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# Disinflation in an Open-Economy Staggered-Wage DGE Model: Exchange-Rate Pegging, Booms and the Role of Preannouncement\*

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## ABSTRACT

A dynamic general equilibrium model of an open economy with staggered wages is constructed. We analyse disinflation through pegging the exchange rate. In accordance with the stylised facts, an initial boom in output can result, depending on the exact level of the peg. The reason is an element of preannouncement in the policy. Disinflation through reducing monetary growth is shown to be equivalent to disinflation through pegging the exchange rate, if the latter includes an initial currency revaluation. This helps explain why such disinflation causes a short-run slump. The model can also help explain inflation persistence.

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**Keywords:** Exchange-rate-based disinflation, money-based disinflation, staggered wages, preannouncement effects.

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## 1. Introduction

Despite the fact that, early in the first decade of the third millennium, inflation around the world reached a low not seen in the previous fifty years<sup>1</sup>, as the decade has worn on inflationary pressures have been rising.<sup>2</sup> Amongst the approaches currently in use to restore control over inflation are some relative newcomers such as inflation targets, but also some old favourites such as monetary targets and exchange-rate pegs. Notwithstanding the interest of the new policies, in this paper we draw attention to unfinished business in the analysis of the old ones. This is important not just for historical reasons. These policies are still in operation in a number of countries, and are likely to regain prominence in the coming years.

One of the most tantalising stylised facts about simple disinflation rules is that, whereas money-based (MB) disinflations have tended to cause slumps on impact, exchange-rate-based (ERB) disinflations have tended to cause booms. Various explanations have been advanced for this. The puzzle is particularly the boom, since, from a traditional Keynesian perspective, a contractionary monetary policy would be expected to cause a slump.<sup>3</sup> Here we present a theoretical analysis which highlights a neglected factor in explaining the boom under an ERB disinflation. This is the role of preannouncement. By ‘preannouncement’ we mean the fact that the policy (or at least some stages of it) is announced in advance by the authorities.

A recent paper by Hamann et al. (2005) provides empirical evidence supporting the importance of preannouncement, arguing that the conventional view that ERB disinflations cause booms is rejected by the data if disinflation policies are categorised on ‘de facto’ rather than (as is usually done) on ‘de jure’ grounds. An ERB disinflation is ‘de jure’ if the policy is announced to be one of pegging the exchange rate, but ‘de facto’ if, ex post, the exchange rate is observed to be pegged. The de facto classification turns out to enlarge the set of ERB disinflations. When this is used Hamann et al. find on average no difference between ERB and non-ERB disinflations as concerns the initial boom. However, since there *is* a difference

when the de jure classification is used, they conclude that the announcement itself is important in causing the boom.

In this paper, we investigate disinflation policies using a qualitative dynamic general equilibrium (DGE) model of a small open economy with tradeable and nontradeable sectors, and wages set in a staggered fashion. Although a staggered-price or -wage framework has often been used in disinflation analysis before, most authors to date have not taken a complete DGE approach, where behaviour in all sectors is derived from intertemporal optimisation and is consistent across sectors. With the ‘direct postulation’ approach of the more traditional literature, on the other hand, some parameter restrictions which should apply across different equations of the model are overlooked. Exploiting these restrictions enables us to avoid certain of the puzzles arising in earlier contributions.<sup>4</sup>

An outline of why a preannounced ERB disinflation can cause a short-run boom in such a setting is as follows. A disinflation policy announced but not immediately implemented causes private agents, under rational expectations, to alter their behaviour immediately. With staggering of wages, wage-setters need to be forward-looking. Expectations of lower future price inflation cause wage inflation to begin to moderate in advance of the fall in price inflation. There is thus a favourable supply-side effect, tending to expand output and employment. However, in the case of a preannounced monetary disinflation there is another effect, working through the demand side, which counteracts this. The expectation of lower inflation reduces the current nominal interest rate, increasing the demand for real money balances. The current supply of real balances cannot increase since the nominal money stock is unchanged and nominal rigidity prevents a significant fall in the price level, so consumption must fall in order to choke off the extra money demand. This contracts the demand for output. On balance, it turns out that a preannounced money-growth slowdown produces a recession. In the case of a preannounced exchange-rate peg, on the other hand -

where devaluation continues at a predetermined rate until a certain date at which the exchange rate is fixed at the level then reached - the demand-side effect is absent. The reason is that the money supply is endogenous in such a regime, and is thus able to jump upwards to meet the increased demand for it. The supply-side effect of the preannouncement therefore prevails, resulting in a boom.

In the earlier literature it was noted by Fischer (1986), regarding *unanticipated* disinflations, that pegging the exchange rate rather than reducing money supply growth could be a way of avoiding a slump, and he recognised an endogenous increase in the money supply as the mechanism which could enable this. Fischer even acknowledged the possibility of a boom. However, he was not setting out to explain a boom and he did not study preannounced policy.<sup>5</sup> Preannounced policy, on the other hand, does - at least implicitly - play a role in Ball's (1994) closed-economy analysis, in which he obtains a boom following a *money*-based disinflation. Ball interprets the boom as an empirical failure of the basic staggered-price macro model and thus as a key weakness of it. The mechanism behind it in our model is essentially the same as in Ball's, except that in our case the boom results only from an *exchange-rate*-based disinflation. In our case the boom is therefore a virtue of the model, not a weakness.

Perhaps the most influential analysis to date, contrasting the effects of ERB and MB disinflation, is by Calvo and Végh (1994), who explain the initial boom under the former mainly by the rationally anticipated collapse of the policy. Our paper in part updates theirs, by basing staggered price or wage setting on intertemporal optimisation and thus embedding it in dynamic general equilibrium; and in part complements it, by proposing an explanation for the boom which does not rely on the policy's expected failure. Our emphasis on a supply-side explanation echoes a similar theme in the insightful survey of Rebelo and Végh (1995), although our supply-side mechanism differs from those they consider.

Although our paper emphasises preannounced disinflation, we begin by studying the more basic case of unanticipated disinflation. This yields some subsidiary results of interest. In an unanticipated ERB disinflation, we first argue that there is a range of values at which the exchange rate could be fixed, any of which are roughly consistent with the idea of pegging it at its ‘current’ value. We show that while some of these values cause a short-run slump, others cause a boom. The exact level of the peg hence emerges as very important. Subsequently we explain the boom outcome by arguing that an element of preannouncement can be present even in a seemingly ‘unanticipated’ ERB disinflation. We also show that if one allows the level of the peg in the case of an unanticipated ERB disinflation to be chosen freely, then the case of an unanticipated MB disinflation is encompassed within the set of these more general ERB disinflations. This ‘equivalence’ result makes it easy to see why an unanticipated MB disinflation is always contractionary whereas an unanticipated ERB disinflation (in which the exchange rate is pegged at its ‘current’ level) is not.

Lastly, although we mainly focus on short-run output effects, our analysis has implications for the question of inflation ‘persistence’. Various authors have argued that basic staggered-price or -wage models predict an implausibly rapid reduction of inflation after the introduction of a disinflation policy. We show that while this remains true for MB disinflation in our model, it is not true for ERB disinflation. Therefore some of the recent extensions of the basic price-staggering assumptions which such a criticism has motivated may in fact be unnecessary.

The structure of the rest of the paper is as follows. Section 2 presents the microeconomic elements of the model. In Section 3 we look at the general macroeconomic equilibrium and derive a loglinearised version as the basis for subsequent applications. The analysis of unanticipated disinflation is conducted in Section 4, while preannounced policy is

considered in Section 5. Section 6 discusses the effects on some other variables, and Section 7 concludes.

## 2. Structure of the Model

There are two output sectors: nontradeables and tradeables. We use subscripts  $N$  and  $T$  to denote these sectors, respectively. We adopt the simplifying assumption that output of the tradeable sector is exogenous, time invariant and given by 1.<sup>6</sup> Output of the nontradeable sector at time  $t$  is  $Y_{Nt}$ . Labour is the one variable factor of production and the production function for nontradeables is:

$$Y_{Nt} = N_t^\sigma, \quad 0 < \sigma \leq 1. \quad (1)$$

where  $N_t$  is a composite of labour inputs (defined below). Later we show that the assumption of exogenous tradeable output, together with others, implies that the balance of trade and current account are always zero. This eliminates dynamics arising from the accumulation of net foreign assets over time, and affords a major simplification of the analysis.

We assume markets for both types of good are perfectly competitive and hence their prices are flexible. In the tradeable sector, the law of one price holds, i.e.,  $P_{Tt} = E_t$ , where  $P_{Tt}$  is the domestic-currency price of tradeables and  $E_t$  is the nominal exchange rate, the domestic currency price of foreign exchange. (We normalise the foreign-currency price of tradeables to unity.) In the nontradeables market, the price  $P_{Nt}$  adjusts to equate demand and supply. In the labour market, there is a continuum of labour skills, indexed by  $j \in [0,1]$ . A household controls the supply of each type of labour and sets its money wage for two periods, subject to a demand function presented below.

As regards financial markets, there are two currencies, home and foreign, held only by the residents of the countries concerned. Money is demanded because of the liquidity services it provides. International borrowing and lending may take place between home and foreign private agents, by issuance or purchase of bonds. Since the initial outstanding stock of bonds

will be assumed to be zero, and there is no uncertainty after the policy change at  $t = 0$ , their currency of denomination is immaterial. Perfect capital mobility means that domestic and foreign (gross) interest rates are linked by the usual interest parity condition,  $I_t = I_t^*(E_{t+1}/E_t)$ , where  $I_t$  ( $I_t^*$ ) is the domestic (foreign) gross interest rate.

