beta) \mu dt + \left( \begin{array}{c}
\sigma dz \\
0 \\
\end{array} \right)
\end{align*}
\]

where

\[
\sigma = \sqrt{\sigma_p^2 + (\sigma_p^2 + \sigma_e^2)/(1 - \delta)^2}.
\]

The transient certainty-equivalent rational expectations response of this reduced form to an unanticipated permanent increase in the long-run component of the money supply \( \mu \) is presented in Figure 1, both for a low and a high coefficient of monetary accommodation.

### 3.2 Rational expectations and short-run dynamics

The fundamental is predetermined, whilst the exchange rate is a non-predetermined, forward-looking variable. The rational expectations equilibrium must thus be a saddlepath solution. This requires one eigenvalue with a negative real part and one eigenvalue with a positive real part, which is ensured as long as \( \beta < 1 \). It can be shown that the economy has a faster speed of adjustment (i.e. the modulus of the eigenvalue with the negative real part is higher) if there is more mean reversion in the stochastic processes for prices and shocks to goods and money demand and also if the coefficient of monetary accommodation falls. The non-explosive rational expectations solution is:

\[
e - \mu = \omega (f - \mu) \quad \text{with} \quad \omega = \frac{\delta (1 + \phi \lambda) + \phi \eta (1 - \beta) - \sqrt{[\delta (1 + \phi \lambda) + \phi \eta (1 - \beta)]^2 + 4 \phi \delta \lambda (1 - \beta - \delta)}}{2 \phi \delta \lambda}.
\]

The slope of the saddlepath increases (\( \omega \)) if the degree of monetary accommodation \( \beta \) increases. For low degrees of monetary accommodation, i.e. \( \beta < 1 - \delta \), there is a negative correlation between the nominal exchange rate and the fundamental, i.e. the saddlepath has a negative slope (\( \omega < 0 \)). This implies that the nominal exchange rate overshoots in response to an unanticipated and
permanent change in the long-run money supply $\mu$ (cf. Dornbusch, 1976). For high degrees of monetary accommodation, $1-\delta<\beta<1$, the saddlepath slopes upwards ($\omega>0$), which implies undershooting of the nominal exchange rate. The turning point between overshooting and undershooting of the nominal exchange rate in response to an unanticipated permanent change in the money supply corresponds to a degree of monetary accommodation that ensures a fixed nominal exchange rate (i.e. $\beta=1-\delta$), so that $e=\mu$ and $\omega=0$. This nominal exchange rate regime will be referred to as a peg. The relationship between $\omega$ and $\beta$ pivots around the 'pegpoint' ($\beta=1-\delta$) towards the horizontal axis as $\phi$ increases. For a classical model with full employment (i.e. $\phi\to\infty$), $\omega\to0$ and all transitional dynamics disappear. The steady state corresponds to the mean of the asymptotic distributions and is independent of the monetary accommodation coefficient $\beta$. In the long run relative purchasing power parity holds and money is neutral.

The (certainty-equivalent) full-employment locus requires a stable fundamental ($df=0$) and is steeper than 45°, because its slope (i.e. $1+\eta(1-\beta)/\lambda\delta$) is greater than unity. A one per cent increase in the fundamental reduces aggregate demand through an appreciation of the real exchange rate and through a contraction of real money balances, hence to ensure full employment the nominal exchange rate must depreciate by more than one percent. The effect on real money balances is less if the monetary accommodation coefficient is high, so that as $\beta$ increases the full-employment locus becomes flatter and tilts towards the 45° line.

The interest parity locus requires that the market expects a stable exchange rate ($E,de=0$). An increase in the fundamental corresponds on the one hand to a monetary contraction and thus an increase in the interest rate, less so if there is a high degree of monetary accommodation, and on the other hand to an appreciation of the real exchange rate, a fall in aggregate demand and a fall in the interest rate. The latter (former) effect is more likely to dominate if $\beta$ is high (low), in which case a depreciation (appreciation) of the nominal exchange rate is required to push up (depress) the interest rate back to the foreign rate. More precisely, the slope of the interest parity locus (i.e. $-\eta(1-\beta-\delta)/\delta$) is negative for low degrees of monetary accommodation ($\beta<1-\delta$), whilst it is positive and less than unity for high degrees of monetary accommodation ($1-\delta<\beta<1$).

An unanticipated increase in the long-run component of the money supply $\mu$ causes overshooting of the nominal exchange rate for low degrees of accommodation ($\beta<1-\delta$) (cf. Dornbusch, 1976) - see Figure 1(a). The market expects an interest rate differential in favour of the rest of the world and thus over time a gradually appreciating exchange rate, so that the exchange rate must on impact over-react. However, for large coefficients of monetary accommodation ($1-\delta<\beta<1$), the exchange rate undershoots on impact - see Figure 1(b). A gradual increase in prices is accompanied by a gradual expansion of the money supply, so that the
anticipated gradual rise in interest rates is less pronounced. Consequently, the exchange rate depreciates less and the interest rate falls less on impact, thereby leading to undershooting rather than overshooting of the nominal exchange rate.

3.3 Special cases: Peg, clean float, PPP exchange rate rule and NIT

Under a peg the monetary authorities use unsterilised interventions to fix the nominal exchange rate. If the foreign interest rate exceeds the domestic interest rate, there is an incipient capital outflow and pressure on the currency to depreciate. Under a peg, the central bank defends the exchange rate by selling foreign reserves and buying its own currency. As a result, the money supply falls until the domestic interest rate is pushed up to the level of the foreign interest rate. Hence, a peg corresponding to \( e = e_p \) implies that the domestic interest rate is anchored to the foreign interest rate, and that an independent domestic monetary policy is infeasible. A peg corresponds to a specific money supply rule, namely \( m = (1 - \delta) f^* + \delta e_p \). Hence, a peg implies an accommodation coefficient of \( \beta = 1 - \delta \) and a long-run component of the money supply of \( \mu = \mu_p \). Under a peg the fundamental follows an Ornstein-Uhlenbeck process of the form \( df = -\beta \delta (f - e_p) dt + \sigma dz \). The asymptotic mean and variance of this process are \( \text{mean}(f) = \mu = \mu_p \) and \( \text{var}(f) = \frac{1}{2} \sigma^2 / \phi \delta \).

Other special cases are zero monetary accommodation (\( \beta = 0 \)), which we refer to as a clean float and always implies exchange rate overshooting, and, at the other extreme, full accommodation (\( \beta = 1 \), \( m = f \)). The mnemonics for these cases are FLOAT and FA, respectively. Under a clean float the monetary authorities neither give in to changes in wages and prices, nor to changes in the demand for domestic goods or money and thus keep the nominal money supply fixed in the face of shocks. However, full accommodation implies that all shocks to the fundamental are accommodated. If \( \beta \to 1 \), the saddlepath solution tilts towards the 45°-line, \( e = f \), the domestic interest rate is pegged to the foreign interest rate, and the nominal price level and exchange rate, as well as the fundamental, become non-stationary (\( \text{var}(p), \text{var}(e), \text{var}(f) \to \infty \)). The degree of accommodation needed to target the real exchange rate, i.e. a PPP exchange rate rule, depends on the source of the shocks. If there are only supply shocks, full accommodation corresponds to a PPP rule in which the real exchange rate is targeted (cf. Dornbusch, 1982). However, if there are only money demand shocks a PPP rule corresponds to \( \beta = 1 - \delta \), i.e. to pegging the nominal exchange rate.

