THE EFFECT OF STEADY INFLATION ON INTEREST RATES AND THE REAL EXCHANGE RATE IN A WORLD WITH FREE CAPITAL FLOWS

David W. R. Gruen*

Research Discussion Paper

9101

February 1991

Research Department
Reserve Bank of Australia

* I am grateful to Mark Britten-Jones, Malcolm Edey and Stephen Grenville for helpful suggestions. The views expressed in this paper are those of the author and should not be attributed to the Reserve Bank of Australia.

ABSTRACT

Over the last six years, Australia has experienced relatively high steady inflation and high real interest rates – especially short-term rates. This paper argues that these high real rates are a consequence of the interaction between the relatively high inflation and a tax system which taxes nominal income. The paper then explains how these high real rates can persist in a world with free global capital flows. We argue that foreign lenders find Australian nominal assets attractive, and their demand for them appreciates the Australian real exchange rate. However, foreign demand for Australian nominal assets is not insatiable. Having driven up the Australian real exchange rate, foreigners eventually conclude that the excess return on the high Australian interest rates is offset by the possibility that the over-valuation of the real exchange rate will unwind.

The paper formalizes these ideas in a model.

TABLE OF CONTENTS

THE EFFECT OF STEADY INFLATION ON INTEREST RATES AND THE REAL EXCHANGE RATE IN A WORLD WITH FREE CAPITAL FLOWS

David W. R. Gruen

1. INTRODUCTION

This paper presents a model to help explain important aspects of the behaviour of the Australian macroeconomy over the recent past. Figure 1 shows inflation[1] from March 1984 to June 1990 in Australia, in the US and in four large OECD economies (the figure shows an arithmetic average of inflation in the US, Japan, West Germany and the UK). Figure 2 shows both short and long-term real pre-tax interest rates[2] over the same period and Table 1 provides summary statistics. Figure 3 shows the Australian real exchange rate and terms of trade over the 1980s.[3]

---

1 To avoid the problems associated with the consumer price index (CPI) – particularly the inclusion of mortgage interest payments – we use each country's implicit price deflator for private consumption to derive inflation.

2 Real interest rates are derived by deflating nominal rates by the 12 month ended inflation rates calculated for Figure 1. For short rates, we use 3 month Euro-currency rates for all countries other than Australia. Because of data limitations, for Australia we use the 90-day bank bill rate. Over the period for which Australian Euro-rates were available (since December 1987), the average difference between the 90-day bank bill rate and the mid-point of bid and offer Australian 3 month Euro-rate was 0.36%p.a. Long rates are long-term government bond yields from International Financial Statistics, IMF.

3 The real exchange rate is the trade-weighted index published by the Reserve Bank of Australia, deflated using the ratio of Australian 'Medicare adjusted' CPI to OECD G7 CPI. An increase in the index represents an appreciation of the Australian dollar. The terms of trade is for goods and services. See the Discussion Section for further analysis on the level of Australia's real exchange rate.

Figure 1

INFLATION RATES
(12 month ended)

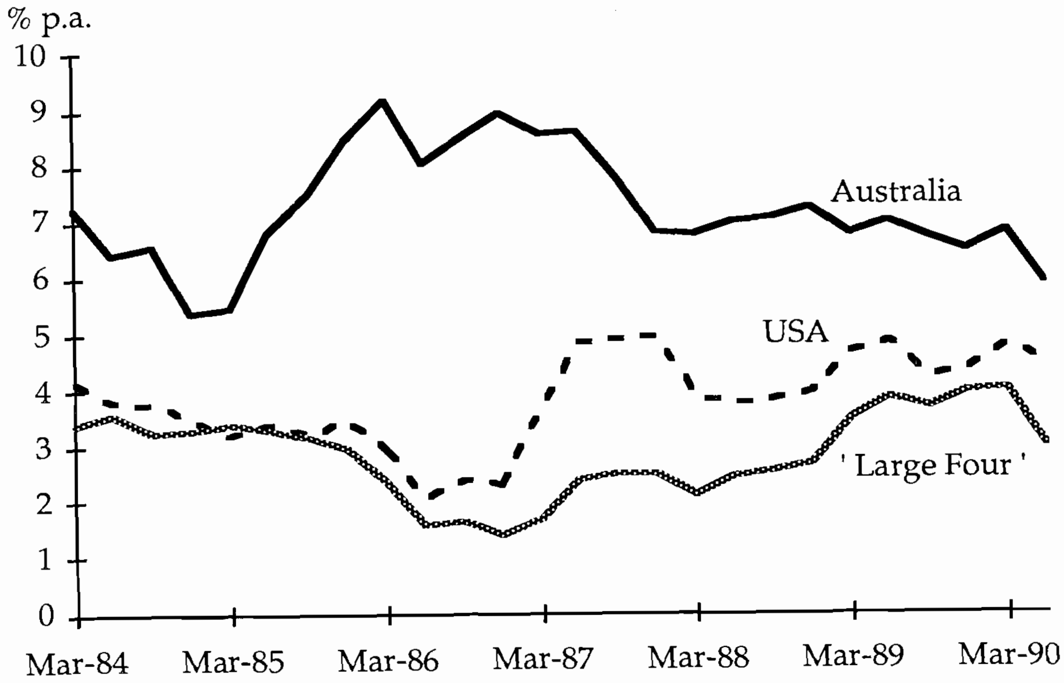
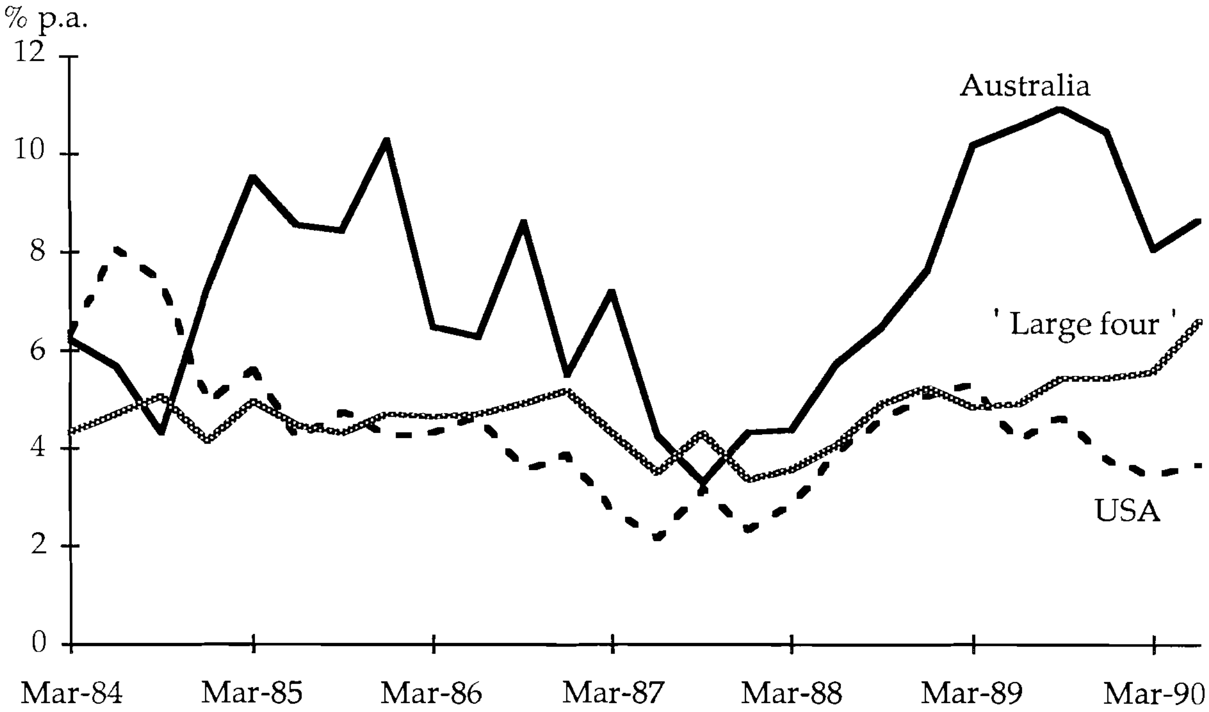