We turn now to the optimisation problem of individual agents. A typical firm in the nontradeable sector allocates its spending across labour types, where the wage of type  $j$  is  $W_{jt}$  and the quantity of labour each household supplies to the typical firm is  $L_{jt}$ , so as to minimise the cost of achieving a certain amount of a composite labour input given by:

$$N_t = \left[ \int_0^1 L_{jt}^{(\varepsilon-1)/\varepsilon} dj \right]^{\varepsilon/(\varepsilon-1)}, \quad \varepsilon > 1. \quad (2)$$

Here  $\varepsilon$  is the elasticity of technical substitution across labour types. Solving the problem gives a standard conditional demand function for labour of type  $j$ :

$$L_{jt} = N_t (W_t / W_{jt})^\varepsilon, \quad (3)$$

where  $W_t \equiv \left[ \int_0^1 W_{jt}^{1-\varepsilon} dj \right]^{1/(1-\varepsilon)}$  is the wage index. Combined with (1), this then implies the following supply function for nontradeable output:

$$Y_{Nt} = (W_t / \sigma P_{Nt})^{\sigma/(\sigma-1)}. \quad (4)$$

Household  $j$  is representative of all households supplying labour skill  $j$ . It obtains utility from consumption of both types of goods and from real balances, and disutility from supplying labour. As the sole supplier of type- $j$  labour, it is a monopoly union for that labour type. However, since there is a continuum of households over  $j \in [0,1]$ , each household is ‘small’, and thus a price taker, in every other market. The household’s preferences over goods are represented by a Cobb-Douglas sub-utility function:

$$C_{jt} = C_{Njt}^\alpha C_{Tjt}^{1-\alpha}, \quad 0 < \alpha < 1. \quad (5)$$

This is maximised subject to a given aggregate nominal expenditure,  $\Omega_{jt}$ , defined by  $\Omega_{jt} \equiv P_{Nt}C_{Njt} + P_{Tt}C_{Tjt}$ . The resulting demand functions are then:

$$C_{Njt} = \alpha \Omega_{jt} / P_{Nt}, \quad C_{Tjt} = (1 - \alpha) \Omega_{jt} / P_{Tt}. \quad (6)$$

The indirect utility function for this problem can be written as  $C_{jt} = \Omega_{jt}/P_t$ , where  $P_t$  is the consumer price index:

$$P_t = P_{Nt}^\alpha P_{Tt}^{1-\alpha} / \alpha^\alpha (1 - \alpha)^{1-\alpha}. \quad (7)$$

The above spending allocation problem may now be embedded in household  $j$ 's higher-level optimisation problem. Wage staggering is introduced, as in Taylor (1979), by assuming that households are divided into two sectors: A, comprising labour types  $j \in [0, 1/2]$ ; and B, with types  $j \in [1/2, 1]$ . The money wage must be set for two successive periods at the same level. Households in sector A choose their wage in even periods, and solve the following problem:

$$\text{maximise } U_j = \sum_{t=0}^{\infty} \beta^t \left[ \delta \ln C_{jt} + (1 - \delta) \ln(M_{jt} / P_t) - \eta L_{jt}^\zeta \right] \quad (\beta < 1, \zeta \geq 1) \quad (8)$$

$$\text{s.t.} \quad M_{jt-1} + I_{t-1} B_{jt-1} + W_{jt} L_{jt} + \Pi_t + S_t = P_t C_{jt} + M_{jt} + B_{jt}, \quad (9)$$

$$L_{jt} = (W_t / W_{jt})^\varepsilon N_t, \quad \text{for } t = 0, 1, 2, \dots, \infty; \quad (10)$$

$$W_{jt} = W_{jt+1} \equiv X_t, \quad \text{for } t = 0, 2, 4, \dots, \infty. \quad (11)$$

The problem of a sector-B household is the same, except that its wage is given at time 0 and is chosen in odd periods. According to (8), a household derives positive utility from consumption and real money balances, but derives disutility from working.  $\zeta$  is the elasticity of this disutility with respect to labour supplied. The LHS of the budget constraint (9) states that the household's resources in period  $t$  consist of money ( $M_{jt-1}$ ) and bonds ( $I_{t-1} B_{jt-1}$ ) brought forward from the previous period, labour income earned in the period ( $W_{jt} L_{jt}$ ), an equal share in firms' profits ( $\Pi_t$ ), and a lump-sum subsidy from the government ( $S_t$ ). These resources are allocated between consumption, money balances and bond holdings, as shown on the RHS. Equation (10) is the demand function for labour of type  $j$ , derived above, and equation (11) is the wage-setting constraint, implying newly set wages obtain for two periods. We denote the



‘new’ wage by  $X_t$ .<sup>7</sup> Agents are assumed to have rational expectations; completely unanticipated policy changes may occur, but (as is standard in the literature) we assume that once they have occurred, agents put a zero probability on any further policy change happening and have perfect foresight about the future development of the economy.

The above optimisation problem gives rise to the following first-order conditions:

$$C_{jt+1} = \beta [I_t P_t / P_{t+1}] C_{jt}, \quad (12)$$

$$M_{jt} / P_t = [(1 - \delta) / \delta] C_{jt} I_t / (I_t - 1), \quad (13)$$

$$X_t = \frac{\varepsilon}{\varepsilon - 1} \frac{\eta \zeta}{\delta} \frac{L_{jt}^\zeta + \beta L_{jt+1}^\zeta}{L_{jt} / P_t C_{jt} + \beta L_{jt+1} / P_{t+1} C_{jt+1}}. \quad (14)$$

The first two equations are the optimality conditions for intertemporal consumption choice and money holding, respectively. The third gives the new wage as a mark-up ( $\varepsilon/(\varepsilon-1) > 1$ ) over a weighted average of the two wages which would apply within each period were the labour market competitive and not subject to the constraint that the wage is fixed for two periods.

The third type of agent in the model is the government, whose role is to determine either the exchange rate or the growth rate of the money supply. The counterpart of monetary growth is lump-sum subsidies to households. The government’s budget constraint is hence:

$$S_t = M_t - M_{t-1}. \quad (15)$$

We now turn to the market equilibrium conditions. The aggregate demand for money can be found by summing the individual demands, given by (13), across all households  $j$ . Denoting aggregate values by dropping the  $j$  subscript (i.e.,  $C \equiv \int_0^1 C_j dj$ ,  $M \equiv \int_0^1 M_j dj$ ), the equilibrium condition is then:

$$M_t / P_t = [(1 - \delta) / \delta] C_t I_t / (I_t - 1). \quad (16)$$

Whether or not the money supply  $M_t$  is exogenous will depend on the policy rule, as discussed below. Market clearing for nontradeables requires that supply as determined by (4) should equal demand as determined by the aggregate version of (6):

$$(W_t / \sigma P_{Nt})^{\sigma/(\sigma-1)} = \alpha \Omega_t / P_{Nt}. \quad (17)$$

Thus  $P_{Nt}$  is an implicit function of  $(W_t, \Omega_t)$ . Domestic supply of tradeables is fixed exogenously at 1, and may in principle differ from domestic demand as determined by the aggregate version of (6), resulting in a trade surplus or deficit. We denote the surplus by:

$$T_t = 1 - C_{Tt}. \quad (18)$$

Over time, deficits must be balanced by surpluses (appropriately discounted) plus any initial net foreign assets. The national intertemporal budget constraint states this:

$$-I_{-1}B_{-1} = \sum_{t=0}^{\infty} [I_0 I_1 \dots I_{t-1}]^{-1} P_{Tt} T_t. \quad (19)$$

$B_{-1}$  (with no  $j$  subscript) denotes the exogenous total initial private bond holdings. The home government issues no bonds, so  $B_{-1}$  is also the home country's initial net foreign assets. Equation (19) is derived from a no-Ponzi-game condition, ensuring that indebtedness does not go to infinity. Although we start with this general formulation, later we will show that, under our assumptions, in equilibrium the balance of trade is in fact zero in every period.

Turning to the labour market, by substituting out  $L_{jt}$  and  $L_{jt+1}$  from the wage-setting condition (14), using the labour demand function (10) and the wage-setting constraint (11), we obtain the following expression for the new wage:

$$X_t = \left[ \frac{\varepsilon}{\varepsilon-1} \frac{\eta \zeta}{\delta} \frac{W_t^{\varepsilon \zeta} N_t^{\zeta} + \beta W_{t+1}^{\varepsilon \zeta} N_{t+1}^{\zeta}}{W_t^{\varepsilon} N_t / P_t C_{jt} + \beta W_{t+1}^{\varepsilon} N_{t+1} / P_{t+1} C_{jt+1}} \right]^{\frac{1}{1+\varepsilon(\zeta-1)}}. \quad (20)$$

Note that  $W_t$ , which appears in this, can be expressed as:

$$W_t = [0.5(X_t^{1-\varepsilon} + X_{t-1}^{1-\varepsilon})]^{1/(1-\varepsilon)}. \quad (21)$$

This follows from the formula for the wage index and the facts (see below) that  $W_{jt} = X_t$  for all  $j$  in sector A,  $W_{jt} = X_{t-1}$  for all  $j$  in sector B (when  $t$  is even; the sectors are reversed when  $t$  is odd). A necessary last step in elaborating the expression for  $X_t$  is to relate  $C_{jt}$  to aggregate  $C_t$ . Since there is symmetry amongst the preferences and constraints of households, and since we henceforth assume that all households start with common asset stocks, it is clear that  $C_{jt} = C_{kt}$ ,  $W_{jt} = W_{kt}$  for any  $j, k$  in the same sector. We now in addition assume that  $C_{jt} = C_{kt}$  for any  $j, k$  in *different* sectors. This can be justified by assuming complete domestic asset markets, allowing agents to insure against any initial shocks that would affect agents in different sectors differently because of the staggering structure. Under these conditions  $P_t C_{jt}$ , which appears in (20), can be equated to  $\Omega_t$ , average (and aggregate) nominal consumption.