\[ 12 \text{ In general, we have } \mu = e_p + p^* \gamma (\eta + \lambda) / \delta \text{ so that a lower foreign price level and a higher foreign interest rate require a more restrictive monetary policy in order to defend the value of the currency at a given rate } e_p. \]
Hence, a peg, a clean float and a PPP rule correspond to targets for, respectively, the nominal exchange rate (or the nominal interest rate), the nominal money supply and the real exchange rate. An alternative is to target nominal income, say \( y+p = n_p \), which we call a NIT (e.g. Bean, 1983; Alogoskoufis, 1989). If shocks to goods demand, money demand and aggregate supply are observable, a NIT can be attained with a money supply rule of the form 
\[
m = n_r - \lambda i + w = (1 - \beta)(n_p + \omega) + \beta f. \tag{13}
\]
A NIT thus requires a coefficient of monetary accommodation equal to \( \beta = \bar{\beta} \), where \( \bar{\beta} \) is implicitly defined by the equation \( \lambda (1 + \delta (\omega - 1) + \eta \beta) = 0 \). Examination of the expression for \( \omega \) in (9) shows that a NIT implies leaning against the wind, i.e. \( \beta = \beta < 0 \).

Hence, the lower the price level, the bigger the adverse shock to the demand for goods and the higher the targeted level of nominal income, the looser the supply of money under a NIT. If the semi-elasticity of money demand with respect to the interest rate is zero \( (\lambda = 0) \), a NIT corresponds to a free float (i.e. \( \beta = 0 \)). In that case, attaining a NIT corresponds to setting the money supply to the desired NIT plus the shock to money demand. We refer to the class of regimes without a band (excluding a PEG, FLOAT or FA) as an unrestricted dirty float, i.e. an UDF.\(^{14}\)

### 3.4 Stabilisation policy in an uncertain environment

Substituting (9) into (6), we obtain the dynamics of the price level:
\[
dp = \left[ \frac{[\phi\delta\lambda(\omega - 1) + \phi\eta(\beta - 1)](1 - \delta)(p - \mu) + [\phi\lambda(1 + \delta(\omega - 1)) + \phi\eta\beta]v + [\phi\delta\lambda\omega + \phi\eta(\beta + \delta - 1)]w}{(1 - \delta)(\eta + \lambda)} \right] dt + \sigma_p dz_p.
\]

With the aid of (10), (6) and (7), we calculate the asymptotic variances and covariances:
\[
\begin{align*}
\text{var}(p) &= (2\phi)^{-1} \left[ k_1(\beta) \sigma_p^2 + k_2(\beta) \sigma_i^2 + k_3(\beta) \sigma_w^2 \right], \\
\text{var}(y) &= (2\phi)^{-1} \left[ \sigma_p^2 + k_2(\beta) \sigma_i^2 + \delta k_3(\beta) \sigma_w^2 \right]/k_1(\beta), \\
\text{var}(c) &= \omega^2 \text{var}(f), \quad \text{var}(i) = \{(1 - \beta - \delta(1 - \omega))/(\eta + \lambda)\}^2 \text{var}(f),
\end{align*}
\]

where
\[
\begin{align*}
k_1(\beta) &= \frac{\eta + \lambda}{\eta(1 - \beta) + \delta\lambda(1 - \omega)}, & k_2(\beta) &= \frac{[\lambda(1 + \delta(\omega - 1)) + \eta\beta]^2}{(1 - \delta)^2[\lambda(1 + \delta(1 - \omega)) + \eta(2 - \beta)][\delta\lambda(1 - \omega) + \eta(1 - \beta)]},
\end{align*}
\]

\(^{13}\) Note that the information requirement for attaining a NIT is somewhat stronger than for the rules; in the former case both authorities and private agents should be able to observe realisations of money demand shocks separately.

\(^{14}\) Boyer (1978), Roper and Tumovsky (1980), and Turnovsky (1983) discuss the merits of exchange rate intervention policy under an UDF.
It can readily be verified that \( k_1' > 0 \); \( k_2' < 0 \) for \( \beta < \bar{\beta} \) and \( k_2' > 0 \) for \( 1 > \beta > \bar{\beta} \), where \( \bar{\beta} < 0 \) is implicitly defined by \( \lambda(1 + \delta(\omega-1)) + \eta\bar{\beta} = 0 \). Also, we establish that \( k_1' < 0 \) for \( \beta < 1-\delta \) and \( k_1' > 0 \) for \( 1-\delta < \beta < 1 \), \( \partial(k_1/k_1)/\partial\beta < 0 \) for \( \beta < \bar{\beta} \) and \( \partial(k_1/k_1)/\partial\beta > 0 \) for \( 1 > \beta > \bar{\beta} \), and \( \partial(k_2/k_1)/\partial\beta < 0 \) for \( \beta < 1-\delta \) and \( \partial(k_2/k_1)/\partial\beta > 0 \) for \( 1-\delta < \beta < 1 \).

To highlight the effects on variances of different degrees of monetary accommodation for various shocks, Table 1 makes use of (11) to tabulate var(\( p \)) and var(\( y \)) for a number of special values of \( \beta \). Note that the variances of output and the price level under a peg, nominal income target or full accommodation do not depend on the semi-elasticities of goods and money demand with respect to the interest rate (i.e. \( \eta \) and \( \lambda \)). The expected speed of mean reversion towards the steady state increases and thus the variances of output and the price level decrease with the degree of labour market flexibility (\( \phi \)).

**Proposition 1: Optimal stabilisation without a band**

(a) If there are only goods demand shocks, imposing a NIT (i.e. \( \beta = \bar{\beta} < 0 \)) stabilises both output and the price level (i.e. var(\( y \)) = var(\( p \)) = 0).

(b) If there are only money demand shocks, a peg (i.e. \( \beta = 1-\delta \)) stabilises both output and the price level.

(c) If there are only supply shocks, the variance of output decreases while the variance of the price level increases in the coefficient of monetary accommodation \( \beta \). Full accommodation stabilises output, while the variance of the price level tends to zero as the authorities lean more and more against the wind (i.e. if \( \beta \to -\infty \)). The asymptotic trade-off between the variance of output and the variance of the price level is convex. Hence, the optimal coefficient of monetary accommodation increases if the authorities attach relatively more weight to the variance of output rather than to the variance of the price level.

A boost to the demand for goods (e.g., an increase in world trade) puts upward pressure on the price level, thereby depressing real money balances, raising the nominal interest rate and partly choking off the excess demand for goods. Increasing the money supply in response to this shock mitigates the effect on the interest rate, which stimulates the demand for goods and fuels inflation. Hence, a better policy for the central bank is to contract the money supply in response to an exogenous boost to demand. However, if the authorities lean too much against the wind (i.e. \( \beta < \bar{\beta} \)), the contraction of demand induced by the tighter monetary policy more than offsets the
exogenous boost to demand, so that a deflationary recession results. Hence, too much leaning against the wind also destabilises the economy. In fact, the optimal value of the monetary accommodation coefficient in response to goods demand shocks is the one that corresponds to a NIT.\textsuperscript{15,16}

Shocks to the demand for money can exactly be offset by compensating changes in the money supply (i.e. $\beta=1-\delta$). This corresponds to a target for the nominal exchange rate. Exogenous increases in the nominal wage rate or in oil prices (supply shocks) induce higher prices and thus less demand for goods (stagflation). Accommodation of such shocks depresses the interest rate, which mitigates the effects on aggregate demand and employment at the expense of higher inflation. Hence, in a situation of supply shocks, it is optimal to have a lot of monetary accommodation if the variance of the output is judged to be relatively much more important than the variance of the price level.