Figure 2

REAL PRE-TAX 3 MONTH INTEREST RATES



REAL PRE-TAX LONG-TERM BOND RATES

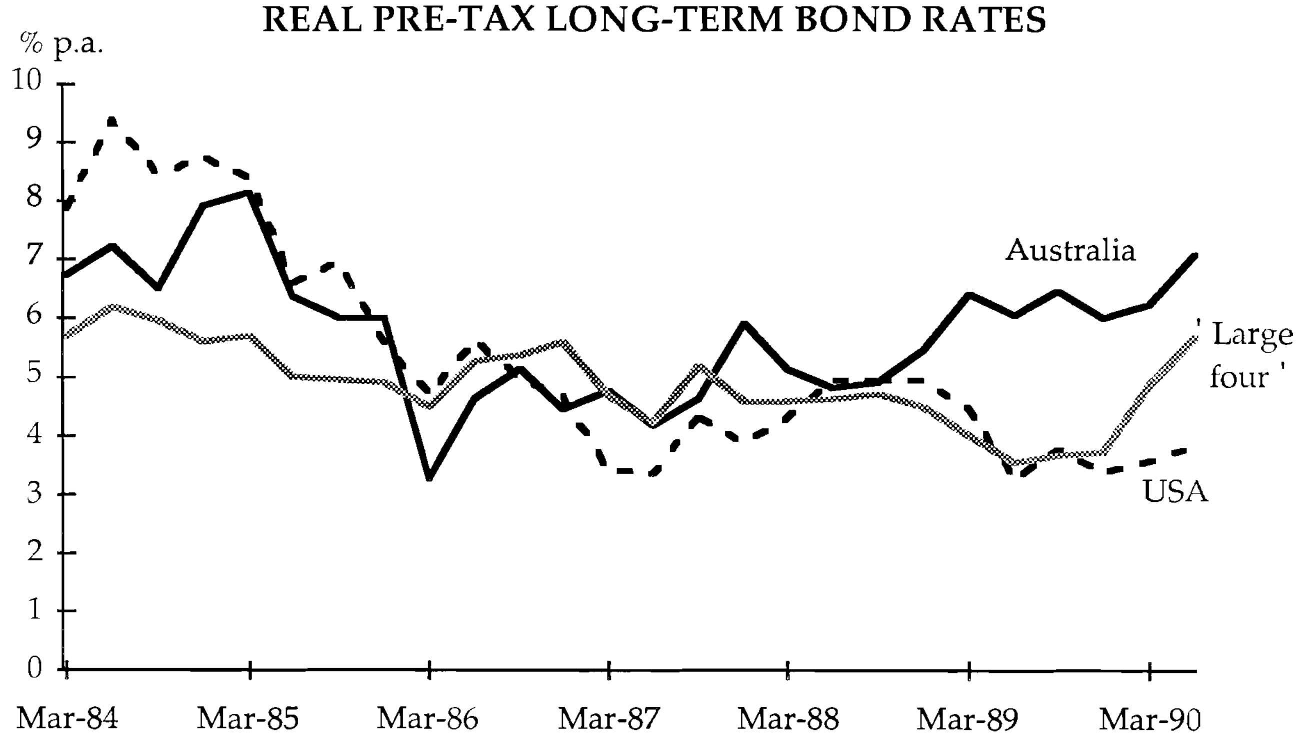
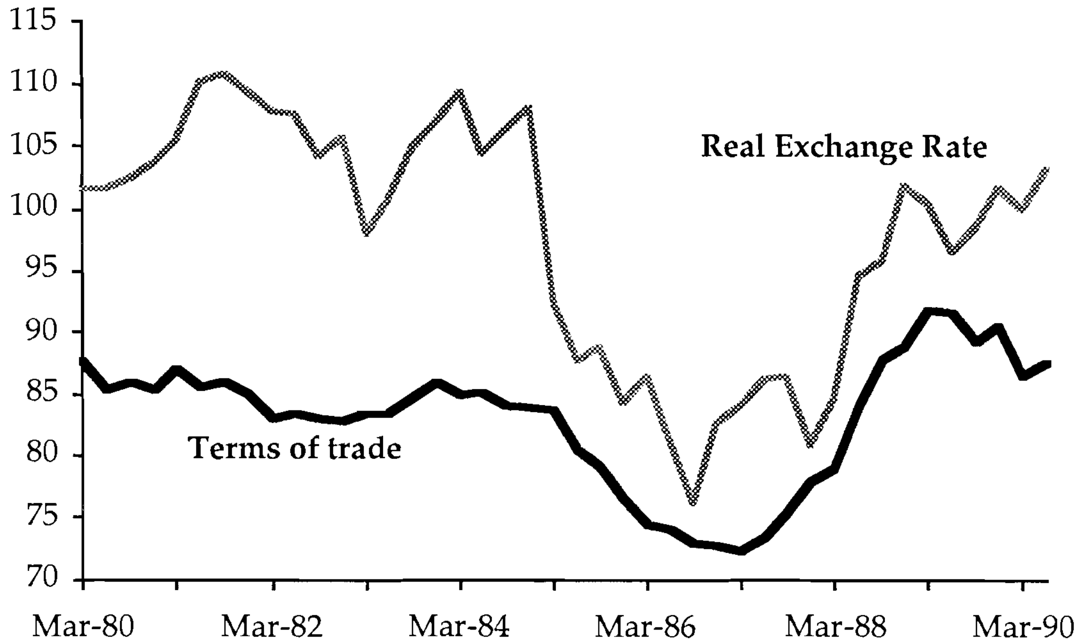


Figure 3

AUSTRALIA'S REAL EXCHANGE RATE AND TERMS OF TRADE



As Figure 1 shows, for over six years, Australian inflation has been fairly steady and well above US or 'large four' inflation. As Figure 2 shows, real short-term interest rates in Australia have been substantially above world real interest rates for most of this six year period – on average, over $2\frac{1}{2}$%p.a. above world rates – and real Australian long bond rates have also been somewhat above world rates.

Table 1
Average Inflation and Real Interest Rates
Mar '84 – Jun '90 (expressed as % p.a.)

	12 month ended inflation rate	Real pre-tax 3 month interest rate	Real pre-tax long-term bond rate
Australia	7.2	7.3	5.8
United States	3.8	4.4	5.3
Average of Large Four (US, Japan, UK WGermany)	2.8	4.7	4.9

Since Australia is a small open economy operating, over the last six years, with no impediments to the movement of capital into or out of the country, Australian interest rates should satisfy international arbitrage conditions.[4] With these arbitrage conditions in mind, there

[4] Expressed formally, for a representative investor from country j, the arbitrage condition in terms of real interest rates is

$$r^A = r^j + E(\Delta S/S) + rp, \qquad (1)$$

where r^A and r^j denote the real pre-tax interest rates on comparable Australian and country j assets ($r^k \equiv i^k - \pi^k$, where i^k and π^k denote the nominal interest rate and the inflation rate in country k, and k denotes either Australia or country j); S is the bilateral real exchange rate (Australian currency price of country j currency, deflated by the ratio of Australian to country j consumer price indices), and ΔS is the change in S over the life of the asset. The risk premium, rp, is the real excess return demanded by the foreign investor to hold the Australian denominated are two possible explanations for the fact that Australian short-term pre-tax real interest rates have averaged over $2\frac{1}{2}$%p.a. above comparable world rates for over six years. Either there has been a sizable risk premium[5] demanded by foreign investors to hold Australian short-term nominal assets, or the market has continually expected significant **real** depreciation of the Australian dollar – or, perhaps, a combination of these two explanations.

Smith and Gruen (1989) rejected the possibility of a large risk premium for the Australian dollar. The volatility of the return on short-term Australian nominal assets is similar to the volatility of the return on comparable assets from other countries,[6] and the risk premium required by foreign investors to compensate them for that volatility should also be similar. Both theoretical calculations (extending the work of Frankel and Engle (1984) and Frankel (1988)) and estimates based on surveys of the exchange rate expectations of market participants (using the approach of Froot and Frankel (1989)) suggest that, on average, the risk premium is much too small to account for the short-term real interest differential between Australia and the world over the last six years.[7]

---

asset. Part 1 of the Appendix justifies the focus on an arbitrage condition expressed in terms of **pre-tax** interest rates.

[5] The term 'risk premium' is often used loosely to mean the excess return demanded by investors to compensate them for the 'risk' of an exchange rate fall. Here, we use the term in its technical sense. For a given expectation of the return on an asset, the risk premium is the excess return required because of the expected volatility of the return and the expected correlation of the return with the returns on other assets.

[6] Over a four-week horizon, an investment in short-term Australian nominal assets by a US investor has experienced a variance of **real** returns of 0.00119 (Smith and Gruen, (1989)). This may be compared with the average variance of real returns (over a month) for a US citizen investing in short-term nominal assets in the UK (0.00080), France (0.00099), Germany (0.00113) or Japan (0.00099) – Frankel, (1985).