### 3. General Equilibrium

To study the model's properties, we take a log-linear approximation around the zero-inflation steady state (ZISS). This is a standard procedure (see, for example, Woodford, 2003, p.79) and is acceptable provided the rate of inflation is not too large. Note that the reference steady state (whose values we denote by an  $R$  subscript) is not the same as the initial steady state. As we are studying disinflation policies, we assume that the economy is initially in a constant-inflation steady state (CISS). In addition, we assume that net foreign assets are zero both initially and in the reference steady state (i.e.,  $B_{-1} = B_R = 0$ ). The trade balance is then also zero in these steady states, since there are no net international interest receipts or payments which could sustain a permanent non-zero trade balance.

The log-linearised equations are presented below. Their derivations (where they are at all complex), as well as some other technical material, are given in a Technical Appendix.<sup>8</sup> Except where noted, lower-case symbols represent log-deviations of variables from their reference steady-state values, so  $v_t \equiv \ln(V_t/V_R)$ , where  $V_t$  denotes any variable, and  $V_R$  its value in the reference steady state.

$$\mu_{t+1} \equiv m_{t+1} - m_t \quad (22)$$

$$\omega_t \equiv p_t + c_t \quad (23)$$

$$z_t \equiv m_t - \omega_t \quad (24)$$

$$z_t = -[\beta/(1-\beta)]i_t \quad (25)$$

$$z_{t+1} = (1/\beta)z_t + \mu_{t+1} \quad (26)$$

$$e_{t+1} - e_t = i_t \quad (27)$$

$$y_{Nt} = [\sigma/(1-\sigma)](p_{Nt} - w_t), \quad y_{Tt} = 0 \quad (28)$$

$$c_{Nt} = \omega_t - p_{Nt} = y_{Nt}, \quad c_{Tt} = \omega_t - e_t \quad (29)$$

$$p_t = \alpha p_{Nt} + (1-\alpha)e_t \quad (30)$$

$$y_t = \alpha y_{Nt} \quad (31)$$

$$\tau_t = -c_{Tt} \quad (32)$$

$$\sum_{t=0}^{\infty} \beta^t \tau_t = 0 \quad (33)$$

$$x_t = \frac{1}{1+\varepsilon(\zeta-1)} \left\{ \frac{1}{1+\beta} [\omega_t + \varepsilon(\zeta-1)w_t + (\zeta-1)n_t] + \frac{\beta}{1+\beta} [\omega_{t+1} + \varepsilon(\zeta-1)w_{t+1} + (\zeta-1)n_{t+1}] \right\} \quad (34)$$

$$w_t = 0.5(x_t + x_{t-1}) \quad (35)$$

$$n_t = (1/\sigma)y_{Nt} \quad (36)$$

Equations (22) – (24) define the monetary expansion rate ( $\mu_t$ ), nominal consumption ( $\omega_t$ ) and money demand per unit of consumption ( $z_t$ ), respectively. The negative relationship of  $z_t$  to the nominal interest rate, shown in (25), can be interpreted as the ‘money demand’ function. It comes from the aggregate version of the first-order condition, (13). Equation (26) shows how  $z_t$  evolves over time when  $\mu_t$  is exogenous. It is obtained by combining the aggregate versions of first-order conditions (12) and (13). Equation (27) is the uncovered interest parity (UIP) condition, under the assumption (made henceforth) that the log-deviation

of the foreign interest rate is zero. Turning to goods markets, the nontradeables supply function (28) is a logged version of that in (4) above. Equation (29) gives the two sectoral demand functions, which depend on nominal consumption and the relevant price; the nontradeable goods market equilibrium condition is also included. The consumer price index, (30), is obtained by taking logs of (7). Real gross domestic product is defined in levels as  $Y_t \equiv (P_{Nt}Y_{Nt} + P_{Tt}Y_{Tt})/P_t$ . When loglinearised with coefficients evaluated in the balanced-trade steady state we obtain (31). For the trade balance, we cannot derive a *loglinear* approximation, as the log-deviation of a variable from zero is undefined. Instead we define  $\tau_t$  as  $T_t$ , the ‘levels’ trade balance scaled by tradeables output (which is unity). It is then related to the log-deviation of tradeables consumption by (32). The approximated version of (19), the national intertemporal budget constraint, is given by (33) (in which we have already set initial net foreign assets, the right-hand side, to zero). Turning to the labour market, the wage-setting equation (20) becomes (34) upon loglinearisation, and the wage index formula (21) becomes (35). Lastly, aggregate employment,  $n_t$ , is just equal to nontradeables employment, as in (36).

The dynamics of our model are third-order. However, a special property of the model, which results from the particular utility function used, is that we can solve for the time paths of certain monetary-sector variables separately from those in the rest of the economy. We next show how this separability comes about. Later we exploit it in order to solve for perfect-foresight time paths in a partially recursive manner. This effectively reduces the dynamics to being second-order, and enables us to derive our results analytically. Unlike numerical simulations, our procedure also reveals the inner workings of the equilibrium.

The monetary sector equations are (22) - (27). How we solve them depends on the monetary policy regime. Suppose first that the monetary growth rate is fixed at the value  $\mu$  (some exogenous initial level for  $m_t$  also being chosen). It is then clear that (26) is an

autonomous first-order difference equation in  $z_t$ . Since  $z_t$  (money demand per unit of consumption) is a non-predetermined state variable, this equation must be solved in a forward-looking manner. It is evidently unstable in the forward dynamics (noting  $\beta < 1$ ), whence the unique non-divergent solution is for  $z_t$  to take its steady-state value, namely:

$$z = \beta(\beta - 1)^{-1} \mu. \quad (37)$$

It then follows from the money demand function (25) that:

$$i = \mu. \quad (38)$$

Knowing  $i$ , depreciation of the exchange rate is pinned down by the UIP condition (27):

$$e_{t+1} - e_t = \mu. \quad (39)$$

Lastly, nominal consumption spending must move together with the exogenous money supply, being given from (24) by:

$$\omega_t = m_t + \beta(1 - \beta)^{-1} \mu. \quad (40)$$

Thus the time paths of money demand per unit of consumption, the nominal interest rate and nominal consumption are completely pinned down by the monetary-sector equations. They are independent of what is happening elsewhere in the economy. Moreover, so long as monetary policy itself is time-invariant, these variables are always at their steady state levels, or on their steady-state growth paths. The same is true for the exchange rate as regards its *depreciation rate*. However, the *overall level* of the exchange rate is not tied down in the monetary sector alone: it must be solved for using other equations, as we explain below.

In the case where monetary policy is used instead to control the exchange rate, a similar separability result applies. Suppose that the government chooses an initial level of the exchange rate and a devaluation rate,  $d$ . UIP then fixes  $i$  at  $d$ ; the money demand function thence fixes  $z$  at  $\beta(\beta - 1)^{-1} d$ ; and, using this, the difference equation for  $z_t$  serves to tie down the endogenous monetary growth rate, yielding  $\mu = d$ . In summary, if we call the devaluation rate

$\mu$ , instead of  $d$ , all of (37) - (40) still hold. The key difference is that the overall level of the exchange rate is now exogenous, while the overall level of the money supply is now endogenous. The money supply thus swaps places with the exchange rate in the general solution scheme, and hence we again need to appeal to equations outside the monetary sector to complete the determination of its time path.

A second special property of the model under our assumptions is that the equilibrium value of the trade balance is always zero. We can show this as follows. From (32) and (29) we have:

$$\tau_t = -c_{Tt} = e_t - \omega_t. \quad (41)$$

This shows that the trade surplus depends only on the difference between the nominal exchange rate and nominal consumption. First-differencing gives:

$$\tau_{t+1} - \tau_t = (e_{t+1} - e_t) - (\omega_{t+1} - \omega_t).$$

Now, by UIP, (equation (27))  $e_{t+1} - e_t = i_t$ . We can also easily show that  $\omega_{t+1} - \omega_t = i_t$ : this is simply the Euler equation for consumption. (In our list of equations above, such a relationship is embedded in (26).) It is then clear that  $\tau_{t+1} - \tau_t = 0$ , i.e., that the trade balance is time-invariant along a perfect-foresight path. Inserting this time-invariant value -  $\tau$ , say - into the national intertemporal budget constraint, (33), reduces it to:

$$\tau / (1 - \beta) = 0. \quad (42)$$

The only value of  $\tau$  which satisfies the intertemporal budget constraint is therefore zero. In turn this implies, from (41), that the exchange rate is given by:<sup>9</sup>

$$e_t = \omega_t. \quad (43)$$

The forces governing the wage dynamics can be examined more closely by combining the wage-setting equation, (34), with the wage index equation, (35), and substituting out employment from (34) by relating it to nontradeable output and hence nontradeable goods

demand. In the post-disinflation regime, in which nominal consumption is constant over time at  $\omega$ , this yields the following second-order difference equation in the ‘new’ wage,  $x_t$ :

$$-\frac{1}{1+\beta} \frac{1-\gamma}{1+\gamma} x_{t-1} + x_t - \frac{\beta}{1+\beta} \frac{1-\gamma}{1+\gamma} x_{t+1} = \frac{2\gamma}{1+\gamma} \omega. \quad (44)$$

This is essentially the same equation as in Taylor (1979). The equation tells us that the new wage set today depends positively on both the new wage set in the previous period and the new wage rationally expected to be set next period. This is because of overlapping wage-setting – the new wage set last period is still in force in the current period, hence affecting the current wage index and the wage it is rational for wage setters to choose in the current period. Similarly, current wage setters need to anticipate what next period’s wage setters will do as the wage they set this period lasts for two periods. Finally, in equation (44), the new wage depends positively on the RHS of the equation, which represents aggregate demand. The difference from Taylor here is that the parameter  $\gamma$  (which captures the responsiveness of the new wage to the level of economic activity) is derived from the underlying microeconomic parameters, rather than being postulated directly. Specifically,  $\gamma \equiv \zeta / [1 + \varepsilon(\zeta - 1)]$ .