In practice, the central bank may want to impose a money supply rule to stabilise output, but may have no clear idea (for example, because the collection of macroeconomic data is poor) which is the dominant source of shocks hitting the economy. It would then be desirable to implement a rule which is robust against various types of shocks.

**Proposition 2: Robustness**

(a) If shocks hit only goods demand, a peg (i.e. the optimal exchange rate regime in a situation of only money demand shocks) yields a lower variance of output than full accommodation (which ensures a zero variance of output if there are only supply shocks).

(b) If shocks only impact money demand and $\delta\geq 1/3$, the optimal rule against goods demand shocks ($\beta=\beta^*<0$) yields a lower variance of output than full accommodation.

(c) If there are only supply shocks, a peg yields a lower variance of output than the optimal rule against goods demand shocks. Hence, targeting the nominal exchange rate is preferred to targeting nominal income.

(d) Let the welfare loss function be given by $\text{var}(y) + \gamma \text{var}(p)$ ($\gamma \geq 0$). Suppose that the individual source of shocks cannot be observed. However, the authorities have a flat prior about the true

\textsuperscript{15}One disadvantage of a NIT might be that nominal income data are much less precise and appear with a longer lag than money supply, interest rate or exchange rate data.

\textsuperscript{16}The optimal policy under goods demand shocks is a NIT, which corresponds to leaning against the wind. Sutherland's (1993) model reduces to our model if labour markets are fully flexible (i.e. $\phi_\tau \to \infty$ and $\eta=\pi=\varphi_\tau=\varphi=0$). In that case, a free float is the optimal stabilisation policy under goods demand shocks. The difference arises from our assumption that $\varphi_\tau>0$, which is required for stationarity and thus for the existence of variances of output and prices in our model.
type of shock and know that the instantaneous variances of the three types of shocks are equal.\textsuperscript{17} If the central bank attaches relatively high weight to output stabilisation (i.e. $\gamma < \delta$), a peg is preferred to full accommodation or a NIT. However, if the central bank attaches relatively high weight to price stabilisation (i.e. $\gamma > \delta$), a NIT is preferred to a peg or full accommodation.\textsuperscript{18}

In (a) and (c), a peg is preferred, because the corresponding degree of monetary accommodation ($\beta = 1 - \delta$) is closer to what is optimal under the true shock type. If the sensitivity of the demand for home goods for the real exchange rate increases (i.e. $\delta$ increases), the degree of accommodation that pegs the exchange rate moves in the direction of the degree of accommodation $\beta$ that insulates output from goods demand shocks (case (b)). Part (d) says that a peg is a relatively safe intermediate position if authorities lack full information about the shocks and care a lot about output stabilisation.\textsuperscript{19} Of course, if $0 \leq \gamma < \delta$, a peg is not the optimal regime; it is only better than a NIT and full accommodation. Similarly, if $\gamma > \delta$, a NIT is not the optimal regime. If the prior of goods demand shocks (being the true type of shock) increases or if the variance of goods demand shocks increases relative to the other variances, imposing a NIT becomes relatively more attractive. It is remarkable that for none of the three shocks a clean float is optimal. However, if the authorities are not sure whether shocks occur in money demand or in goods demand, a clean float may have some virtue.

If there is only one type of shock, the authorities can fully stabilise output by an appropriate choice of the coefficient of monetary accommodation. If there is a combination of different types of shocks, this is not possible anymore due to a lack of policy instruments. In many cases there is a trade-off between the insulation from one type of shock against the insulation of output and/or the price level from another type of shock. In the following, we assume that the welfare loss function of the policy maker is given by $\text{var}(y) + \gamma \text{var}(p)$ with $\gamma \geq 0$.

**Proposition 3: Stabilisation with multiple source of shocks**

(a) If there are both goods demand and money demand shocks, the central banker chooses a relatively tight degree of accommodation or a policy of leaning against the wind (i.e., a $\beta$ between

\textsuperscript{17} Alternatively, the central bank does not know the instantaneous variance of each shock, but it attaches the same prior distribution to each of these variances.

\textsuperscript{18} For a slightly different setting where authorities know the instantaneous variance of the fundamental for some reason, one can show that the results are exactly the same.

\textsuperscript{19} A formal proof of (d) is obtained by taking for $\beta = \bar{\beta}$, $\beta = 1 - \delta$ and $\beta = 1$ the unconditional mean (with respect to the prior distribution) of $\text{var}(y)$ and comparing the resulting expressions.
(b) If there are both goods demand and supply shocks, a policymaker who cares only about output stability (γ very small) chooses an accommodation coefficient between β<0 and 1. In contrast, a policymaker who is only concerned about price stability (γ very large), will choose a policy of much more severe leaning against the wind (i.e. β<β<0).

(c) If there are money demand and supply shocks, a policymaker who cares only about the stability of output chooses a high degree of monetary accommodation (i.e. 1<β<1). On the other hand, if the central bank only cares about the stability of the price level, a tighter degree of accommodation is chosen (i.e. β<1).

In part (a), authorities obtain stabilisation gains with respect to both sources of shocks by increasing the degree of accommodation if β<β and by decreasing it if 1<β<1. Since α>0 and α<0, the optimal degree of accommodation lies strictly between β and 1, and not at the boundaries of this range. The reason is that, if the optimal degree of accommodation was β, then by slightly increasing β, there is second-order stabilisation loss from the presence of goods demand shocks, but a first-order stabilisation gain from the presence of money demand shocks. A similar reasoning can be applied to parts (b) and (c).

3.5 Labour market flexibility

If the labour market clears immediately, all variances and covariances go to zero. Hence, the degree of monetary accommodation becomes irrelevant, as long as there is not full accommodation, and the choice of exchange rate regime does not matter either. In practice, the labour market does not clear immediately and it is of interest to investigate how a policy to improve labour market flexibility affects the optimal degree of monetary accommodation. If there are only money demand shocks, a peg is the best exchange rate regime. The corresponding coefficient of monetary accommodation is independent of the degree of labour market flexibility (β=1-δ). However, if there are only goods demand shocks, a NIT is the best policy. It can be shown that the corresponding coefficient of monetary accommodation declines with the degree of labour market flexibility (i.e. β falls if φ rises). If there are only supply shocks, a more flexible labour market induces the authorities to shift the optimal degree of monetary accommodation away from the pegpoint, i.e. authorities who originally chose β<1-δ further decrease their accommodation coefficient, while authorities who originally chose 1<β<1 further increase their degree of accommodation. The reason is that the ratio var(φ)/var(γ) increases in φ if β<1-δ and decreases in φ if 1<β<1. Hence, more conservative central bankers view a more flexible
labour market as a reason to tighten the response of the money supply to shocks, while the opposite is the case for more left-wing central bankers.