[7] The theoretical calculations suggest that the risk premium a utility-maximizing investor should demand to hold short-term Australian nominal assets is at least a factor of ten smaller than this average real interest differential. An alternative possibility is that a risk premium exists because of a default risk on Australian short-term nominal assets. Over the six years under study, the real interest differential between Australian and US 3-month Treasury bills has also averaged more than 2.5% p.a. Since the Australian Federal Government has a low level of debt and, over the last three years, has been running large budget surpluses, it seems highly unlikely that a 'default risk premium' explains the high short-term Australian interest rates.

This paper provides an alternative explanation for the consistently high Australian short-term pre-tax real interest rates, and examines its consequences. The main body of the paper presents a formal model, but the key ideas can be set out descriptively.

With relatively high domestic inflation and a tax system which is not inflation-neutral, the monetary authorities will find it necessary to maintain high domestic short-term pre-tax real interest rates simply to keep inflation steady.[8] Domestic lenders will receive a nominal interest return high enough to at least partly compensate them for being taxed on their full nominal interest receipts. Similarly, domestic borrowers will be willing to pay these interest rates because they can deduct the full nominal value of their interest costs when calculating their taxable income.

In contrast to their domestic counterparts, to the extent that foreign lenders are taxed, their tax is levied on their nominal $A interest receipts adjusted for any depreciation.[9] Hence, foreign lenders will find the high domestic short-term interest rates attractive even when they anticipate that the domestic exchange rate will depreciate to offset the domestic/foreign inflation differential. In the process of satisfying their demand for Australian nominal assets, foreigners will cause the domestic nominal and real exchange rate to appreciate. When this happens, foreign lenders will be aware of two things: that domestic real interest rates are relatively high, and that the domestic real exchange rate is over-valued (compared with its level if domestic real interest rates were equal to world real rates). Equilibrium is established when the marginal foreign investor's assessment is that the excess return on the high domestic interest rates is offset by the expected loss should the domestic currency depreciate in real terms.

Thus, while the relatively high domestic inflation persists, foreign lenders continue to receive an exchange-rate-adjusted return higher than the world interest rate. This does **not** cause them to invest so heavily in domestic nominal assets that the domestic pre-tax real

---

[8] The monetary authorities control short-term interest rates, while long-term rates are determined by the market.

[9] See Part 1 of the Appendix for further details.

interest rate is driven down to the world level because foreigners remain wary of the possibility that the persistent real exchange rate over-valuation will unwind – which would occur if, for example, the domestic inflation was to end.

To summarize, while the combination of relatively high steady domestic inflation, a non-inflation-neutral domestic tax system and free global capital flows persists, domestic short-term pre-tax real interest rates remain above comparable world rates and the domestic real exchange rate remains over-valued.

To support this intuitive argument, the paper develops a formal model. The development proceeds in two stages. In the first stage (Section 2 of the paper) we consider a small open economy with steady inflation and a non-inflation-neutral tax system in a world with no inflation and free global capital flows. A critical assumption is that there is no future uncertainty – both the steady domestic inflation and the tax system are expected to remain unchanged. Then, international investors force domestic real pre-tax interest rates to equal world real pre-tax interest rates. This is a standard result, and clearly such a model cannot explain Australia's high short-term real interest rates over the past six years.

At the second stage of development (Section 3) we introduce uncertainty. In turn, we examine three sources of uncertainty – the possibility that, firstly, the steady domestic inflation will end, or secondly, the non-inflation-neutrality of the tax system will be eliminated, or thirdly, a 'real interest equalization tax' will be introduced. Then, as the model demonstrates, for as long as the combination of steady domestic inflation, a non-inflation-neutral domestic tax system and free global capital flows (hereafter referred to as "the combination") persists, the domestic short-term pre-tax real interest rate will be higher than the comparable world real rate. Furthermore, the model predicts that while "the combination" persists, the domestic yield curve will be inverse (i.e., with short rates higher than long rates) – as has been the case for most of the last six years in Australia.

In both the Section 2 and Section 3 versions of the model, the interaction of steady inflation with a non-inflation-neutral domestic tax system and free global capital flows leads to an over-valued domestic real exchange rate.

To conclude this introduction, we highlight the quite different implications of the two alternative explanations for the high Australian real interest rates. If the high Australian real interest rates were a consequence of a risk premium, two things would follow. Firstly, the real interest differential would remain for as long as the risk factors causing the risk premium remained. Secondly, the high domestic real interest rates would not cause the Australian real exchange rate to be over-valued, because, adjusted for risk, Australian real interest rates would be the same as world real interest rates. By contrast, if the explanation presented in this paper is correct, while "the combination" persists, the real exchange rate is continually over-valued – which has resource mis-allocation consequences.

2. THE MODEL WHEN THE FUTURE IS CERTAIN

We analyse a modification of the model introduced by Buiter and Miller (1981). The main modification is to include a tax system which is not inflation-neutral. The model provides a simple description of a small open economy in a world of floating exchange rates and perfect capital mobility. Accepting the arguments presented in the introduction, we assume that risk premia are small enough to be ignored, and that world investors base their investment decisions on expected pre-tax rates of return. The log-linear equations of our model are:

$m - p = ky - \lambda i\,(1 - \tau);$ $\quad k, \lambda > 0$ (LM curve) (2)

$y = -\gamma\,(i\,[1 - \tau] - Dp) + \delta\,(e - p);$ $\quad \gamma, \delta > 0$ (IS curve) (3)

$Dp = \varphi y + \pi;$ $\quad \varphi > 0$ (Phillips curve) (4)

$\pi = \mu$ $\quad$ (Core inflation) (5)

$De = i - i^*$ $\quad$ (International arbitrage condition) (6)

List of symbols

m logarithm of the nominal money stock

p logarithm of the domestic price level

y logarithm of real domestic output (zero represents "full employment" real output)

i	domestic nominal short-term interest rate on non-money assets[10]
i^*	world nominal short-term interest rate on non-money assets
r	domestic pre-tax short-term real interest rate ($r \equiv i - Dp$)
r^*	world pre-tax short-term real interest rate
e	logarithm of the nominal exchange rate (domestic currency price of foreign currency)
D	the differential operator, so, for example, $Dp \equiv dp/dt$.
π	"core" rate of domestic inflation
μ	rate of growth of the domestic nominal money supply; $\mu = D^+m$ where D^+m is the right-hand side derivative of $m(t)$: $D^+m(t) \equiv \lim_{h \to 0} \{ [m(t+h) - m(t)]/h\}, h > 0.$
τ	domestic tax rate, assumed to apply equally to **nominal** income earned by individuals and companies; $0 < \tau < 1$
l	logarithm of domestic real balances ($l \equiv m - p$)
c	logarithm of the domestic real exchange rate ($c \equiv e - p$).

A short description of the model follows. The demand for real balances (equation 2) increases with the level of real activity in the economy and falls with the after-tax opportunity cost of holding money. The level of real activity (equation 3) depends negatively on the after-tax real interest rate, and positively on the real exchange rate. We assume that there is no foreign inflation, so that the world nominal and real interest rates are equal ($i^* = r^*$). Without loss of generality, we assume that the logarithm of the world price level is equal to zero and so the log of the domestic real exchange rate is c ($c \equiv e - p$). Note that, as defined, a **fall** in the real exchange rate corresponds to a real exchange rate **appreciation**. Domestic inflation is generated by an expectations-augmented Phillips curve (equation 4), with "core" inflation determined by the expected future growth of the nominal money supply (equation 5). The exchange rate is determined by rational forward-looking risk-neutral agents who understand the structure of the economy as well as the parameters of the model. They ensure that expected rates of return on foreign and domestic nominal assets are

[10] In the model in this Section, there is no future uncertainty and no distinction between short and long interest rates. However, as we shall see, assuming all interest rates are short-term simplifies the analysis in Section 3.

equalized (equation 6). Equation (6) is equivalent to equation (1) with the risk premium, rp, set to zero.