As in Taylor, and as is necessary for existence and uniqueness of a non-divergent perfect foresight equilibrium, equation (44) is ‘saddlepath’ stable, meaning one eigenvalue lies outside, and one inside, the unit circle. The speed of adjustment of  $x_t$  following a shock is governed by the size of the latter, stable, eigenvalue, which is given by:

$$\lambda = \frac{(1+\beta)(1+\gamma) - \sqrt{(1+\beta)^2(1+\gamma)^2 - 4\beta(1-\gamma)^2}}{2\beta(1-\gamma)}. \quad (45)$$

As  $\gamma$  tends to zero,  $\lambda$  tends to 1; while as  $\gamma$  tends to 1,  $\lambda$  tends to zero.<sup>10</sup> Slow adjustment to the new steady state is thus associated with a low value of  $\gamma$ , and hence with a high elasticity of substitution amongst labour types ( $\varepsilon$ ) and a high elasticity of disutility of work with respect to labour supply ( $\zeta$ ).<sup>11</sup>



Before we turn to disinflation policy, where we shall be concerned mainly with short- and medium-run effects, we note that in this model output is affected by the inflation rate in the long run. From the equations presented it is straightforward to derive the steady-state relationship:

$$y_N = \frac{\sigma(1-\beta)}{2(1+\beta)\gamma} \mu. \quad (46)$$

This equation shows that, to the extent that  $\beta < 1$ , inflation has a positive effect on output in the long run, implying a non-vertical long-run Phillips curve, a feature which has been discussed by some other authors in the context of staggered-price models.<sup>12</sup> The mechanism behind it, in intuitive terms, is as follows. When wages must be set for two periods at the same level, a wage-setter chooses a ‘compromise’ level between his two ideal flexible wages. For a given path of rising prices, the later ideal flexible wage will be greater than the earlier one. If the discount factor,  $\beta$ , equals one, the chosen wage will be exactly half-way between these; but if  $\beta$  is less than unity it will be biased towards the earlier, and thus the lower, one. Under discounting then, inflation lowers the average real wage. Together with the demand for labour function, this raises employment and output. In our view this effect is unlikely to be empirically significant, since a realistic value of  $\beta$  is very close to unity. Nevertheless, the effect is unavoidably present in the model since we cannot plausibly set  $\beta = 1$ .

#### **4. Unanticipated Disinflation and the Level of the Exchange-Rate Peg**

Suppose the economy is in an initial steady state with a constant inflation rate  $\mu_I$ . (The subscript  $I$  will be used to denote the initial CISS values of variables.) As discussed in Section 3, other nominal variables (the money supply, the exchange rate, nominal consumption and nominal GDP) must also be growing at the rate  $\mu_I$ . It is immaterial whether we think of the monetary policy in this initial steady state as being one of fixing the monetary growth rate, the devaluation rate or the nominal GDP growth rate.

The policy of disinflation is introduced at  $t = 0$ . It takes the form of pegging the exchange rate from  $t = 0$  onwards at  $e_t = \bar{e}$ . We assume that this change is unanticipated and fully credible, meaning by the latter that the announcement of the permanent policy change is believed by all agents. We will study the effect of various alternative values of  $\bar{e}$ . It is helpful to parameterise  $\bar{e}$  in relation to its own lagged value and rate of growth by:

$$\bar{e} = e_{-1} + \chi\mu_I. \quad (47)$$

A standard type of ERB disinflation policy might be where  $\chi = 0$ : the exchange rate is pegged at its value in the previous period. Equally plausibly, however, it might be where  $\chi = 1$ : the exchange rate is pegged at the value it would have reached under unchanged policies. Since both are roughly consistent with the idea of pegging the exchange rate at its ‘current’ value and it is not obvious a priori which is more worthy of attention, we shall study both. The formulation (47) also allows us to study intermediate cases where  $0 < \chi < 1$ . Moreover, cases in which  $\chi$  lies outside the interval  $[0,1]$  also turn out to be of interest, as we will show.

Our particular concern is with the impact effect of the disinflation on output. By combining the supply and demand functions for nontradeables, (28) and (29), we have:

$$y_{Nt} = \sigma(\omega_t - w_t). \quad (48)$$

Thus, what happens to nontradeable (and hence total) output depends on what happens to nominal consumption spending and to the wage. These are clearly demand-side and supply-side factors, respectively. Output in the impact period relative to its initial CISS value is obviously:

$$y_{N0} - y_{NI} = \sigma[(\omega_0 - \omega_{-1}) - (w_0 - w_{-1})]. \quad (49)$$

Whether a boom or slump occurs therefore depends simply on whether nominal consumption growth exceeds or falls short of wage inflation in the impact period. We next look separately at the determinants of these.

First, we know from (43) that nominal consumption spending simply tracks the nominal exchange rate one-for-one, i.e.,  $\omega_t = e_t$ . Nominal consumption growth in the impact period hence just equals the exchange rate depreciation in that period:

$$\omega_0 - \omega_{-1} = \bar{e} - e_{-1} = \chi \mu_I. \quad (50)$$

$\omega_0 - \omega_{-1}$  is therefore determined by the level of the exchange-rate peg: if  $\chi = 0$ , consumption spending levels off abruptly; while if  $\chi = 1$ , it continues along its old path for one final period.

Second, wage inflation in the impact period can be expressed as:

$$w_0 - w_{-1} = (1/2)(x_0 - x_{-1}) + (1/2)(x_{-1} - x_{-2}), \quad (51)$$

which has been obtained by differencing the wage index formula, (35). The term  $x_{-1} - x_{-2}$  in (51) is predetermined and equals  $\mu_I$ , reflecting inflation in the new wage still ‘in the pipeline’. The term  $x_0 - x_{-1}$  is endogenous, since  $x_0$  is set in the knowledge of the policy announcement in period 0. The perfect foresight solution for  $x_0$  is readily derived by standard reasoning and its derivation is outlined in the Appendix. Substituting it into (51), we obtain:

$$w_0 - w_{-1} = (1/2)(1-\lambda)(\bar{e} - e_{-1}) + (1/2) \left[ (1/2)(1-\lambda) \left( \frac{1-\beta}{1+\beta} \frac{1}{\gamma} - 1 \right) + 1 \right] \mu_I. \quad (52)$$

This shows that, like consumption growth, wage inflation is increasing in the exchange-rate depreciation allowed in the impact period,  $\bar{e} - e_{-1}$ . Unlike consumption growth, it is less than proportional to such depreciation.

[Figure 1 about here]

Figure 1 depicts period-0 consumption growth and wage inflation as functions of the chosen period-0 exchange-rate depreciation. It is apparent that whether there is a boom or a slump in the impact period depends on the size of this depreciation. That is, it depends on the value of the exchange-rate peg,  $\bar{e}$  - or, equivalently, on  $\chi$ . When  $\chi = 0$ , ( $\bar{e}$  is pegged at  $e_{-1}$ ), the sudden fall of nominal consumption growth from  $\mu_I$  to zero in the impact period causes a

slump. Although there is also some offsetting reduction in wage inflation, the latter does not drop to zero, and this reduction is hence not enough to compensate for the fall in consumption growth without a slump. On the other hand, when  $\chi = 1$ , i.e.,  $\bar{e}$  is pegged at  $e_{-1} + \mu_L$ , there is no fall in consumption growth in the impact period. Wage inflation does fall, as before.<sup>13</sup> It does not fall to zero, but any fall is enough to cause a boom, given that nominal consumption has not yet deviated from its old trajectory. In summary, despite the fact that both  $\chi = 0$  and  $\chi = 1$  appear, broadly speaking, to be cases of pegging the exchange rate at its ‘current’ value, they have opposite implications for the impact effect on output.