4 Stabilisation and Intramarginal Intervention under an Exchange Rate Band

4.1 Restricted dirty float: A band on the exchange rate

With an exchange rate band, we postulate a twice differentiable function for the saddlepath:

\[ e - \mu = \Omega(f-\mu). \]  \hspace{1cm} (9')

Use of Ito's Lemma, \( d\Omega = \Omega' (df-d\mu) + \frac{1}{2} \sigma^2 \Omega'' dt \), yields a second-order nonlinear differential equation:

\[
\frac{1}{2} \sigma^2 \Omega''(f-\mu) + \phi(\eta + \lambda)^t \left\{-[\delta \lambda + \eta(1-\beta)] (f-\mu) + \delta \lambda \ \Omega(f-\mu) \right\} \Omega'(f-\mu) - \\
(\eta + \lambda)^t [(1-\delta-\beta) (f-\mu) + \delta \ \Omega(f-\mu)] = 0. \]  \hspace{1cm} (12)

This equation yields a time-invariant relationship between the nominal exchange rate and fundamental. Note that there are only two linear solutions corresponding to the stable and unstable arms of the saddlepath solution of the unrestricted dirty float (see section 3.2). These linear solutions are, of course, not compatible with a band on the nominal exchange rate.

The solution for the exchange rate in the band depends on the nature of the interventions undertaken by the monetary authorities if the exchange rate reaches the boundaries of its band. The band on the nominal exchange rate consists of an upper bound \( (e^u) \) and a lower bound \( (e_L) \). The authorities ensure that the exchange rate does not move outside this band by imposing thresholds \( f^u = \mu + \Omega^t (e^u-\mu) \) and \( f_L = \mu + \Omega^t (e_L-\mu) \) on the fundamental. We focus only on exchange rate solutions that are symmetric about the origin by normalising the central parity to zero (i.e. \( \mu = 0 \)). Hence, \( f^u = f_L \) and \( e^u = -e_L > 0 \). If the fundamental is between \( f^u \) and \( f_L \), the exchange rate is inside its band and the coefficient of intramarginal monetary accommodation is \( \beta \), while, beyond these thresholds, the coefficient of inframarginal accommodation corresponds to the one that is needed to keep the exchange rate fixed at the upper, respectively, lower boundary of the band (i.e. \( 1-\delta \)). The money supply rule which supports this policy is given by the piecewise-linear
$m = \beta f$, for $f^u < f < f_L$ if $\beta < 1-\delta$ and $f_L < f < f^u$ if $1-\delta < \beta < 1$.

$m = (1-\delta)f + \delta e_L$, for $f \geq f_L$ if $\beta < 1-\delta$ and $f \leq f_L$ if $1-\delta < \beta < 1$, \hspace{1cm} (8')

$m = (1-\delta)f + \delta e^u$, for $f \leq f^u$ if $\beta < 1-\delta$ and $f \geq f^u$ if $1-\delta < \beta < 1$.

Note that (8') makes use of $\Omega' < 0$ for $\beta < 1-\delta$, and $\Omega' > 0$ for $1-\delta < \beta < 1$, which correspond to an inverted and regular S-shaped solution of $\Omega(\cdot)$, respectively. The switch points $f^u = \Omega^1(e^u)$ and $f_L = \Omega^1(e_L)$ follow implicitly from the smooth pasting conditions, which are the appropriate boundary conditions (cf. Miller and Weller, 1991). If the fundamental crosses $f^u$ (or $f_L$) from the interior of its band, the nominal interest rate differential, i.e. $i - i^*$, jumps from a negative (positive) value to zero. Hence, the monetary authorities have to implement a discrete contraction (expansion) of the nominal money supply in order to raise (depress) the interest rate and prevent the exchange rate from moving outside its band. Because the market anticipates this regime switch at the boundaries of the band, the exchange rate solution bends and becomes horizontal as the economy approaches the boundaries. This is called the "honeymoon effect".

Beetsma and Van der Ploeg (1993) discuss in detail the dependence of the exchange rate solution on the coefficient of intramarginal monetary accommodation. For $\beta < 1-\delta$, the upper bound $e^u$ translates into a lower bound on the fundamental, $f^u < 0$, which decreases towards minus infinity as $\beta$ approaches the value corresponding to a peg $(\beta \uparrow 1-\delta)$, while for $1-\delta < \beta < 1$, the upper bound $e^u$ translates into an upper bound on the fundamental, $f^u > 0$, which decreases from plus infinity as $\beta$ approaches unity. Figure 2(a) portrays exchange rate solutions for a given bandwidth under various degrees of intramarginal intervention, while Figure 2(b) does the same for the implicit bands on the fundamental.

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20 This specification does not allow intramarginal interventions to depend on how close the exchange rate is to the edges of the band. This would complicate the solution without changing the qualitative features of the analysis very much.

21 Although it is not possible to obtain a closed-form expression for $\Omega(\cdot)$, one can characterise the solution qualitatively (cf. Miller and Weller, 1989). There is a unique solution in the band which fulfills the smooth pasting conditions (for $1-\delta < \beta < 1$ this is guaranteed if $\phi < 1$). For $\beta < 1-\delta$ the solution is downward sloping and for $1-\delta < \beta < 1$ it is upward sloping. It is strictly concave in the upper half of the band, and strictly convex in the lower half of the band.
4.2 Variances of output and the price level under a band

Because an exchange rate band makes the model nonlinear, a solution is not available in closed form and distributions of macroeconomic variables are unknown. Hence, we resort to Monte Carlo simulations in order to study the effects of a band on variances of macroeconomic outcomes (see Appendix 2). Since the optimal intramarginal coefficient of monetary accommodation is invariant to proportional changes in $e_t$ and $\sigma$, we only consider changes in bandwidth as these have the opposite effect of changes in the standard deviation of the fundamental.

Most of the time the exchange rate is inside the band, where intramarginal monetary accommodation (intervention) takes place with accommodation coefficient $\beta$, and the remainder of the time the exchange rate is held fixed at the boundaries. Hence, $\text{var}(y)$ and $\text{var}(p)$ under a band are approximately a weighted average of corresponding variances under an unrestricted dirty float and a fixed exchange rate. Whether variances under a band are closer to variances under an unrestricted dirty float or under a peg, depends on the amount of time the exchange rate spends inside the band relative to the amount of time it spends on the edges of the band. This fraction of time depends on three factors: the speed of mean reversion, the shape of the exchange rate solution (in particular, its steepness in absolute terms) and the width of the band. A higher degree of mean reversion induces variances under a band to behave more like under an unrestricted dirty float. The steeper the exchange rate solution, for a given degree of mean reversion and bandwidth, the more variances under a band behave like under a peg. Finally, a wider band also reduces the relative amount of time spent on the edges, ceteris paribus, thereby making variances behave more like under an unrestricted dirty float.

An increase in labour market flexibility ($\phi$) flattens the saddlepath (cf. section 3.2). Hence, with a band on the nominal exchange rate, the implied gap between the thresholds on the fundamental, beyond which the exchange rate is held on the boundaries of its band, increases. A higher variance of the fundamental ($\sigma^2$) and a higher value of the semi-elasticity of the demand for money with respect to the interest rate ($\lambda$) induce a stronger honeymoon effect on the exchange rate solution, i.e. the solution for the nominal exchange rate flattens. A higher variance shortens the expected time towards stabilisation of the exchange rate at its boundaries. The prospect of future stabilisation strengthens the exchange rate now if it is in the upper half of its band, and weakens the exchange rate if it is in the lower half of the band. Similarly, a higher $\lambda$ adds to the forward-looking character of the solution and increases the response of the current spot exchange rate to changes in the expected rate of change in the future (cf. Krugman, 1991). Hence, the imminent stabilisation at the boundaries of the band has a stronger stabilising effect on the
exchange rate now. Summarising, via their effect on the exchange rate solution, a higher $\sigma^2$, a higher $\lambda$ and a higher $\phi$ shift variances under a band in the direction of their counterparts under an unrestricted dirty float. However, these parameter changes also affect the degree of mean reversion. A higher variance leads to relatively more time being spent at the edges of the band, counteracting its effect via the exchange rate solution. However, a higher $\phi$ increases the degree of mean reversion (Beetsma and van der Ploeg, 1993), thus strengthening the effect of an increase in $\phi$ through the shape of the exchange rate solution.