Following Buiter and Miller, we assume in this Section of the paper that the forward-looking agents in the foreign exchange market expect the domestic nominal money supply to continue to grow at rate μ forever, and hence expect domestic inflation at rate π ($\pi = \mu$) to continue forever. In equilibrium, $Dl = Dc = 0$, and these conditions allow the equilibrium domestic levels of interest rates, real balances and the real exchange rate to be derived:

$$r^E \equiv i^E - \pi = i^* \equiv r^* \tag{7}$$

$$r^E_{AT} \equiv i^E (1-\tau) - \pi = r^* (1-\tau) - \tau \pi \tag{8}$$

$$l^E = -\lambda (1-\tau)(r^* + \pi) \tag{9}$$

$$c^E = \frac{\gamma}{\delta} [(1-\tau) r^* - \tau\pi] \tag{10}$$

where the superscript E denotes equilibrium and the subscript AT denotes after-tax. Note that the international arbitrage condition (equation 6) ensures that in equilibrium, the domestic pre-tax real interest rate is equal to the world pre-tax real interest rate (equation 7). This fact, together with a domestic tax system which is not inflation-neutral implies that the domestic real after-tax interest rate is a decreasing function of domestic inflation (equation 8). In equilibrium, output is at its full-employment level. Since output is a function of the real after-tax interest rate and the real exchange rate (equation 3) it follows that the equilibrium real exchange rate is also a function of the rate of domestic inflation (equation 10). The higher the level of steady domestic inflation, the more over-valued the real exchange rate.[11]

Intuitively, this result can be understood as follows. A lower after-tax real interest rate increases domestic demand – and, in particular, increases demand for domestic non-traded goods. For the non-traded goods market to continue to clear, it is necessary for there to be an increase in the relative price of non-traded goods – that is, an appreciation of the real exchange rate.

---

[11] As defined, a low level of c corresponds to an over-valued real exchange rate.

3. INTRODUCING UNCERTAINTY

3a The possibility that steady inflation will end

Countries with relatively high inflation face a dilemma not shared by countries with relatively low inflation. When inflation is low, there is general agreement that it should be kept low. When inflation is relatively high, there is no comparable consensus. Some argue that even moderate steady inflation is sufficiently costly that it must be eliminated quickly. Others counter that the output costs of eliminating inflation are themselves sufficiently high that they outweigh the benefits of lower inflation. While relatively high inflation persists, even when it is steady, there are continual calls for it to be reduced.[12]

Thus, when a country runs inflation, even steady inflation, at a rate significantly higher than its trading partners, it is unrealistic to assume that this inflation will never be reduced. Importantly, dropping this assumption changes the nature of the equilibrium – as we now demonstrate. Assume instead that there are two possible monetary policy regimes. Initially, the domestic economy is in equilibrium with steady inflation, π ($\pi > 0$), and the monetary authorities set the nominal interest rate, i, to maintain this steady inflation at "full employment" output. This is regime I. The second monetary policy regime (regime II) involves an immediate ending of nominal money **growth** coupled with an increase in the **level** of the money supply sufficient to allow the economy to instantly jump to its new long-run equilibrium.[13] When the monetary policy regime changes from I to II, we assume that it is immediately credible and expected to be permanent.[14] Thus, **after** the

---

[12] This asymmetry between the policy choices facing countries with high and low inflation rates has recently been invoked to explain why high inflation raises inflation uncertainty (Ball, 1990). An alternative possible source of uncertainty is a belief in the market that the monetary authorities might, at least temporarily, give up the fight against inflation and loosen monetary policy. This possibility is examined in footnote 19.

[13] In the new zero-inflation equilibrium, the opportunity cost of holding money is smaller and hence the demand for money is larger. From equation (9), the required increase in the level of the money supply is $\Delta m = \lambda (1 - \tau) \pi$. See Buiter and Miller (1981) for further discussion.

[14] It is difficult to imagine that regime II, as described, would be immediately credible. The specification chosen simplifies the analysis. In Part 2 of the

regime change, all uncertainty has been resolved, and the economy immediately jumps to the equilibrium defined by equations (7) – (10) with $\pi = 0$.

We assume that while the first (steady inflation) regime persists, agents assess the probability of a regime change occurring in the next infinitesimal time interval dt as ε dt.[15] We now derive the appropriate international arbitrage condition for regime I.

In equilibrium with the domestic economy inflating steadily at rate π, the nominal exchange rate depreciates steadily at rate π, so that the real exchange rate remains unchanged. Hence, the excess return earned over an infinitesimal time interval dt by a foreigner holding all her wealth, F, in short-term domestic nominal assets rather than comparable foreign assets is $F. (i - r^* - \pi)$ dt.

In general, when the monetary policy regime change occurs, there is a jump in the real exchange rate, Δc, because uncertainty has been resolved. When the jump occurs, the capital **loss** to our foreigner if she is holding all her wealth in domestic short-term nominal assets, is $F. \Delta c$.[16] Since, by assumption, foreign investors are risk-neutral, the expected excess return from investing in domestic assets must be zero,

---

Appendix, we specify regime II **without** the step increase in the level of the money supply. Note that the nominal interest rate is the monetary policy instrument in regime I, while regime II involves a monetary target. Again, this simplifies the analysis. In Part 3 of the Appendix, we briefly deal with the version of the model in which regime I is specified in terms of steady money growth at rate $\mu = \pi$.

[15] If ε is constant over time, the probability that the regime change **does not** occur over a time interval of length T is $e^{-\varepsilon T}$. On average, regime I persists for the length of time $1/\varepsilon$. Note that this specification implies that the steady inflation regime (regime I) must eventually end. However, it is easy to extend the model to the case where investors think that there is a probability $1 - q$ $(0 < q < 1)$ that regime I will continue forever. The probability of a regime change occurring in the next infinitesimal time interval dt is then $q.\varepsilon$ dt rather than ε dt. All results are as in the text, with $q\,\varepsilon$ replacing ε.

[16] We use the common approximation that, for small x, $\ln(1 + x) \approx x$, where x is the proportionate change in the real exchange rate. Assuming all interest rates are short-term avoids dealing with the change in the capital value of outstanding long-term bonds when the monetary policy regime changes. See Section 3c for the implications of the model for longer-term interest rates and Part 4 of the Appendix for a plausible alternative specification.

i.e., $F. (i - r^* - \pi)\, dt = F. \Delta c. \varepsilon\, dt,$ or equivalently,

$$r - r^* = \varepsilon \,.\, \Delta c\,, \qquad (6')$$

where, as before, r is the domestic short-term pre-tax real interest rate.

We may now derive the equilibrium. While steady inflation persists, the real exchange rate, c, satisfies equation (3) at full-employment output ($y \equiv 0$). When regime II is established, the real exchange rate jumps to its zero-inflation equilibrium level, $c^E = \frac{\gamma}{\delta}(1 - \tau)\, r^*$. Therefore, the jump in the real exchange rate, Δc, when regime II is established is,

$$\Delta c = \frac{\gamma}{\delta}[\,(1 - \tau)\,(r^* - r) + \tau\pi\,]. \qquad (11)$$

Solving equations (6′) and (11) gives,

$$r = r^* + \pi\left[\frac{\tau}{(1 - \tau) + \delta/\varepsilon\gamma}\right] \quad \text{and} \qquad (12)$$

$$r_{AT} = r^*(1 - \tau) - \pi\left[\frac{1}{\varepsilon\gamma(1 - \tau)/\delta + 1}\right] \quad \text{and} \qquad (13)$$

$$c = \frac{\gamma}{\delta}\left\{r^*(1 - \tau) - \pi\left[\frac{\tau}{(1 - \tau)\,\varepsilon\,\gamma/\delta + 1}\right]\right\}. \qquad (14)$$

Thus, while steady inflation persists, the domestic pre-tax real interest rate, r, exceeds the world pre-tax real interest rate, r^*, while the domestic after-tax real interest rate is lower than it would be if there was no domestic inflation. The real exchange rate is over-valued. The higher the level of steady inflation, the higher the domestic pre-tax real interest rate, the lower the after-tax real interest rate and the more over-valued the real exchange rate.

It follows from equations (12) and (14) that both $\frac{dr}{d\varepsilon}$ and $\frac{dc}{d\varepsilon}$ are unambiguously positive. Thus, an increase in the perceived probability of inflation coming to an end shifts the steady inflation equilibrium to a higher domestic real interest rate (both pre-tax and after-tax) and a less over-valued real exchange rate.

3b The possibility that an inflation-neutral tax system or a real interest equalization tax will be introduced

Introducing an inflation-neutral tax system involves taxing real income rather than nominal income. With inflation steady at rate π, and an inflation-neutral tax levied at rate τ, the after-tax real interest rate is $r_{AT} = (i - \pi).(1 - \tau)$. Equation (3) then becomes:

$$y = -\gamma\,(i - Dp).(1 - \tau) + \delta\,(e - p). \qquad \gamma, \delta > 0 \ \text{(IS curve)} \qquad (3')$$

Even while steady inflation continues, upon introduction of such a tax system (and the associated adjustment of the nominal interest rate to keep output at its full employment level) the equilibrium in the real economy is characterised by

$$r = r^* \qquad \text{and} \qquad (12')$$

$$r_{AT} = r^*(1 - \tau) \qquad \text{and} \qquad (13')$$

$$c = \frac{\gamma}{\delta}\, r^*(1 - \tau). \qquad (14')$$

Thus, not surprisingly, introducing an inflation-neutral tax system leads to the same equilibrium in the real economy as is achieved by eliminating inflation.