Having seen that whether the short-run outcome is a boom or slump is sensitive to the exact value of the exchange rate peg, it is a small step to calculate the value which would ensure neither. This is where the  $\omega_0 - \omega_{-1}$  and  $w_0 - w_{-1}$  schedules cross in Figure 1. It obviously occurs at a value of  $\chi$  strictly between 0 and 1. We can calculate this critical value as:

$$\chi_A = \frac{1}{2} + \frac{(1-\lambda)(1-\beta)}{2(1+\lambda)(1+\beta)\gamma}. \quad (53)$$

Notice that  $\chi_A$  tends to exactly 1/2 as  $\beta$  tends to one. Since we expect  $\beta$  to be close to 1,  $\chi_A$  is about halfway between the two values just considered. It should be noted that, although setting  $\chi$  equal to  $\chi_A$  would avoid any immediate disturbance to output from an ERB disinflation, it would not prevent a disturbance in periods  $t > 0$ . This point will be taken up below.

Next, consider what happens to the path of the money supply - an endogenous variable under the above policies. In Section 3 we showed that, under a policy of a constant devaluation rate,  $d$ , the money supply would jump immediately to a constant growth path, with a growth rate,  $\mu$ , equal to  $d$ . Since  $d = 0$  in our ERB disinflation policy, it follows that  $\mu = 0$ : i.e., the money supply goes straight away to its new steady-state value. From (24), this value can be calculated as:

$$m = z + \omega = \bar{e}. \quad (54)$$

(We have used (37) and (43) here.) A similar calculation yields an expression for  $m_{-1}$ , the money supply in the initial CISS, whence the monetary growth rate in period 0 (the last period before it hits zero) is:

$$m - m_{-1} = [\chi + \beta(1 - \beta)^{-1}] \mu_I. \quad (55)$$

(55) shows that, if the exchange rate is pegged at the value it would have reached under unchanged policies ( $\chi = 1$ ), money supply growth will in fact increase (i.e., exceed  $\mu_I$ ) in the impact period. There will be a last period of acceleration before the money supply levels out. This is illustrated in Figure 2. Even if  $\chi = 0$ , monetary growth will still be positive in the impact period, and could still exceed  $\mu_I$ . This final upward jump in the money supply is the ‘remonetisation’ effect, as first noted by Fischer (1986). The disinflation policy immediately reduces the nominal interest rate, via the UIP condition, which raises the demand for real money balances. This is met by an increase in the nominal supply of money, which has to be determined passively given that the government is fixing the exchange rate.

[Figure 2 about here]

Following this analysis, it is easy to see what will happen if, instead of conducting an ERB disinflation, the government instead carries out an MB disinflation. In this case, the monetary growth rate is reduced from  $\mu_I$  to zero in  $t = 0$  and held at zero thereafter. The exchange rate floats. Having just seen that under an ERB disinflation monetary growth endogenously drops to zero in periods  $t = 1$  onwards, while in  $t = 0$  it is given by (55), it is clear that the time path of  $m_t$  required for a MB disinflation can be exactly reproduced by carrying out an ERB disinflation and using (55) to choose  $\bar{e}$ , or  $\chi$ , such that  $m - m_{-1} = 0$ . In other words, in our model a MB disinflation is just a particular type of ERB disinflation, where:

$$\chi = -\beta(1-\beta)^{-1} \quad (\equiv \chi_B, \text{ say}). \quad (56)$$

Clearly  $\chi_B$  is negative. To bring monetary growth to zero  $\bar{e}$  must be chosen to be below  $e_{-1}$ , meaning that not only must the trend depreciation in the exchange rate be halted in  $t = 0$ , but there must be a once-and-for-all *appreciation* of the exchange rate at the start of the disinflation as illustrated in Figure 3. The reason for this is to stop the upward jump in the money supply which occurs under a standard ERB disinflation, as just seen above. The exchange-rate appreciation is an alternative mechanism of ‘remonetisation’: the higher demand for real balances due to the ending of inflation can no longer be satisfied by a jump in the nominal money supply, so it must be satisfied by a drop in the general price level. An exchange-rate appreciation achieves this by lowering the domestic price of tradeables, thereby also switching demand away from nontradeables and putting downward pressure on their price too.

A comparison of the different paths for the exchange rate and the money supply in Figures 2 and 3 makes it apparent why a MB disinflation is more contractionary than a standard type of ERB disinflation. The exchange rate follows a more appreciated trajectory in the former, and also the money supply is more restricted. We can also view this in terms of Figure 1. Having seen that an MB disinflation is associated with a negative value of  $\chi$ , it is clear from the diagram that for such a policy wage inflation must exceed nominal consumption growth by a greater margin than it does for an ERB disinflation with  $\chi = 0$ , and hence that the forces tending to depress output are unambiguously more powerful.

## 5. Preannounced Exchange-Rate Pegging

The analysis in Section 4 has shown that our model can explain the widely documented fact that MB disinflations tend to cause slumps on impact whereas ERB disinflations tend to cause booms. However it also revealed that the boom outcome is sensitive to the level of the

exchange-rate peg, and that for one reasonable interpretation of what it means to peg the exchange rate at its ‘current’ level (the case where  $\bar{e} = e_{-1}$ ), the boom would not occur. In practice, however, ERB disinflations have usually been more gradual than in the simple representation we have used here. A typical feature of Latin American ERB disinflations of the 1970s and 1980s was the use of a ‘tablita’: the announcement of a schedule of progressive reductions in the rate of devaluation of the exchange rate. In such a case, parts of the policy change are ‘preannounced’: they are announced in one period for implementation in a later one. Of the two simple cases of a basic type of ERB disinflation which we considered, the  $\chi = 1$  case could in fact be argued already to contain a small element of ‘preannouncement’, because the exchange rate in the first period of the new policy,  $e_0$ , does not immediately differ from the value it would have taken anyway; it is only in periods  $t = 1, 2, \dots$  that it differs. This suggests that it would be of interest to analyse an explicitly preannounced ERB disinflation policy. We do this in the present section.

We now assume that in  $t = 0$  the authorities announce that in  $t = T$  and thereafter the exchange rate will be pegged such that  $\bar{e} = e_{T-1}$ . We further assume that for  $t = 0, \dots, T-1$ , the exchange rate continues to be devalued at its old trend rate,  $\mu_t$ , so that over this interval  $e_t$  follows the same path that it would have followed under unchanged policies. There are hence two phases: the ‘pre-implementation’ phase, from  $t = 0$  to  $T-1$ ; and the ‘post-implementation’ phase, from  $t = T$  to  $\infty$ . The difference equations governing the dynamics of the economy are different in each phase. The Appendix explains how we solve for the equilibrium in this case.

Focusing on the impact effect on output, equation (49) remains relevant, telling us that this is proportional to the gap between nominal consumption growth and wage inflation in the impact period. Equation (50) also continues to apply, i.e., nominal consumption growth equals exchange rate depreciation in the impact period. Such depreciation is now always equal to  $\mu_t$ , since the disinflation policy has yet to be implemented. Whether or not the

announcement causes a boom therefore depends on whether wage inflation in the impact period drops below  $\mu_I$ . Our previous expression for this, (52), must be modified to take account of the preannouncement. Doing this and substituting the result into (49), we obtain:

$$y_{N0} - y_{NI} = (\sigma/2)(1/\lambda')^{T-1} \left\{ \lambda + (1-\lambda)[1 - (1-\beta)(1+\gamma)/2\gamma](1+\beta)^{-1} \right\} \mu_I, \quad (57)$$

where  $\lambda'$  ( $>1$ ) denotes the unstable eigenvalue of the equation (44). (57) is evidently positive for  $\beta$  sufficiently close to 1, and in fact we can show (see the Appendix) that it is positive for all  $\beta$ . A preannounced ERB disinflation therefore always causes a boom. As can be seen, the boom is smaller the greater is  $T$ , i.e., the farther into the future is the planned implementation. As we reduce  $T$ , the size of the boom increases. The lowest value of  $T$  for which (57) is valid is  $T = 1$ . It can readily be checked that when  $T = 1$ , (57) exactly reproduces the result of Section 4 for the case  $\chi = 1$ . This hence confirms that an ‘unanticipated’ ERB disinflation in which the exchange rate is pegged at the value it would have reached under unchanged policies is actually an example of a preannounced ERB disinflation. Like the cases of more obvious preannouncement where  $T > 1$ , it generates a boom; and unlike the case of an unanticipated pegging of the exchange rate at its lagged value, it does not generate a slump.

We have already pointed to the mechanism underlying the boom in the Introduction. As previously observed with reference to equation (49), the effect of the policy change on output depends on the difference between the effect on aggregate demand, represented by current exchange rate depreciation, and the effect on aggregate supply, represented by current wage inflation. When the policy is preannounced, there is no immediate effect on demand. However, there is an effect on supply, because wages are set in a forward-looking manner, and anticipation of the reduction in inflation causes workers to start reducing wage inflation ahead of the change in the path of the exchange rate. This can be contrasted with what happens under a preannounced MB disinflation.<sup>14</sup> There, the exchange rate is free to float. Forward-looking behaviour in money demand implies that anticipation of the reduction in



inflation causes a rise in money demand in  $t = 0$ . However, the path of the money supply has not yet changed in  $t = 0$ , and nominal rigidity in wages prevents the price level from falling by enough to generate the necessary higher supply of real balances. For money market equilibrium, consumption has to fall, to lower money demand. Under preannounced MB disinflation there is hence a contractionary effect of anticipated lower inflation working through the demand side which counteracts the expansionary effect working through the supply side. The former turns out to be the dominant effect. Another way of understanding the difference in outcomes is to note, as was done for unanticipated disinflation, that under ERB disinflation the money supply is endogenous. This permits it suddenly to rise to satisfy money demand, eliminating the contractionary demand-side effect of the anticipated fall in inflation.