How does the degree of intramarginal intervention affect the variances of output and the price level under various bandwidths? Figure 3 depicts $\text{var}(y)$ under, respectively, goods demand, money demand and supply shocks, for varying coefficients of intramarginal accommodation and a number of bandwidths (including an unrestricted dirty float). Figure 3 also graphs $\text{var}(p)$ under supply shocks. The simulations assume $\eta=\lambda=\delta=\phi=0.5$, $\sigma_w=0.0125$, $\sigma_n=0.0125$ and $\sigma_z=0.05$. The instantaneous standard deviations have been chosen to ensure that they yield the same instantaneous standard deviation for the fundamental, $\sigma$. Hence, for given $\beta$, the solution of the exchange rate as a function of the fundamental is the same for each type of shock. Figure 3 confirms that, for a given coefficient of intramarginal intervention in the range $0<\beta<1$, the variance under a band lies between the variance under an unrestricted dirty float and the variance under a peg.

**Proposition 4: Variances under various bandwidths**  
(a) If there are only goods demand shocks, the variances of output and the price level under a band exceed (are less than) the corresponding variances under an unrestricted dirty float for small (large) coefficients of intramarginal accommodation, i.e. for $0<\beta<1-\delta$ (i.e. for $1-\delta<\beta<1$). In fact, the variances of output and the price level decline (rise) with the bandwidth for relatively small (large) intramarginal accommodation coefficients.  
(b) If there are only money demand shocks, the variances of output and the price level increase with the bandwidth for all coefficients of intramarginal monetary accommodation (except $\beta=1-\delta$). Hence, the introduction of a band reduces the variances of output and the price level.  
(c) If there are only supply shocks, for relatively low coefficients of intramarginal monetary accommodation, i.e. $\beta<1-\delta$, $\text{var}(y)$ is smaller and $\text{var}(p)$ is larger, the narrower the band. However, for $1-\delta<\beta<1$, $\text{var}(y)$ rises and $\text{var}(p)$ falls as the band narrows. Clearly, an unrestricted dirty float is desirable for output (price) stability if the coefficient of intramarginal

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22 The behaviour of $\text{var}(p)$ under goods demand and money demand shocks is qualitatively the same as that of $\text{var}(y)$, so for sake of brevity we have not plotted $\text{var}(p)$. 

accommodation coefficient is relatively high (small).

Figure 3 also indicates that, with goods demand shocks, a given bandwidth yields a better performance (in terms of output/employment stability) than an unrestricted dirty float for relatively high coefficients of intramarginal intervention (i.e. $1-\delta<\beta<1$). With money demand shocks, a band always performs better than an unrestricted dirty float. With supply shocks, a band improves performance in terms of output stability at the expense of price stability if the coefficient of intramarginal monetary accommodation is small (i.e. $\beta<1-\delta$), and vice versa if $\beta$ is large (i.e. $1-\delta<\beta<1$).

4.3 Second-best foreign exchange market intervention

A standard result in the literature (e.g. Davis 1977, Chapters 5 and 6) states that with a quadratic objective function and a linear dynamic model, a linear control rule will be optimal. As an exchange rate band corresponds to a piece-wise linear money supply rule, a band cannot (in the absence of speculative bubbles) outperform an unrestricted dirty float. Hence, in a first-best situation, a central bank does not wish to restrict the use of the money supply instrument, and thus an exchange rate band is not advisable. However, in practice many countries do maintain a band on the exchange rate, the most notable example being the member countries of the European Monetary System (EMS). These bands are probably not installed to ensure better macroeconomic stabilisation, but for political reasons or credibility purposes. The latter is often suggested to be a major motivation for tying one’s currency to the D-mark (e.g., see Giavazzi and Pagano, 1988) or for having a band on the exchange rate (e.g., Svensson, 1992b; Cukierman, Kiguel and Leiderman, 1993). We take the presence of an exchange rate band as given and investigate how a band affects welfare losses.

Proposition 5: Welfare losses under a band
(a) If there are only money demand shocks, establishing an exchange rate band does not induce welfare losses. Also, the optimal degree of intramarginal intervention under a band is the same as under an unrestricted dirty float.
(b) If there are only goods demand shocks or supply shocks, an exchange rate band generally induces welfare losses. Relative (to an unrestricted dirty float) welfare losses under a band are larger if the band is narrower and the instantaneous variance of the exogenous shocks is higher.

With money demand shocks a band does not lead to welfare losses, since the central bank
simply keeps the exchange rate at the central parity. For the other two types of shocks, a
narrower band or a higher variance makes a band relatively more harmful. With goods demand
and supply shocks, a band forces monetary authorities to switch to sub-optimal foreign exchange
market intervention from time to time in order to defend the band. This induces a change in the
degree of monetary accommodation inside the band away from what would have been optimal
under a UDF. In a sense, there is a trade-off between sub-optimal intramarginal intervention and
sub-optimal inframarginal intervention. Both the direction and the size of the bias in the degree of
inframarginal intervention depend on how much worse a peg is compared to the optimal degree of
monetary accommodation under a UDF and on how the fraction of time spent in either regime is
affected. In general, shifting the degree of intramarginal accommodation away from the 'pegpoint'
(β = 1-δ) implies a stronger honeymoon effect and thus a larger part of the time being spent inside
the band. At the same time, a shift in the degree of intramarginal intervention changes the degree
of mean reversion of the exchange rate. Stronger mean reversion implies that the exchange rate
spends a larger fraction of its time inside the band.

Another second-best case arises if the central bank bank is restricted to a given, for
example zero, degree of intramarginal intervention. Is it then desirable to join an exchange rate
arrangement which imposes a band on the exchange rate?

Proposition 6: Desirability of a band for a given degree of intramarginal intervention

(a) If there are only goods demand shocks, introducing a band induces welfare losses if $\beta \leq \beta < 1-\delta$
and welfare gains if $1-\delta \leq \beta < 1$.

(b) If there only money demand shocks, an exchange rate band is desirable for any degree of
inframarginal intervention $\beta \neq 1-\delta$.

(c) If there are only supply shocks, the desirability of a band depends on the weight attached to
price stability. For low degrees of intramarginal accommodation (i.e. $\beta < 1-\delta$), a central banker
who places a relatively high weight on price stability ($\gamma$ large) does not want to impose a band,

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23 This seems contradictory, because a band sometimes requires the central bank to change its degree of
monetary accommodation in order to defend the band. However, one can think of a situation where the
rules of a multilateral exchange rate system have priority to national rules. For example, central banks of
EMS participants are obliged, as part of the arrangement, to intervene if exchange rates are at the edges of
their bands. However, the arrangement does not involve any commitment to monetary policy if the
exchange rate is inside the band.