A real interest equalization tax[17] is designed to eliminate the real interest premium earned by foreigners investing in domestic nominal assets. It involves imposing a tax, Θ, on foreign lenders with $\Theta = r - r^*$. Equation (6′) becomes

$$De = i - i^* - \Theta \qquad \text{or}$$

$$De - Dp \equiv Dc = 0. \qquad (6'')$$

Upon imposition of such a tax (and the associated adjustment of the nominal interest rate to keep output at its full employment level) the equilibrium is characterised by

$$r = r^* + \frac{\pi\,\tau}{1 - \tau} \qquad (12'')$$

with r_{AT} and c again given by equations (13′) and (14′).

---

[17] Liviatan (1980) and Dornbusch (quoted in Buiter and Miller (1981)) suggested a real interest equalization tax in the context of reducing inflation in a world with free global capital flows. The analysis here suggests that their argument also applies in an economy which must run short-term real interest rates higher than comparable world rates to keep inflation steady.

Thus, we may re-interpret the model of Section 3a as follows. Re-define regime II as a permanent and immediately credible introduction of **either** an inflation-neutral domestic tax system **or** a real interest equalization tax combined with a continuation of nominal money growth at rate $\mu = \pi$.[18] The introduction of either of these versions of regime II leads to the same capital loss on short-term nominal assets as in the Section 3a model. As a consequence, while regime I persists, the equilibrium in the real economy is again given by equations (12) – (14).

3c The yield curve

By assumption, there is no uncertainty in the world economy and hence the world interest rate on nominal securities with any maturity is r*. For the Section 3a model, the domestic nominal exchange rate depreciates at rate π until the regime change occurs, when there is a jump depreciation of magnitude Δc, followed by no further nominal depreciation (because domestic inflation has ceased). Hence, while regime I persists, the appropriate arbitrage condition for a domestic security which pays nominal interest at rate i_T ($i_T \equiv r_T + \pi$) over the time interval $0 \leq t \leq T$ and is then redeemed at T for one unit of domestic currency is:

$$\int_0^T e^{-\varepsilon t} \varepsilon \left[\int_0^t (r_T + \pi)\, e^{-(r^* + \pi)\tau}\, d\tau + e^{-\pi t}(1 - \Delta c) \left\{ \int_t^T (r_T + \pi)\, e^{-r^*\tau}\, d\tau + e^{-r^*T} \right\} \right] dt$$

$$+ \; e^{-\varepsilon T} \left\{ \int_0^T (r_T + \pi)\, e^{-(r^* + \pi)\tau}\, d\tau + e^{-(r^* + \pi)T} \right\} = 1. \qquad (15)$$

The probability that the regime change will occur between times t and t + dt is $e^{-\varepsilon t} \varepsilon\, dt$, and the term in square brackets is the present discounted value of the security if the regime change occurs at time t, $0 \leq t \leq T$. The probability that the regime change will not occur over the time interval $0 \leq t \leq T$, is $e^{-\varepsilon T}$.

For the Section 3b models, steady domestic inflation continues after the regime change and hence so does the steady nominal depreciation of the domestic exchange rate. Hence, while regime I persists, the

[18] As in Section 3a, to allow an immediate jump to the long-run equilibrium it is also necessary to have a step change in the level of the money supply.

appropriate arbitrage condition for a domestic nominal security with a life of T is:

$$\int_0^T e^{-\varepsilon t}\,\varepsilon\left[\int_0^t (r_T+\pi)\, e^{-(r^*+\pi)\tau}\, d\tau + (1-\Delta c)\left\{\int_t^T (r_T+\pi)\, e^{-(r^*+\pi)\tau} d\tau + e^{-(r^*+\pi)T}\right\}\right] dt$$

$$+\ e^{-\varepsilon T}\left\{\int_0^T (r_T+\pi)\, e^{-(r^*+\pi)\tau}\, d\tau + e^{-(r^*+\pi)T}\right\} = 1. \qquad (16)$$

Both equations (15) and (16) lead to complicated expressions with little intuitive appeal. However, in the limit as $T \to \infty$, the expressions reduce to:

$$r_\infty = (r^*+\pi)\left[1+\frac{\varepsilon\,\{\pi-\Delta c\,(r^*+\pi)\}}{r^*\,(r^*+\pi+\varepsilon)}\right]^{-1} - \pi \qquad \text{and} \qquad (15')$$

$$r_\infty = (r^*+\pi)\left[1-\frac{\varepsilon\,\Delta c}{r^*+\pi+\varepsilon}\right]^{-1} - \pi \qquad (16')$$

$$\approx\ r^* + \varepsilon\,\Delta c\,\frac{r^*+\pi}{r^*+\pi+\varepsilon}\,. \qquad (16'')$$

There are several notable features of these equations. To begin, consider the case when steady inflation is expected to continue after the regime change (i.e., the Section 3b models for which the relevant equations are (16), (16′) and (16″)). Then, while regime I persists, holders of infinitely-lived domestic securities demand a real interest rate higher than the world real interest rate (equation (16′) implies that $r_\infty > r^*$). However, they do not require an interest rate as high as the short-term interest rate (equation (16″) implies that $r_\infty - r^* < \varepsilon\Delta c = r - r^*$).

Intuitively, this can be understood as follows. Over each short time interval while regime I persists, foreign holders of short and infinitely-lived domestic securities face the same expected capital loss – arising from the possibility of a regime change. Hence, they both require a real return higher than the world interest rate. However, holders of short-term securities require a higher interest rate than holders of infinitely-lived securities because, unlike the former, the latter have locked-in a favourable interest rate for the infinite life of their security.

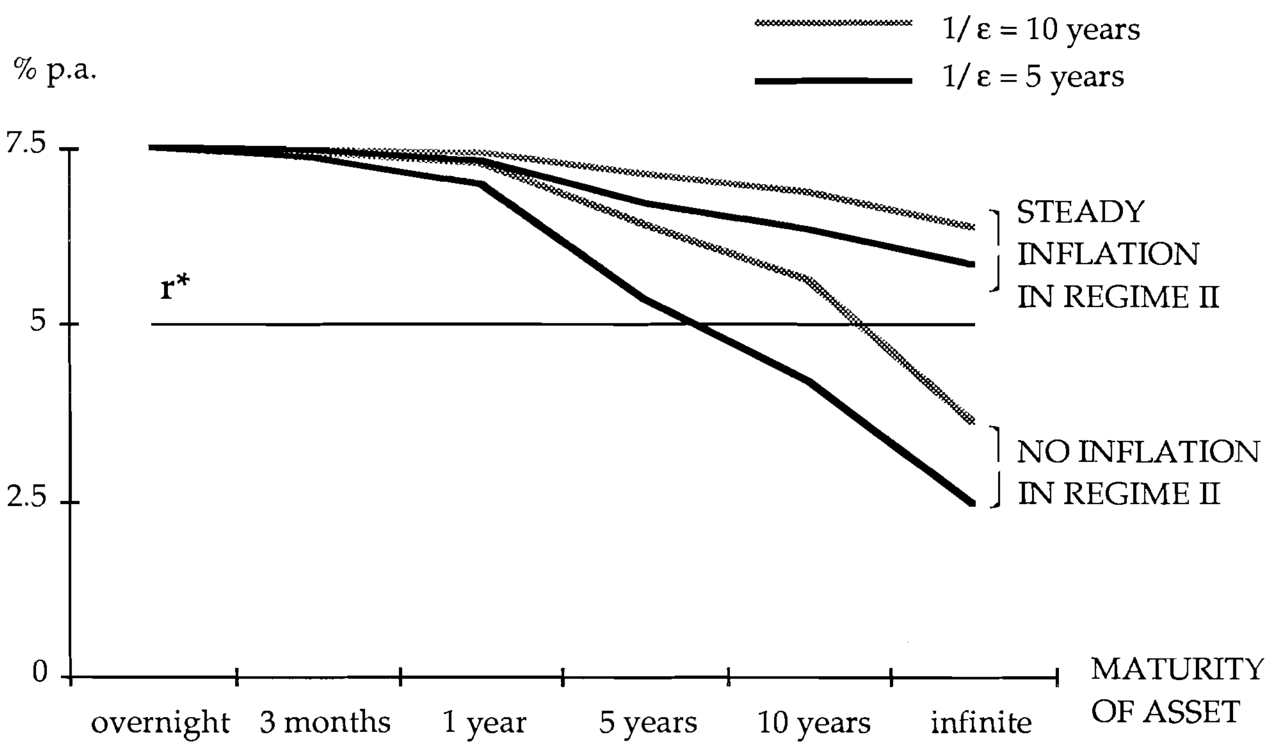
In the case when steady inflation is expected to end after the regime change (i.e., the Section 3a model), the relevant equations are (15) and (15′). Holders of infinitely-lived domestic securities now receive a further compensation not available to holders of short-term securities.