The source of the boom in our model is essentially the same as in Ball (1994). Ball used a closed-economy, directly-postulated, staggered-price model and considered a disinflation policy in which the monetary growth rate declines linearly until it reaches zero. This means there is a preannounced element to the policy. As in the present paper, the boom is caused by forward-looking price-setters who start to reduce inflation in advance of the monetary slowdown. However, despite considering a MB disinflation, Ball obtains no contractionary effect operating through the demand side, because he postulates an ad hoc money demand function with zero interest elasticity, and this eliminates any such effect. In the present paper we have also eliminated the contractionary effect, but in such a way that the model now matches a key stylised fact, rather than contradicts one.

The time path of output after the impact period can also be calculated. We can show that output continues to expand throughout the pre-implementation period, peaking in  $t = T-1$ . Thereafter it declines monotonically to its new steady-state level. The expansion occurs because wage inflation is lower throughout this period than it would have been under

unchanged policies, while the path of the exchange rate is the same, and so there is a cumulative effect on the gap between the exchange rate and the wage.

## 6. Effects of Disinflation on Other Variables

Although our main concern in this paper is with effects on output, it is of interest to consider the effects on some other variables. We here return to the unanticipated disinflation policies described in Section 4.

In practice inflation invariably responds with a lag to the attempt to reduce it. Authors such as Fuhrer and Moore (1995) and Mankiw and Reis (2002) have criticised basic staggered-price models for failing to exhibit ‘inflation persistence’. The predictions of our model on this score therefore merit attention. We shall focus on wage inflation. Tradeables price inflation is just equal to the rate of exchange-rate depreciation, while nontradeables price inflation is just a weighted average of wage inflation and the rate of exchange-rate depreciation.<sup>15</sup>

The dynamics of wage inflation are governed by those of the ‘new wage’,  $x_t$ . The perfect-foresight solution for  $x_t$  following an unanticipated disinflation in  $t = 0$  is the saddlepath solution of (44):

$$x_t - x = \lambda^{t+1}(x_{-1} - x). \quad (58)$$

Here  $x$  is the value of  $x_t$  in the post-disinflation steady state, and  $x_{-1}$  is the predetermined lagged value of  $x_t$  in the period in which the policy begins. It is clear that if  $x > x_{-1}$ , then  $x_t$  rises during the transition to the new steady state, and hence wage inflation is positive during the transition. This is what we will call ‘inflation persistence’.  $x < x_{-1}$ , on the other hand, would imply negative inflation during the transition. In the latter case inflation converges on zero from below, not from above, and hence it must drop from its initial positive value to a negative one at the start of the policy. This less plausible behaviour we will call ‘inflation overshooting’.

We can calculate  $x - x_{-1}$  as (see Appendix):

$$x - x_{-1} = [\chi - 1/2 + (1-\beta)/(1+\beta)2\gamma]\mu_t. \quad (59)$$

If  $\chi = 0$  then this is negative, given our general presumption that  $\beta$  is close to 1. That is, if the exchange rate is pegged at its lagged value, there is no inflation persistence. This is true a fortiori if  $\chi < 0$ , which we saw to hold under MB disinflation. The time path of wage inflation following a MB disinflation is depicted in Figure 3. Similar predictions in other staggered-wage or -price models of an implausibly rapid drop in inflation have been noted by other authors, such as those cited above. This perceived weakness has motivated a number of modifications to the standard assumptions about the staggering of wages or prices - see again the cited authors.<sup>16</sup> In the present case where  $\chi = 1$ , however - which we have argued is closer to real-world ERB disinflations - (59) shows that  $x - x_{-1}$  is positive. In this case inflation persistence *does* occur. Hence the version of our model which generates a boom following an ERB disinflation also has no problem in generating inflation persistence. The time path of wage inflation following an ERB disinflation with  $\chi = 1$  is depicted in Figure 2.

A corollary is that there exists a critical value of  $\chi$  - i.e. of the exchange rate peg - which avoids both inflation persistence and inflation overshooting. This is the value which equates (59) to zero, i.e.:

$$\chi = 1/2 - (1-\beta)/(1+\beta)2\gamma \quad (\equiv \chi_C, \text{ say}). \quad (60)$$

With this value of  $\chi$ , as (58) shows,  $x_t$  will move straight to its new steady-state value. Wage inflation,  $w_t - w_{t-1}$ , will reach zero in  $t = 1$  and will stay there. Moreover, all other dynamics will also be cut off, so that the economy will be in its new steady state from  $t = 1$  onwards. As can be seen from the fact that  $\chi_C < \chi_A$ , however (cf. (53)), this will be at the cost of a slump in the impact period.

Disinflations, whether money- or exchange-rate based, have usually been accompanied by short-run real exchange rate appreciations in practice.<sup>17</sup> The real exchange rate here is the

relative price of tradeable to nontradeable goods, or  $e_t - p_{Nt}$  (a rise indicating a real depreciation). In our model, this simply moves one-for-one with nontradeables output:<sup>18</sup>

$$e_t - p_{Nt} = y_{Nt}. \quad (61)$$

It follows that a MB disinflation, which causes a slump, is indeed accompanied by a real appreciation. However an ERB disinflation with  $\chi = 1$ , which causes a boom, is accompanied by a real depreciation. This is contrary to what is typically observed in reality. It is not hard to see intuitively why the mechanism which we have highlighted as causing the boom must also be associated with a real depreciation. As pointed out, this mechanism is the element of preannouncement in the policy and the supply-side stimulus which this creates. When  $\chi = 1$ , exchange rate depreciation continues along its old trend in the impact period while wage inflation begins to moderate. Since the nontradeables price is just a weighted average of the wage and of the exchange rate,<sup>19</sup> the reduction in wage inflation causes nontradeables inflation to begin to moderate too, whence  $e_t - p_{Nt}$  must rise.

The counterfactual response of the real exchange rate obliges us to acknowledge that the preannouncement mechanism cannot provide a complete explanation for the stylised facts associated with ERB disinflations. A further factor which seems indispensable is an initial boom in aggregate demand, something which is absent from our analysis. By itself this would raise the relative price of nontradeables - rather than lower it, as occurs with a stimulus to aggregate supply - because the domestic price of tradeables is fixed by the world price and the pegged exchange rate, whereas that of nontradeables is not. Other authors have advanced theories as to why an ERB disinflation may create an aggregate demand boom. Best known is the argument of Calvo and Végh (1994) that it could be caused by a rationally anticipated breakdown of the disinflation policy, i.e., by ‘temporariness’ of the disinflation. Alternatively, De Gregorio et al. (1998) propose that there is a boom in consumer durables demand, resulting from ‘lumpy’ adjustment costs. The contribution of our paper is not to

deny that such mechanisms creating a demand boom are important, but rather to point out that preannouncement is also likely to play a role. This role may have been overlooked partly because, on its own, it seems inconsistent with the implications for the real exchange rate. The truth about ERB disinflations is probably that both supply-side and demand-side factors matter, although, in the case of the real exchange rate, the supply-side factor merely dampens the initial appreciation.

## 7. Conclusions

We have taken an analytical approach to the study of exchange-rate-based disinflation in an open economy, using a staggered-wage DGE model. Our main result is that the puzzling boom at the start of such disinflations can be explained, at least to some extent, by an element of preannouncement in the policy. Recent empirical evidence backs this idea. We have also shown that a money-based disinflation can be understood as a special type of exchange-rate-based disinflation in which the currency is revalued just before it is pegged, something which makes it easy to see why such a policy causes an initial slump. Our model can furthermore explain why a standard type of exchange-rate-based disinflation is associated with inflation persistence, i.e., with a gradual decline in inflation to zero, behaviour which staggered-wage or -price models often fail to exhibit. On the other hand it does not succeed in explaining an initial real exchange-rate appreciation, which we accept as an indication that preannouncement is not the whole story.

Our model possesses two somewhat special properties which we have exploited in order to reveal the structure of the solution and hence the underlying forces at work, and it is legitimate to ask what happens if these are relaxed. The (partial) separability of the monetary sector equilibrium is what causes monetary-sector variables to attain their new steady state immediately after an unanticipated disinflation. Under MB disinflation this means there is no exchange-rate ‘overshooting’ (or indeed undershooting) à la Dornbusch (1976). In turn this

explains why there is an ‘equivalence’, up to the value of the peg, between ERB and MB disinflation. The separability is the result of additive separability of utility in composite consumption, labour supply and real balances, combined with a logarithmic functional form for the latter. If utility of real balances were generalised to the CRRA functional form, separability and thus our equivalence result would disappear. With a ‘relative risk aversion’ parameter greater than one, for example, exchange-rate overshooting would be restored.<sup>20</sup> However, such an extension has few implications for the analysis of ERB disinflation since it only affects the behaviour of the endogenous money supply, a variable of minor interest.

A second special property is the zero equilibrium value of the trade balance. This is a consequence of exogenous tradeables output plus additive separability of tradeables consumption in the utility function (and of zero initial net foreign assets). Clearly this prevents our model from generating the initial trade deficit, and thus capital inflow, which is a hallmark of ERB disinflations. However it also greatly simplifies the formal solution procedure since, by removing accumulation or decumulation of net foreign assets, it eliminates the permanent effect which the latter would have on the new steady state, and hence removes the path-dependence property often possessed by this type of model. In work not presented here we have investigated the effect of endogenising tradeables output by treating production in that sector in an analogous way to nontradeables production. We find that an ERB disinflation (with  $\chi = 1$ ) then also generates an initial boom in tradeables output, but accompanied by a trade *surplus*, rather than the deficit typically observed. A more promising extension might be to allow an elasticity of substitution between tradeables and nontradeables different from one, i.e., to generalise (5). In combination with a demand-side boom from a source such as mentioned in Section 6, this may have the potential to generate a short-run trade deficit.