24 A central bank, constrained by a given $\beta$, may wish to impose a band that is as narrow as possible
(i.e., a peg). However, such regimes are usually multilateral with a common bandwidth for all bilateral
exchange rates (as in the EMS). Hence, the question is whether an authority restricted to a given $\beta$ wishes
to join such an arrangement with a given bandwidth.
while a central banker who places relatively little weight on price stability (γ small) finds a band desirable. However, if 1-δ<β<1, conservative central bankers find a band on the nominal exchange rate worthwhile.

If there are only goods demand shocks, a very countercyclical monetary policy (i.e. β much less than β) makes a band worthwhile as variances under a UDF may exceed variances under a peg. In part (c), by a central bank that places 'relatively high weight' on price stability, we mean a central banker who would choose a degree of monetary accommodation lower than (1-δ) in absence of a band. Proposition 7 thus suggests that a band is preferred to an unrestricted dirty float if the given degree of intramarginal intervention is sub-optimal compared to β=1-δ.

5 Concluding remarks

We have analysed macroeconomic stabilisation and foreign exchange market interventions within the context of small open economy. With money demand shocks a pegged exchange rate is optimal, but with goods demand shocks a nominal income target is best. With supply shocks the optimal coefficient of monetary accommodation rises with the relative weight attached to output rather than price stability. A clean float is seldom optimal. Countries impose exchange rate bands for various reasons to do with politics and credibility. It is thus interesting to ask whether such a band is desirable from a stabilisation point of view. In a first-best situation a band is not advisable, although with money demand shocks no welfare losses are incurred. For goods demand and supply shocks, a band performs relatively worse the narrower it is and the higher the variance of the shocks is. In a second-best situation in which a given band is in place, authorities trade off enhanced use of interventions at the boundaries versus suboptimal intervention policy inside the band.

In this paper the desirability of exchange rate bands has been studied from a stabilisation point of view. A direction for future research is to investigate whether a welfare case for exchange rate bands can be made on credibility rather than on stabilisation grounds. Such an analysis trades off the benefits of an exchange rate band in terms of enhanced credibility against the costs of a potentially reduced scope for stabilisation. Our analysis has been concerned with stabilising properties of credible exchange rate bands. Hence, a line for further research is to investigate how macroeconomic stability is affected by imperfect credibility of the band.

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Appendix 1: Fiscal policy and monetary accommodation

Allowing for fiscal policy gives the IS-curve:

\[ y = -\eta (i-\pi) + \delta (e+p^* - p) + g + v, \quad \eta > 0, \, 0 < \delta < 1, \quad (1') \]

where \( g \) denotes the fiscal stimulus by the government. If fiscal and monetary policy are given by \( g = \beta_1 f \) and \( m = \beta_2 f \), respectively, where for simplicity we set \( \mu = 0 \), we have:

\[
\begin{aligned}
\begin{bmatrix}
\frac{df}{dt} \\
E_d(e_d)
\end{bmatrix} &= \frac{1}{(\eta + \lambda)} \begin{bmatrix}
\phi \lambda (\beta_1 - 1) + \phi \eta (\beta_2 - 1) & \phi \delta \lambda \\
(1 - \delta) + (\beta_1 - \beta_2) & \delta
\end{bmatrix} \begin{bmatrix}
f \\
e
\end{bmatrix} dt + \begin{bmatrix}
\sigma dz \\
0
\end{bmatrix},
\end{aligned}
\]

where

\[
\sigma = \sqrt{\sigma_p^2 + (\sigma_e^2 + \sigma_w^2)/(1 - \delta)^2}.
\]

The slope of the stable saddlepath, \( \omega \) in \( e = \omega f \), is given by:

\[
\omega = \left[ \frac{\delta (1 + \phi \lambda) + \phi \eta (1 - \beta_2) - \phi \lambda \beta_1 - \sqrt{\delta (1 + \phi \lambda) + \phi \eta (1 - \beta_2) - \phi \lambda \beta_1}^2 + 4 \phi \delta \lambda (1 - \delta + \beta_1 - \beta_2)}{2 \phi \delta \lambda} \right].
\]

**Proposition A.1:** Properties of the saddlepath slope

(a) Let \( \beta_1 < \min\{\delta (1 + \phi \lambda)/\phi \lambda, \delta (1 + \phi \eta)/\phi \eta\} \). Then \( \partial \omega / \partial \beta_2 > 0 \) for \( \beta_2 < 1 \).

(b) Let \( \beta_1 < \min\{2 \delta (1 + \phi \lambda)/(1 + \phi \lambda), (\delta (1 + \phi \lambda) + \phi \eta)/\phi \lambda\} \). Then \( \omega > -1 \) for \( \beta_2 \geq 0 \). In particular, if \( \beta_1 = 0 \) (no fiscal stimulus) and \( \delta \geq 1/2 \), then \( \omega > -1 \) for \( \beta_2 \geq 0 \).

(c) If \( \beta_1 \geq \delta (\phi - 1)/\phi \lambda \), then \( \omega \rightarrow 1 - \beta_2/\delta \), as \( \beta_2 \uparrow 1 \). Otherwise, \( \omega \rightarrow 1/\phi \lambda \) as \( \beta_2 \uparrow 1 \). In particular, if \( \beta_1 = 0 \) (no fiscal stimulus) then, if \( \phi \lambda \leq 1 \) then \( \omega \rightarrow 1 \) as \( \beta_2 \uparrow 1 \), while otherwise \( \omega \rightarrow 1/\phi \lambda \) as \( \beta_2 \uparrow 1 \).

(d) Let \( \beta_2 < \delta \). If \( \beta_2 < 1 - \delta + \beta_1 \), then \( \partial \omega / \partial \phi > 0 \). If \( \beta_2 = 1 - \delta + \beta_1 \), then \( \partial \omega / \partial \phi = 0 \). If \( 1 - \delta + \beta_1 < \beta_2 < 1 \), then \( \partial \omega / \partial \phi < 0 \).

(e) Let \( \beta_2 = 1 \) (full accommodation). If \( \beta_1 \geq \delta (\phi - 1)/\phi \lambda \), then \( \partial \omega / \partial \phi = 0 \). Otherwise, \( \partial \omega / \partial \phi < 0 \).

(f) Let \( \beta_2 < \min\{1 - \delta + \beta_1, 1\} \). Then \( \partial \omega / \partial \beta_1 < 0 \).

This proposition generalises the properties of \( \omega \) as a function of \( \beta_2 \) to allow for the effects of a fiscal stimulus. Part (a) states the conditions under which \( \omega \) increases with the degree of monetary accommodation \( \beta_2 \). Depending on the degree of fiscal activism, (c) gives the limit of \( \omega \) as \( \beta_2 \) approaches full monetary accommodation. The pegpoint now corresponds to \( \beta_2 = 1 - \delta + \beta_1 \). Again, as a function of the degree of monetary accommodation, \( \omega \) pivots around the pegpoint. Finally, part (f) says that the saddlepath slope decreases in the degree of fiscal activism. Using a similar procedure as in section 3.4, we obtain the asymptotic variances of output and the price
level:

\[
\text{var}(p) = (2\phi)^{-1} \left[ k_1(\beta_1, \beta_2) \sigma_p^2 + k_2(\beta_1, \beta_2) \sigma_x^2 + k_3(\beta_1, \beta_2) \sigma_z^2 \right]
\]

\[
\text{var}(y) = (2\phi)^{-1} \left[ \sigma_p^2 + k_2(\beta_1, \beta_2) \sigma_x^2 + \delta k_3(\beta_1, \beta_2) \sigma_z^2 \right] / k_1(\beta_1, \beta_2)
\]