After the regime change occurs, the steady nominal depreciation of the domestic currency ends – which increases the real yield on infinitely-lived securities. If $\pi > \Delta c\ (r^* + \pi)$, this effect is so important that, while regime I persists, $r_\infty < r^*$.

To summarize, both the Section 3a and Section 3b models imply that, while regime I persists, the domestic yield curve will be inverse. Figure 4 provides some empirical model estimates for the domestic yield curve using plausible parameter values. Based on Table 1, the calculations assume: $r^* = 5\%$p.a., $r - r^* = \varepsilon\ \Delta c = 2.5\%$p.a. and $\pi = 4\%$p.a. (roughly the inflation difference between Australia and the 'large four' over the six years). The average duration of regime I is $1/\varepsilon$ and I examine two possible values: $1/\varepsilon = 5$ years (hence $\Delta c = 12.5\%$) and $1/\varepsilon = 10$ years (hence $\Delta c = 25\%$).

Figure 4

THE REAL DOMESTIC YIELD CURVE WHILE REGIME I PERSISTS



The long-term Australian government bonds used in Figure 2 and Table 1 are 10 year bonds. Using the above parameter values, the models predict a domestic real interest rate on 10 year bonds of $r_{10\ year} - r^* = -0.8$%p.a. or 0.6%p.a. when regime II has no inflation and $1/\varepsilon = 5$ years or $1/\varepsilon = 10$ years and $r_{10\ year} - r^* = 1.3$%p.a. or 1.8%p.a. when regime II has steady inflation and $1/\varepsilon = 5$ years or $1/\varepsilon = 10$ years. The real interest differential between Australian 10 year bonds and 'large four' long-term bonds has fluctuated around zero (see Figure 2) and has averaged 0.9%p.a. over the period under study (see Table 1). While this comparison is far from definitive, the prediction from the models that the yield curve should be strongly inverse seems consistent with the Australian experience of the past six years.[19]

4. DISCUSSION

In a simple model of a **closed** economy, the domestic interest rate adjusts to equilibrate aggregate levels of saving and investment. Private saving and investment decisions depend on the after-tax real interest rate, which, when domestic inflation is expected to be steady at rate π, takes the form $r_{AT} = i(1-\tau) - \pi$. Other things equal, a change in the expected rate of domestic inflation induces a change in the domestic nominal interest rate which leaves the after-tax real interest rate unchanged – to ensure that aggregate saving and investment continue to balance. Thus, a change in steady inflation, $d\pi$, induces a change in the nominal interest rate of $di = \frac{1}{1-\tau} d\pi$ and a change in the (pre-tax) real interest rate of $dr = \frac{\tau}{1-\tau} d\pi$. This more than one-for-one change

[19] We are now in a position to examine the possibility that the market believes that the monetary authorities might, at least temporarily, give up the fight against inflation and loosen monetary policy – thereby leading to an immediate fall in the exchange rate. As before, this possibility would lead the market to require a real interest premium on domestic short-term nominal assets. But, as should be clear from the above analysis, it also implies that the yield on domestic longer-term assets should be higher than the yield on short-term assets – to provide compensation for the possibility of higher inflation in the future. We can therefore conclude that market anticipation of such a possibility cannot explain **both** high short-term real rates and lower longer-term real rates in Australia over the last six years.

in the nominal interest rate is often called the tax-adjusted Fisher effect.[20]

This paper extends this simple closed-economy model to examine the interaction between inflation and the tax system in a world with free global capital flows. As we have seen in Section 2, if there is a constant inflation differential between the domestic economy and the world which is expected to be permanent, the tax-adjusted Fisher effect cannot apply to the domestic economy. Instead, international investors ensure that the domestic pre-tax real interest rate is equal to the world pre-tax real rate. This is the standard result.

However, introducing the possibility that the combination of steady domestic inflation, a non-inflation-neutral tax system and free global capital flows may end changes the nature of the equilibrium. In the models of Section 3, while "the combination" persists, the domestic pre-tax real interest rate is higher than the world pre-tax real rate and the real exchange rate is over-valued. This equilibrium is consistent with an efficient risk-neutral forward-looking foreign exchange market because of the ever-present possibility that a regime change will occur – leading to a capital loss on domestic nominal assets.

One might reasonably be sceptical about the details of each of the Section 3 versions of the model. Nevertheless, they suggest an important point. In a world with free global capital flows, relatively high domestic inflation and a tax system which is not inflation-neutral, the monetary authorities will find it necessary to hold the domestic short-term pre-tax real interest rate above the comparable world rate simply to keep inflation steady. Foreigners will find domestic short-term nominal assets attractive, and their demand for these assets will appreciate the domestic nominal and real exchange rate. When this happens, foreign investors will be aware of two things: that domestic interest rates are relatively high, and that the domestic exchange rate is over-valued. Equilibrium is established when the marginal foreign investor's assessment is that the excess return on the high domestic real

[20] See Feldstein (1976) and Feldstein, Green and Sheshinski (1978) for more sophisticated models of the interaction between inflation and the tax system in a closed economy.

interest rates is offset by the expected loss should the domestic currency depreciate in real terms.

In the real world, there are rather more sources of uncertainty than in the models of Section 3. Thus, for example, the authorities presumably view an over-valued real exchange rate as a cause for concern. If so, there are a range of available options – from "talking the currency down", to intervention in the foreign exchange market (which seems to make a difference, see Dominguez and Frankel (1990)), to the possibilities examined in Section 3. It is probably fanciful to imagine foreign investors formally calculating their mathematical expectation for the change in the real exchange rate. Nevertheless, they presumably take informal account of the possibilities before deciding that there is profit to be made from the high domestic interest rates.

Note that it is not simply uncertainty which changes the nature of the equilibrium. Rather, it is asymmetrical expectations. Loosely speaking, for there to be an equilibrium with a real interest differential between the domestic economy and the world, foreign investors must assess the chance of the domestic real exchange rate depreciating as higher than the chance of it appreciating. The key argument in this paper is that, in the process of buying domestic nominal assets and appreciating the domestic real exchange rate, a point will be reached where foreign investors do have such asymmetrical expectations. That point represents an equilibrium in which the domestic economy sits until something changes.[21]

In the models of Section 2 and Section 3, while "the combination" – of steady inflation, a non-neutral tax system and free global capital flows – persists, the domestic after-tax real interest rate, r_{AT}, is less than it would be with no domestic inflation. Provided private investment minus private saving rises as the after-tax real interest rate falls (which is usually assumed), the models imply that the interaction between

[21] For Australia, there is a further reason why investors may expect real depreciation. Over the last five years, Australia's current account deficit has averaged over five percent of GDP, a ratio much higher than the average of the previous two decades. Smith and Gruen (1989) suggest that foreign investors may expect significant real depreciation as part of the adjustment to external balance.

inflation, a non-neutral tax system and free global capital flows leads to a larger domestic current account deficit.

Again, in all versions of the model, while "the combination" persists, the domestic real exchange rate is over-valued. It is not straightforward to establish that the Australian real exchange rate is over-valued. Thus, for example, while Figure 3 suggests that the terms of trade are an important determinant of the real exchange rate, it does not provide strong evidence that the real exchange rate is over-valued. However, the ratios of Australian import and export prices to the GDP deflator have both fallen significantly over the last six years (Alesina, Gruen and Jones (1990)), suggesting that relative prices are encouraging resources to leave the tradeable sector of the Australian economy. The analysis in this paper suggests that these relative price signals are a very undesirable consequence of the interaction between inflation, a non-neutral tax system and free global capital flows.

APPENDIX

1. Justification of a pre-tax international arbitrage condition: equation (1)

There are two relevant justifications – the first applies specifically to US citizens while the second is more general. A pre-tax arbitrage condition is relevant for US citizens because of the nature of the US tax system.[22] US tax is levied on total world income – irrespective of the source of the income or its nature (e.g., interest income, or capital gain/loss[23]). Thus, if US citizens have no liability for Australian withholding tax (for example, by investing in 'widely held securities' e.g., Euro $A raisings by Australian corporates[24]) their investment decisions should depend on relative pre-tax rates of return and on perceived risk. The second justification for equation (1) is the tax treatment of many foreign superannuation funds. As well as being exempt from tax in their own countries, these funds have a general exemption from Australian income tax[25]. The size of these foreign superannuation funds again suggests that pre-tax arbitrage conditions like equation (1) should be satisfied by Australian nominal assets.