In conclusion, we believe that our analysis illustrates some of the strengths of the dynamic general equilibrium approach with staggered wage setting. It can explain several puzzling features of disinflationary experiences. Clearly, a number of extensions would be desirable in order to capture the full set of stylised facts (for example, anticipated collapse of the policy and a role for asset price booms) but we think the current model still generates significant new insights.

## Appendix

### (i) Derivation of (52) - impact effect on wage inflation.

As explained in the main text, (52) is the result of substituting the perfect-foresight solution for  $x_0$  (less its pre-disinflation value) into (51). By rearranging (58) with  $t = 0$  we obtain:

$$x_0 - x_{-1} = (1 - \lambda)(x - x_{-1}).$$

Next, using (59) to eliminate  $x - x_{-1}$  in this and then substituting the resultant expression into (51), we obtain (52). See part (iv) of this Appendix for the derivation of (59).

### (ii) Solution method under preannouncement.

Under preannouncement, the time path of  $e_t$  is given by:

$$e_t = \begin{cases} e_{-1} + (t+1)\mu_I & \text{for } t = -1, \dots, T-1, \\ e_{-1} + T\mu_I (= e_{T-1}) & \text{for } t \geq T-1. \end{cases}$$

$e_t (= \omega_t$ , by (43)) is a forcing variable in the law of motion for  $x_t$  (i.e., in the generalisation of (44) which does not constrain  $\omega_t$  to be time-invariant). When  $e_t$  is substituted out, we obtain two versions of this law of motion:

$$\begin{aligned} x_t &= (1-\gamma)(1+\gamma)^{-1}[(1+\beta)^{-1}x_{t-1} + \beta(1+\beta)^{-1}x_{t+1}] \\ &+ \begin{cases} 2\gamma(1+\gamma)^{-1}[e_{-1} + (1+2\beta)(1+\beta)^{-1}\mu_I + \mu_I t] & \text{for } t = 0, \dots, T-2, \\ 2\gamma(1+\gamma)^{-1}e_{T-1} & \text{for } t \geq T-1. \end{cases} \end{aligned} \quad \begin{matrix} \text{(A1)} \\ \text{(A2)} \end{matrix}$$

The indefinite solutions of the second-order difference equations (A1) and (A2), respectively, are:

$$x_t = A\lambda^t + A'(\lambda')^t + e_{-1} + [2 + \beta - (1-\beta)(1+\gamma)/2\gamma](1+\beta)^{-1}\mu_I + \mu_I t \quad \text{for } t = -1, \dots, T-1, \quad \text{(A3)}$$

$$x_t = B\lambda^t + B'(\lambda')^t + e_{T-1} \quad \text{for } t \geq T-2, \quad \text{(A4)}$$



where  $\lambda, \lambda'$  are the eigenvalues discussed in the main text, and  $A, A', B, B'$  are constants of integration to be determined below. Note in particular that (A3) and (A4) apply for ranges of  $t$  which extend one period beyond the ranges of  $t$  for which (A1) and (A2) apply. This is because the solutions to (A1) and (A2) must be valid for all instances of  $x_t$  to which (A1) and (A2) apply.

We now want to solve for  $A, A', B, B'$  using the known boundary conditions on the perfect-foresight solution. First, since  $\lambda' > 1$ , convergence from period  $T$  onwards clearly requires that  $B' = 0$ : this is the usual saddlepath condition. Next, an expression for the initial predetermined value of  $x_t, x_{-1}$ , may be derived by using the assumption that the economy is in a CISS: see part (iv) below. For now, we treat  $x_{-1}$  as a known parameter. Applying (A3) for  $t = -1$  then gives us a first equation linking the two unknowns  $A, A'$ . To complete the solution, notice that both (A3) and (A4) hold in periods  $T-2$  and  $T-1$ . Writing these out for  $t = T-2$  and  $t = T-1$  then gives four further equations, containing the unknowns  $(A, A', B, x_{T-2}, x_{T-1})$ . Together with the equation in  $x_{-1}$ , we hence have a determinate system of five simultaneous equations in five unknowns. Being a linear system, it is straightforward to solve. This yields:

$$A = \lambda(x_{-1} - e_{-1}) + \lambda \left\{ [(\lambda' - \lambda)^{-1} (\lambda')^{1-T} (1 - \lambda) - 1] H + (\lambda' - \lambda)^{-1} (\lambda')^{1-T} \lambda \right\} \mu_I,$$

$$A' = -(\lambda' - \lambda)^{-1} (\lambda')^{2-T} \{ (1 - \lambda) H + \lambda \} \mu_I,$$

$$B = \lambda(x_{-1} - e_{-1})$$

$$- \lambda \left\{ [(\lambda' - \lambda)^{-1} \lambda' (1 - \lambda) (\lambda^{-T} - (\lambda')^{-T}) - \lambda^{-T} + 1] H + (\lambda' - \lambda)^{-1} \lambda' \lambda (\lambda^{-T} - (\lambda')^{-T}) \right\} \mu_I,$$

$$\text{where } H \equiv [1 - (1 - \beta)(1 + \gamma) / 2\gamma] (1 + \beta)^{-1}.$$

(iii) *Proof that (57) is positive for all  $\beta$ .*

The condition that the term  $\{.\}$  in (57) be positive can be rewritten as the condition:

$$\lambda > (\phi - \beta) / (1 - \beta\phi) [\equiv \theta],$$

where for convenience we define  $\phi \equiv (1-\gamma)/(1+\gamma)$ . Note that under our parameter assumptions,  $0 < \gamma < 1$ , so that  $0 < \phi < 1$ , and hence also  $\theta < 1$ . To show that this condition holds for all  $\beta$ , we use the characteristic equation of the difference equation (44). This characteristic equation is the following quadratic in  $\nu$ :

$$\beta\phi\nu^2 - (1+\beta)\nu + \phi [\equiv F(\nu)] = 0.$$

Its solutions are the eigenvalues  $\lambda, \lambda'$ . The graph of  $F(\nu)$  is a parabola, and since we know that  $0 < \lambda < 1$  and  $\lambda' > 1$  (proved in the Technical Appendix - see endnote 8), it must be downward-sloping in the neighbourhood of  $\lambda$ , one of the two points at which it cuts the horizontal axis. To show that  $\theta < \lambda$ , it therefore suffices to show that  $F(\theta) > 0$ . (Since  $\theta < 1$ ,  $F(\theta) > 0$  cannot imply that  $\theta$  instead lies above  $\lambda'$ .) Evaluating  $F(\nu)$  at  $\nu = \theta$ , after some manipulation we obtain:

$$F(\theta) = (1-\beta\phi)^{-2} \beta(1+\beta)(\phi-1)^2(\phi+1).$$

This is unambiguously positive, which proves the desired result.

*(iv) Derivation of (59) - long-run effect on the new wage.*

$x$ , the steady-state value of  $x_t$  in the post-disinflation steady state, is readily found from (44) to be such that  $x = \omega$ . Since we also know that  $\omega_t = e_t$  (see (43)), then  $x = \bar{e}$  so  $x$  is equal to the exogenous exchange rate peg.

To determine  $x_{-1}$ , we refer to the solutions for variables in the initial CISS, in which inflation is  $\mu_I$ . Since  $x_t$  is a nominal variable and is hence growing over time in a CISS, it is helpful to define the new variable  $s_t \equiv x_t - e_t$ , which will be time-invariant. The CISS value of  $s_t, s_I$ , depends on  $\mu_I$ . In  $t = -1$ , the last period before the unanticipated disinflation, we therefore have:

$$\begin{aligned} x_{-1} &= e_{-1} + s_I \\ &= e_{-1} + [1/2 - (1-\beta)/(1+\beta)2\gamma]\mu_I, \end{aligned}$$

in which we have used the solution for  $s_I$  from the Technical Appendix. Subtracting this from  $x$ , i.e.  $\bar{e}$ , gives (59).