where

\[
k_1(\beta_1, \beta_2) = \frac{\eta + \lambda}{\eta(1-\beta_2) + \delta \lambda (1-\omega) - \lambda \beta_2},
\]

\[
k_2(\beta_1, \beta_2) = \frac{[\lambda(1+\delta(\omega-1)) + \eta \beta_2 + \lambda \beta_2] \lambda}{(1-\delta)^2 \left[ \lambda(1+\delta(1-\omega)) + \eta(2-\beta_2) - \lambda \beta_2 \right] \left[ \delta \lambda (1-\omega) + \eta(1-\beta_2) - \lambda \beta_2 \right]}
\]

\[
k_3(\beta_1, \beta_2) = \frac{[\delta \lambda \omega + \eta(\beta_2 + \delta - 1) + \lambda \beta_2] \lambda}{(1-\delta)^2 \left[ \delta \lambda (1-\omega) + \eta(1-\beta_2) - \lambda \beta_2 \right] \left[ \delta \lambda (2-\omega) + \eta(1-\delta - \beta_2) - \lambda \beta_2 \right]}
\]

In order to guarantee the existence of the asymptotic variances, we assume that \( \beta_1 < \delta, \beta_2 < 1-\delta + \beta_1 \) for \( 0 < \beta_1 < \delta \), and \( \beta_2 < 1 \) for \( \beta_1 \leq 0 \). Since \( \beta_1 + \delta \omega \) increases in \( \beta_1 \), we have the following proposition.

Proposition A.2: Fiscal activism and the optimal degree of monetary accommodation

(a) Suppose shocks only occur in goods demand. Then, if \( \delta - 1 < \beta_1 < \delta \), there exists a degree of monetary accommodation, say \( \beta_2 (\beta_2 \leq 0) \), such that \( \lambda(1+\delta(\omega-1)) + \eta \beta_2 + \lambda \beta_2 = 0 \). Furthermore, \( \partial \beta_2 / \partial \beta_1 < 0 \). In particular, if \( \beta_1 = \delta - 1 \), then \( \beta_2 = 0 \).

(b) Suppose shocks only occur in money demand. Then, if \( 0 \leq \beta_1 < \delta \), there exists a degree of monetary accommodation, say \( \beta_2 \), such that \( \delta \lambda \omega + \eta(\beta_2 + \delta - 1) + \lambda \beta_2 = 0 \). Furthermore, \( \partial \beta_2 / \partial \beta_1 < 0 \).

(c) Suppose only supply shocks occur. Then, if \( \beta_1 < 0 \), full monetary accommodation (\( \beta_2 = 1 \)) stabilises output.

In other words, part (a) states that, in case of goods demand shocks, for a fiscal policy which is neither too pro-cyclical nor too counter-cyclical, there exists a (unique) degree of monetary accommodation (\( \beta_2 \leq 0 \)) which completely stabilises output and producer prices. The degree of counter-cyclical monetary intervention rises with the degree of fiscal pro-cyclical. The intuition is that if a positive goods demand shock provokes a less counter-cyclical fiscal reaction, a
stronger contraction in the money is needed to stabilise output and the producer price level. If there are only goods demand shocks, choosing a degree of fiscal activism corresponding to \( \beta_1 = 1 - \delta \) completely stabilises output and the price level. Hence, using monetary policy to fix the exchange rate stabilises an economy subject to money demand shocks, while using fiscal policy to stabilise the exchange rate stabilises an economy subject to goods demand shocks. If fiscal policy is moderately procyclical, part (b) shows that in case of money demand shocks, there is a (unique) degree of monetary accommodation which completely stabilises output and producer prices.

**Proposition A.3: Effects of more fiscal activism**

(a) Suppose there are only goods demand shocks. If there exists a degree of fiscal activism \(-(1 - \delta) < \beta_1 < \delta\), say \( \beta_1 \), such that \( \lambda (1 + \delta(\omega - 1)) + \eta \beta_2 + \lambda \beta_1 = 0 \), then \( \partial \text{var}(p)/\partial \beta_1 > 0 \) and \( \partial \text{var}(y)/\partial \beta_1 > 0 \) for \( \beta_1 < \beta_1 < \delta \). If for \( \beta_1 = \delta - 1 \), \( \lambda (1 + \delta(\omega - 1)) + \eta \beta_2 + \lambda \beta_1 > 0 \), then \( \partial \text{var}(p)/\partial \beta_1 > 0 \) and \( \partial \text{var}(y)/\partial \beta_1 > 0 \) for \(-(1 - \delta) < \beta_1 < \delta\). In particular, if \( \beta_2 = 0 \) (no monetary accommodation), then \( \partial \text{var}(p)/\partial \beta_1 > 0 \) and \( \partial \text{var}(y)/\partial \beta_1 > 0 \) for \(-(1 - \delta) < \beta_1 < \delta\).

(b) Suppose shocks occur only in money demand. If there exists a degree of fiscal activism \( 0 < \beta_1 < \delta \), say \( \beta_1 \), such that \( \delta \omega + \eta (\beta_2 + \delta - 1) + \lambda \beta_1 = 0 \), then, for \( 0 \leq \beta_1 < \beta_1 \), \( \partial \text{var}(p)/\partial \beta_1 < 0 \) and \( \partial \text{var}(y)/\partial \beta_1 < 0 \), while, for \( \beta_1 < \beta_1 < \delta \), \( \partial \text{var}(p)/\partial \beta_1 > 0 \) and \( \partial \text{var}(y)/\partial \beta_1 > 0 \).

If, for \( \beta_1 = 0 \), \( \delta \omega + \eta (\beta_2 + \delta - 1) + \lambda \beta_1 > 0 \), then \( \partial \text{var}(p)/\partial \beta_1 > 0 \) and \( \partial \text{var}(y)/\partial \beta_1 > 0 \) for \( 0 \leq \beta_1 < \delta \). If, for \( \beta_1 = \delta \), \( \delta \omega + \eta (\beta_2 + \delta - 1) + \lambda \beta_1 < 0 \), then \( \partial \text{var}(p)/\partial \beta_1 < 0 \) and \( \partial \text{var}(y)/\partial \beta_1 < 0 \) for \( 0 \leq \beta_1 < \delta \). In particular, let \( \beta_2 = 0 \) (no monetary accommodation). If \( \lambda < (1 + \phi \eta)(1 - \delta)/\phi \delta \), then \( \partial \text{var}(p)/\partial \beta_1 < 0 \) and \( \partial \text{var}(y)/\partial \beta_1 < 0 \) for \( 0 \leq \beta_1 < \delta \). Otherwise, there exists a degree of fiscal activism \( 0 \leq \beta_1 < \delta \), say \( \beta_1 \), such that \( \delta \omega + \eta (\beta_2 + \delta - 1) + \lambda \beta_1 = 0 \).

(c) If there are only supply shocks, \( \partial \text{var}(p)/\partial \beta_1 > 0 \) and \( \partial \text{var}(y)/\partial \beta_1 < 0 \) for \( \beta_1 < 0 \).