---

22 This information was kindly supplied by the Internal Revenue Service Section of the US Consulate in Sydney on 15 March, 1990.

23 There is one relevant complication: a maximum of $US 3,000 per annum capital loss can be written off against other income for US tax-payers. For large investors, this may be a significant distortion. However, in a diversified portfolio which includes assets from several countries, a capital loss on holdings in one currency can be offset against capital gain on holdings in other currencies. This should reduce the distortion, though not eliminate it.

24 Section 128F, Income Tax Assessment Act 1936 (personal communication, Mr. Will Duda, Australian Tax Office).

25 Section 23(jb), Income Tax Assessment Act 1936 (personal communication, Mr. Will Duda, Australian Tax Office).

2. The model when regime II involves ending nominal money growth with *no jump* in the level of the money supply

This model is more realistic than the one described in Section 3a of the text – but also more difficult to analyse. The system of equations (2) – (6) forms a set of two coupled differential equations:

$$\begin{bmatrix} Dl \\ Dc \end{bmatrix} = \frac{1}{\Sigma}\begin{bmatrix} \dfrac{\varphi\gamma}{1-\tau\varphi\gamma} & \dfrac{\varphi\lambda\delta}{\delta\,(\lambda\varphi(1-\tau)-k)} \\ 1-\tau & 1-\tau \end{bmatrix}\begin{bmatrix} l \\ c \end{bmatrix} + \frac{1}{\Sigma}\begin{bmatrix} \varphi\gamma\lambda & 0 \\ \lambda - k\gamma\dfrac{\tau}{1-\tau} & -\Sigma \end{bmatrix}\begin{bmatrix} \mu \\ r^* \end{bmatrix}, \tag{A1}$$

where $\Sigma = \gamma\,(\varphi\lambda - k) - \lambda$. Equation (A1) describes the evolution of the economy when it is not at equilibrium and when there is no future uncertainty. It may be expressed more compactly as:

$\begin{bmatrix} Dl \\ Dc \end{bmatrix} = \theta \begin{bmatrix} l \\ c \end{bmatrix} + \Omega\, x$ where x is the vector of exogenous variables $\begin{bmatrix} \mu \\ r^* \end{bmatrix}$.

We assume that $\Sigma < 0$ [26] and that $\tau\varphi\gamma < 1$. These assumptions both hold provided the slope of the Phillips curve, φ, is sufficiently small, i.e., provided inflation is sufficiently unresponsive to real activity. Using the notation, $\theta = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$, $\det\theta \equiv AD - BC = \dfrac{\varphi\delta}{\Sigma\,(1-\tau)} < 0$ since $\Sigma < 0$. Hence, θ has a positive and a negative eigenvalue. The negative eigenvalue is $\Lambda_1 = \dfrac{A + D - \sqrt{(A+D)^2 - 4(AD-BC)}}{2}$ (which is negative because AD – BC is negative). The eigenvector corresponding to this eigenvalue represents the stable path upon which the economy regains equilibrium. Solving the equation, $\theta \begin{bmatrix} 1 \\ \alpha \end{bmatrix} = \Lambda_1 \begin{bmatrix} 1 \\ \alpha \end{bmatrix}$, gives

$\alpha = \dfrac{(D-A) - \sqrt{(D-A)^2 + 4BC}}{2B}$. It follows from our assumptions ($\Sigma < 0$ and $\tau\varphi\gamma < 1$), that $B < 0$, and $BC > 0$. As a consequence, $\alpha > 0$. The equation for the stable eigenvector may alternatively be written,

$$c - c^E = \alpha\,(l - l^E), \tag{A2}$$

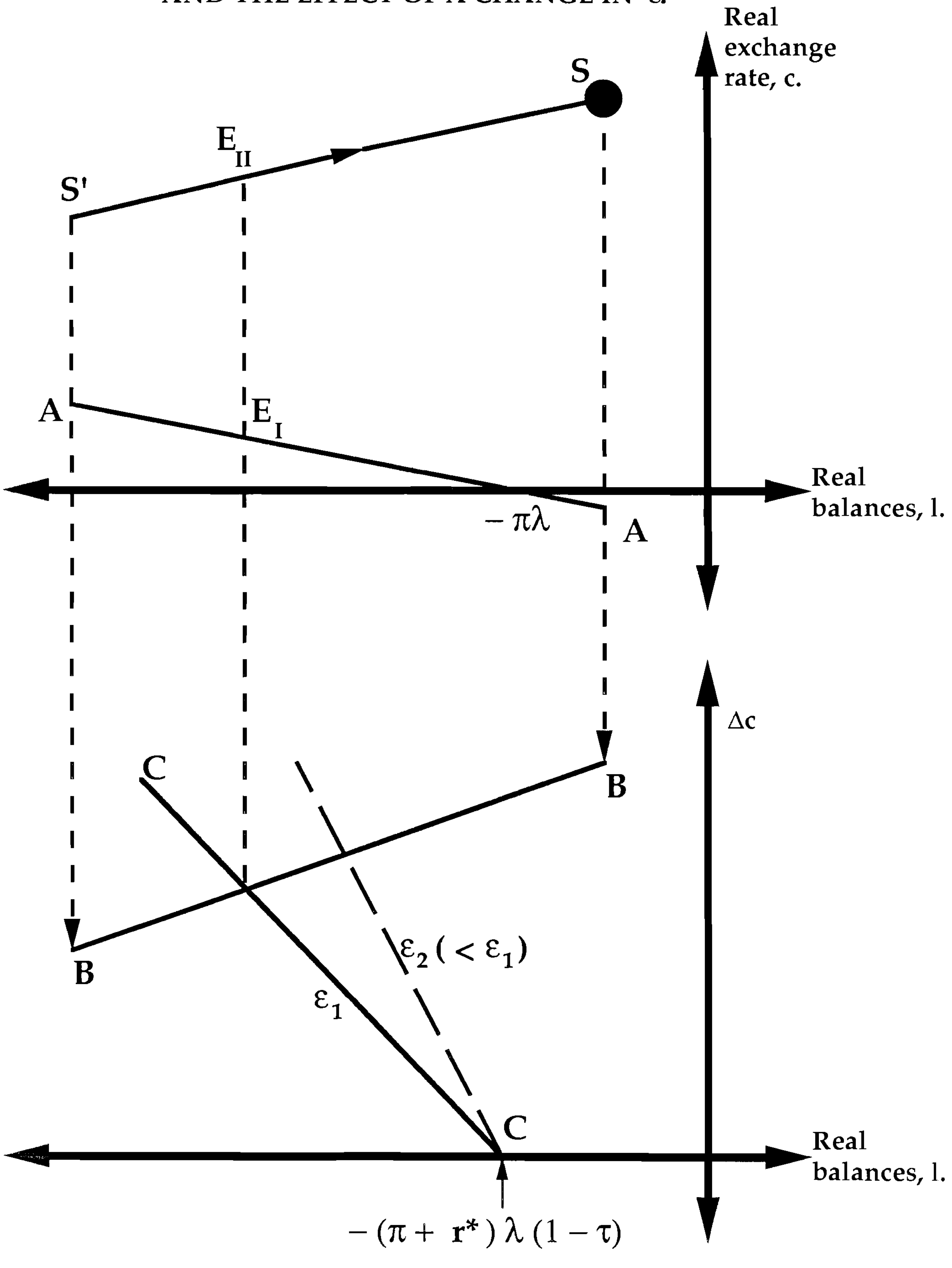
where the superscript E again denotes the equilibrium value.

---

[26] Buiter and Miller (1981) give a justification for this assumption.

Figure 5

DETERMINATION OF EQUILIBRIUM
AND THE EFFECT OF A CHANGE IN ε.