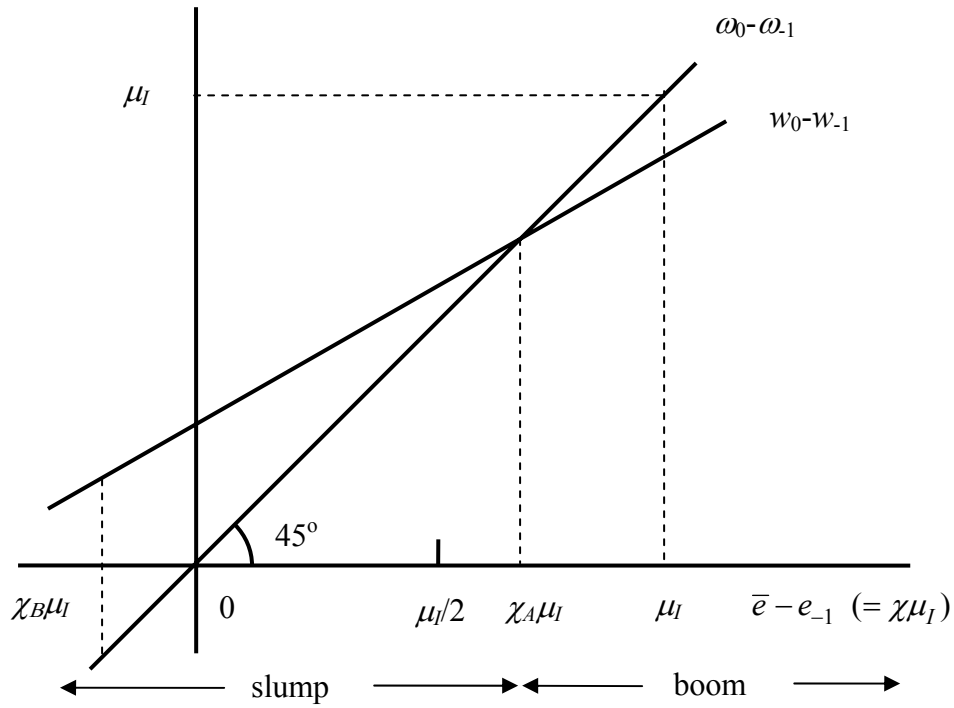


Figure 1. Impact effect of an unanticipated ERB disinflation on output as a function of the exchange rate peg.

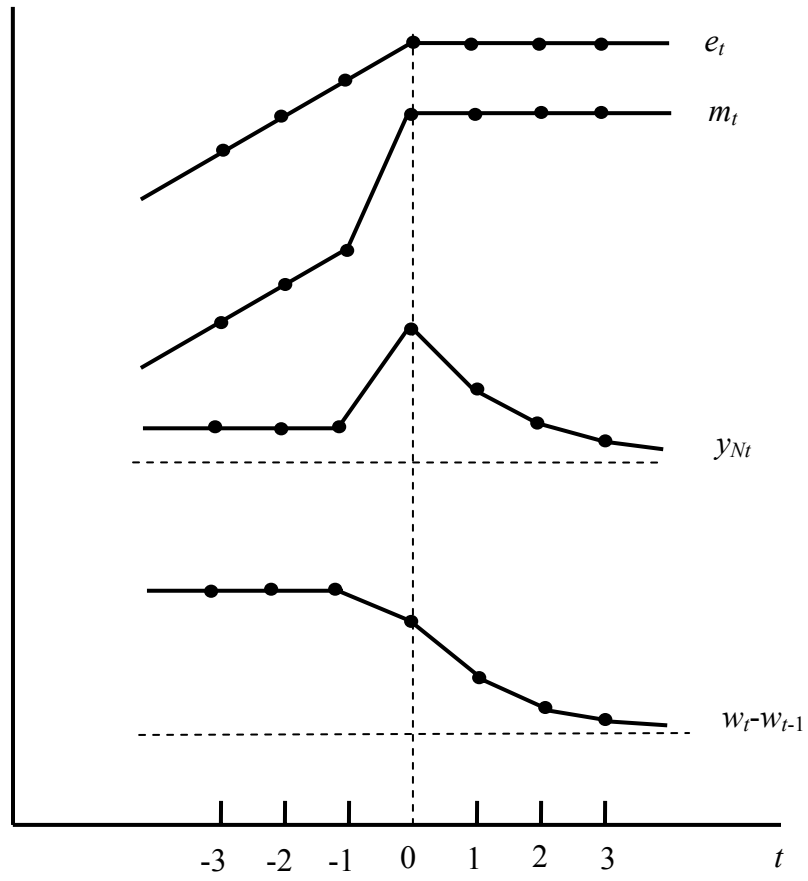


Figure 2. Time paths in response to an unanticipated exchange-rate-based disinflation ( $\chi = 1$ ).

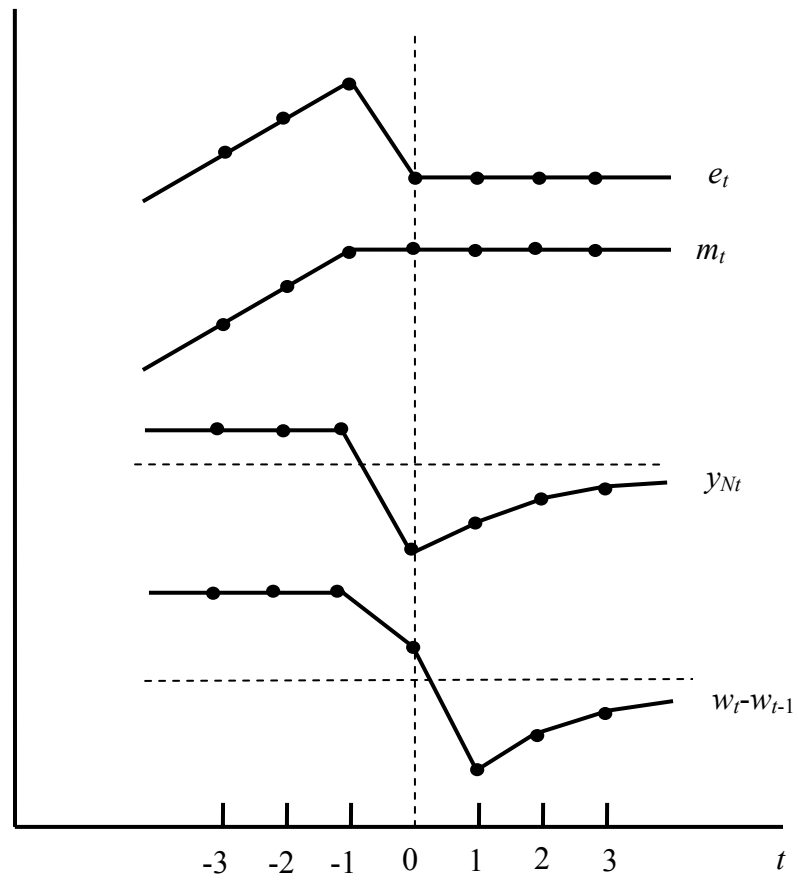


Figure 3. Time paths in response to an unanticipated money-based disinflation.

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## ENDNOTES

<sup>1</sup> As documented, for example, by Rogoff (2003).

<sup>2</sup> Warnings about this can be found in the 2006 Annual Report of the Bank for International Settlements, for instance.

<sup>3</sup> A substantial literature exists on both the empirical and theoretical aspects of disinflation in open economies. Excellent surveys include Calvo and Végh (1999) and Fischer et al. (2002). A recent contribution to the literature on exchange-rate-based disinflation is Celasun (2006).

<sup>4</sup> In spirit, our model is similar to the ‘New Open Economy Macroeconomics’ approach, which was given its greatest impetus by Obstfeld and Rogoff (1995). Lane (2001) provides a survey. Archetypal models of this sort however assume only one-period nominal rigidities. Although multi-period rigidities and staggering have subsequently been introduced by several authors, very few such models to date have been used to address the issue of disinflation in an open economy. One exception is Senay (2000). For a discussion of why the use of non-DGE models can lead to puzzles regarding disinflation in a closed economy, see Ascari and Rankin (2002).

<sup>5</sup> Fischer’s model, like those of its time, was ‘directly postulated’ rather than a DGE model. This permits more freedom in the choice of parameters so that a boom is relatively easy to generate.

<sup>6</sup> This sector could be thought of as extracting some natural resource such as oil, which requires a negligible amount of labour. The same assumption is made in Calvo and Végh (1994).

<sup>7</sup> The lack of the  $j$  subscript anticipates the point that all households in sector  $A$ , though acting independently, will choose the same new wage, as will be seen below.

<sup>8</sup> Available from the authors on request, or at

<http://www.economics.bham.ac.uk/fender/fenderrankin.techappx.pdf>

<sup>9</sup> Another implication is that nominal consumption,  $\omega_t$ , always equals nominal GDP,  $p_t + y_t$ .

<sup>10</sup> The application of l’Hôpital’s Rule to (45) demonstrates the latter.

<sup>11</sup> See Ascari (2000) for a detailed discussion of the microeconomic determinants of ‘output persistence’ in a staggered-wage DGE model.

<sup>12</sup> For example, Calvo (1983), Ascari (1998), Graham and Snower (2004).

<sup>13</sup> To show generally that  $w_0 - w_{-1} < \mu_t$  when  $\chi = 1$ , some algebra is required. However it is already apparent from (52) that this holds in the special case where  $\beta \rightarrow 1$ . For general values of  $\beta$ , the proof in part (iii) of the Appendix applies: see Section 5.

<sup>14</sup> For reasons of space, we shall not present a formal analysis of this here. Ascari and Rankin (2002) do so in a closed-economy version of the present model.

<sup>15</sup> Simple manipulations yield  $p_{Nt} = (1 - \sigma)e_t + \sigma w_t$ .

<sup>16</sup> Another study, close to ours in that it focuses on exchange-rate pegging, is by Miller and Sutherland (1993). They also find a lack of inflation persistence in the basic model, and conclude that it is best explained by imperfect credibility of the policy.

<sup>17</sup> See again the surveys by Calvo and Végh (1999) or Fischer et al. (2002).

<sup>18</sup> This is easily seen from the market-clearing condition for nontradeables in (29), plus the fact that  $\omega_t = e_t$ .

<sup>19</sup> See again endnote 15.

<sup>20</sup> In work not presented here we have proved this for our model. Obstfeld and Rogoff (1996, Ch 10.2) present the equivalent result in a model with one-period nominal rigidities.

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