In part (a) the degree of fiscal activism is restricted to be neither too counter-cyclical nor too procyclical. If shocks come from goods demand and if there exists a degree of fiscal activism which completely stabilises output and producer prices, then, beyond this value for \( \beta_1 \), \( \text{var}(p) \) and \( \text{var}(y) \) monotonously increase in the degree of fiscal activism. Similarly for the case of goods demand shocks. Hence, with goods or money demand shocks, the effects of a more pro-cyclical fiscal policy go in the same direction both for \( \text{var}(p) \) and \( \text{var}(y) \). With supply shocks, however, the effects on \( \text{var}(p) \) and \( \text{var}(y) \) move in opposite directions.
Appendix 2: Monte Carlo simulations

The simulation technique is based on Duffie and Singleton (1988). Prior to simulation, the second-order ordinary differential equation (12) is solved numerically for the function $\Omega(f)$. Given roughly 200 points of this function between the boundaries of the band, intermediate points were found using linear interpolation of the two nearest points. Third-order polynomial interpolation (Davis and Rabinowitz, 1975) yields results that are hardly different. To simulate the structural continuous-time model, it must be discretised. The parameter values that have been chosen correspond to a unit time interval. First, given $p_i$, $v_i$, $w_i$, $e_i$ and a number of draws from the normal distribution for the additive shocks, $p_{i+1}$, $v_{i+1}$, $w_{i+1}$ (hence, $f_{i+1}$) can be calculated as a linear combination of these variables. Second, one can calculate $e_{i+1} = \Omega(f_{i+1})$ from the numerical solution of $\Omega(f)$. It is straightforward to calculate the simulated values of other endogenous variables as well.

Clearly, this discretisation is much too coarse and estimates of asymptotic variances based on this discretisation are inconsistent. Better approximations are obtained if the model is simulated at a higher frequency. Hence, in practice each unit of time is divided into $n$ parts and $n$ in-between simulations are performed over each of the $T$ unit time intervals. Of course, the parameter values are adjusted to allow for the higher sampling frequency. Similarly, the variances of the shocks are adjusted to allow for the higher frequency, i.e. $\sigma_i/n$ replaces $\sigma_i$ ($i=p,v,w$). Although more sophisticated schemes are available, a simple first-order Euler scheme has been used in the simulations presented in this paper. Duffie and Singleton (1988) show that consistent estimation of the variances of the variables requires a minimal ratio $n/T$, at which both $n$ and $T$ should go to infinity.

The set-up of the Monte Carlo simulation procedure is as follows. From a long time series, $N$ series of $T$ observations are drawn, making sure to throw away a number of observations between subsequent sequences of $T$ observations. A grid of size $n$ is used for the in-between simulations. In practice, typical values were $n=25$, $N=10$ and $T=1000$. If $n$ tends to infinity, the discrete approximation to the continuous-time distribution becomes exact. Because all variables are defined to have an asymptotic mean equal to zero and $n$ is chosen to be relatively large, the test statistic

$$s_{x,i}^2 = \frac{(x_{i1}^2 + x_{i2}^2 + \ldots + x_{iT}^2)}{T}, \quad i=1,2,\ldots,N$$

is approximately an unbiased estimator of the unconditional variance of the variable $x$. Clearly,

$$s_x^2 = \frac{(s_{x,1}^2 + s_{x,2}^2 + \ldots + s_{x,n}^2)}{N}$$

is also an estimator of the unconditional variance of $x$. The statistic

$$[(s_{x,1}^2-s_x^2)^2 + \ldots + (s_{x,N}^2-s_x^2)^2]/[N(N-1)]$$

is approximately an unbiased estimator of the unconditional variance of the variable $x$. Clearly,
is approximately an unbiased estimator of the variance of $s_0^2$, given that the number of observations thrown away between subsequent sequences of $T$ observations is large enough to rule out serial correlation between the $s_{a,i}^2$. 
Table 1: Variances of output and the price level under an unrestricted dirty float

(a) $\text{var}(y)$ under various targets and different shocks

<table>
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<tr>
<th>Regime</th>
<th>Goods demand shocks</th>
<th>Money demand shocks</th>
<th>Supply shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIT ($\beta = \beta &lt; 0$)</td>
<td>0</td>
<td>$\frac{1}{2} \sigma_y^2 / \phi(1 + \delta)$</td>
<td>$\frac{1}{2} \sigma_y^2 / \phi$</td>
</tr>
<tr>
<td>FLOAT ($\beta = 0$)</td>
<td>$\frac{[\lambda(1 + \delta(\omega - 1))]^2}{\lambda(1 + \delta(1 - \omega)) + 2 \eta}$</td>
<td>$\frac{[\delta \lambda \omega + \eta(\delta - 1)]^2}{\delta \lambda(2 - \omega) + \eta(1 + \delta)}$</td>
<td>$\frac{[\eta + \delta \lambda(1 - \omega)] \sigma_p^2}{2 \phi(\eta + \lambda)}$</td>
</tr>
<tr>
<td>PEG ($\beta = 1 - \delta$)</td>
<td>$\frac{1}{2} \sigma_y^2 / \phi(1 + \delta)$</td>
<td>0</td>
<td>$\frac{1}{2} \sigma_p^2 / \phi$</td>
</tr>
<tr>
<td>FA ($\beta = 1$)</td>
<td>$\frac{1}{2} \sigma_y^2 / \phi(1 - \delta)^2$</td>
<td>$\frac{1}{2} \sigma_p^2 / \phi(1 - \delta)^2$</td>
<td>0</td>
</tr>
</tbody>
</table>

(b) $\text{var}(p)$ under various targets and different shocks

<table>
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<td>$\frac{(\eta + \lambda) \sigma_p^2}{2 \phi[\eta + \delta \lambda(1 - \omega)]}$</td>
</tr>
<tr>
<td>PEG ($\beta = 1 - \delta$)</td>
<td>$\frac{1}{2} \sigma_y^2 / \phi (1 + \delta)$</td>
<td>0</td>
<td>$\frac{1}{2} \sigma_p^2 / \phi \delta$</td>
</tr>
<tr>
<td>FA ($\beta = 1$)</td>
<td>$\infty$</td>
<td>$\infty$</td>
<td>$\infty$</td>
</tr>
</tbody>
</table>

Remarks: FLOAT = free float; FA = full accommodation (assumes $\phi \lambda \leq 1$ and corresponds to PPP rule in case of supply shocks); NIT = nominal income target; PEG = fixed nominal exchange rate.
Figure 1: Adjustment along the saddlepath under a dirty float after an unanticipated increase in the long-run component ($\mu$) of the fundamental.

(a) Low degree of monetary accommodation ($\beta < 1 - \delta$)

(b) High degree of monetary accommodation ($1 - \delta < \beta < 1$)
Figure 2: Exchange rate solutions and fundamental bands.

(a) Solutions $e=\Omega(f)$ and the degree of intramarginal accommodation ($\beta$)

(b) Bands on the fundamental and the degree of intramarginal accommodation ($\beta$)
Figure 3: Variances of output (and producer prices) under various widths of the nominal exchange rate band and various sources of shocks.

(a) $\text{Var}(y)$ under goods demand shocks only ($\sigma_r > 0$)

(b) $\text{Var}(y)$ under money demand shocks only ($\sigma_w > 0$)

(c) $\text{Var}(y)$ under supply-side shocks only ($\sigma_p > 0$)

(d) $\text{Var}(p)$ under supply-side shocks only ($\sigma_p > 0$)

Note: UDF refers to unrestricted dirty float, while $\pm 2.25\%$ and $\pm 6\%$ refer to the two bandwidths portrayed in the figures.
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