We now use Figure 5 to derive the solution of the model. Once regime II has been established, all uncertainty has been resolved and the economy evolves along the stable path [equation (A2) with $l^E = -\lambda(1-\tau)r^*$, and $c^E = \frac{\gamma}{\delta}(1-\tau)r^*$]. This stable path is shown as the S'S line. While steady inflation (regime I) persists, the behaviour of the economy is determined by equations (2) – (4) and equation (6'), with "core inflation", π, predetermined, and the nominal interest rate, i, set by the monetary authorities to maintain "full employment" output. Equations (2) and (3) can be combined to give the relationship between c and l while steady inflation persists:

$$c = -\frac{\gamma}{\delta}\left[\frac{l}{\lambda} + \pi\right]. \tag{A3}$$

Equation (A3) is backward-sloping in c-l space and is displayed by the line AA. When the regime change occurs, the economy jumps instantaneously from its equilibrium on the line AA to the stable path S'S. Given the structure of the economy, **there is no jump in the level of real balances**. Thus, we may derive the relationship between the jump in the real exchange rate, Δc, and the level of real balances when the jump occurs, l. Given the slopes of AA and S'S, this relationship is upward-sloping in Δc-l space, and is shown by the line BB. Finally, substituting equation (2) into the the international arbitrage condition (equation 6'), gives a second relationship between Δc and l, namely,

$$\varepsilon\,\Delta c = \frac{-l}{\lambda(1-\tau)} - \pi - r^*, \tag{A4}$$

which is backward-sloping in Δc-l space, and is shown by the line CC. While regime I persists, equilibrium is determined by the intersection of BB and CC. Thus, while steady inflation persists, the economy sits at the point E_I in c-l space. When the regime change occurs, the economy immediately jumps to E_{II} and then slowly evolves along the stable path to S.

Figure 5 also enables us to examine the effects of a change in ε. A **fall** in ε rotates the CC line clockwise around its l-axis intercept (see equation A4). Therefore, **iff** $\Delta c > 0$ (or, equivalently, iff $r > r^*$), it leads unambiguously to an increase in Δc, and to a fall in the level of the real exchange rate, c – that is, to further over-valuation of the real exchange rate. Since in regime I, output is kept at its "full employment" level, there is a fall in the domestic nominal and real interest rate, so that the fall in the after-tax real interest rate offsets the output effect of the real appreciation.

Tedious but straightforward manipulation of equations (2), (3), (9), (10), (A2) and (A4) leads to these expressions for the level of the real exchange rate and the nominal interest rate while regime I persists:

$$c = \frac{\gamma}{\delta}\left\{r^*(1-\tau) - \pi\left[\frac{(1-\tau)\,\alpha\varepsilon\lambda + \tau}{(1-\tau)\,\varepsilon\,[\gamma/\delta + \alpha\lambda] + 1}\right]\right\}, \quad \text{and} \qquad \text{(A5)}$$

$$i = r^* + \pi\left[\frac{\varepsilon\gamma + \delta}{\varepsilon\,(1-\tau)\,(\gamma + \alpha\delta\lambda) + \delta}\right] \equiv r^* + \pi\left[1 - \frac{\gamma\tau - (1-\tau)\,\alpha\delta\lambda}{\gamma + \delta/\varepsilon}\right]^{-1}. \qquad \text{(A6)}$$

It follows from equations (A5) and (A6) that

$$\lim_{\varepsilon \to 0} c = \gamma[(1-\tau)r^* - \tau\pi]/\delta, \quad \text{and} \quad \lim_{\varepsilon \to 0} i = r^* + \pi.$$

Thus, as the perceived probability of a regime change falls to zero, the model reverts to its 'certainty' version and the real pre-tax interest rate in the domestic economy reverts to the world real rate.

Equation (A5) implies that $\frac{dc}{d\pi}$ is unambiguously negative. The first expression for i in equation (A6) implies that $\frac{di}{d\pi}$ is unambiguously positive, while from the second expression it follows that, since $\frac{dr}{d\pi} = \frac{di}{d\pi} - 1$, $\frac{dr}{d\pi} > 0$ iff $\gamma\tau - (1-\tau)\,\alpha\delta\lambda > 0$. As the model contains seven parameters, an extensive search in parameter space is a major undertaking. Nevertheless, at least for plausible parameter values, $\frac{dr}{d\pi} > 0$. Thus, assuming these values for the parameters (see below for a brief justification): $k = 1$; $\tau = \phi = \frac{1}{2}$; $\lambda = 2$; $1/\varepsilon = 5$ years; $\delta/\gamma = 0.15$; $1 \leq$ "the multiplier" ≤ 3, implies $0.17 \leq \frac{dr}{d\pi} \leq 0.36$.

2a Parameter values

The values $k = 1$; $\phi = \frac{1}{2}$ and $\lambda = 2$ are used by Buiter and Miller (1982). We see no reason to change them. τ is the domestic tax rate on nominal income. $\tau = \frac{1}{2}$ is approximately the top marginal income tax rate in Australia. Especially since the introduction of full dividend imputation, this seems the appropriate tax rate to choose. $1/\varepsilon$ is the mean length of time for which the steady inflation regime is expected to persist. We choose $1/\varepsilon = 5$ years.[27] γ and δ are the parameters in the IS curve. The effect on output of changes in γ and δ can be analysed in terms of the "direct" effect on the components of output and the "multiplier" effect due to changes in (permanent) income inducing changes in consumption. We assume that the **direct** effect of a 1%p.a. permanent increase in the after-tax real interest rate is to reduce output by 1%. We assume that the price elasticity of both imports and exports is $\frac{1}{2}$ (see Gordon (1986) and Horton and Wilkinson (1989)). For Australia, both imports and exports are about 15% of GDP. Hence, the direct effect of a 1% depreciation of the real exchange rate is to increase output by 0.15%. Thus, $\delta/\gamma = 0.15$. Finally, for the multiplier, we assume the range $1 \leq$ "the multiplier" ≤ 3.

2b Results when taxation system is inflation-neutral

In this version of the model, to make the tax system entirely inflation-neutral requires eliminating the "inflation tax" on holdings of nominal money balances as well as taxing real income rather than nominal income. With the inflation tax eliminated, and inflation steady at rate π, the after-tax opportunity cost of holding money is $(i - \pi).(1 - \tau)$. Equation (2) then becomes

$$m - p = ky - \lambda[(i - Dp).(1 - \tau)]. \qquad k, \lambda > 0 \ \text{(LM curve)} \qquad (2')$$

Solving this inflation-neutral model when there is no uncertainty (that is, solving equations 2′, 3′ and 4 – 6) leads to coupled differential equations analogous to equation (A1):

---

[27] Assuming all the other parameter values unchanged and $1/\varepsilon = 10$ years, implies $0.11 \leq dr/d\pi \leq 0.23$.

$$\begin{bmatrix} Dl \\ Dc \end{bmatrix} = \theta' \begin{bmatrix} l \\ c \end{bmatrix} + \Omega' x \qquad \text{(A1')}$$

where x is the vector of exogenous variables $\begin{bmatrix} \mu \\ r* \end{bmatrix}$, and θ' is the matrix

$\theta' = \dfrac{-1}{k\gamma + \lambda} \begin{bmatrix} \varphi\gamma & \varphi\lambda\delta \\ \dfrac{1}{1-\tau} & \dfrac{-k\delta}{1-\tau} \end{bmatrix}$. It follows that $\det \theta' = \dfrac{-\varphi\delta}{(k\gamma + \lambda).(1-\tau)} < 0$,

and hence θ' has a single negative eigenvalue and this 'inflation-neutral' model is stable. The steady-inflation (regime I) equilibrium again satisfies equations (12′), (13′) and (14′). Thus, again, with an inflation-neutral tax system, the presence of inflation does not alter the equilibrium in the real economy.

3. The consequences had regime I been specified by the money growth rule $\mu = \pi$

This specification leads to a more complex dynamic adjustment for the model. Even while regime I persists, in general during adjustment to a shock, $De \neq \pi$. The correct form for the international arbitrage condition in regime I is then

$$i - r^* - De = \varepsilon . \Delta c. \qquad (6''')$$

Solving equations (2) – (5) and (6‴) leads to a set of two coupled differential equations of the form: $\begin{bmatrix} Dl \\ Dc \end{bmatrix} = \theta'' \begin{bmatrix} l \\ c \end{bmatrix} + \Omega'' x$ where x is the vector of exogenous variables $\begin{bmatrix} \mu \\ r* \end{bmatrix}$, and $\det \theta'' = \det \theta + \varepsilon\varphi\, (\gamma + \alpha\delta\lambda)/\Sigma$. Det θ'' is unambiguously negative and so this version of the model is stable. **While regime I persists**, the adjustment to a shock (for example, an unanticipated permanent shock to ε) involves an instantaneous jump in the real exchange rate to put the economy onto the appropriate stable eigenvector of θ'', after which the economy moves along this stable eigenvector towards the appropriate equilibrium point on the line AA in Figure 5. When the monetary regime changes from I to II, the economy jumps from this stable eigenvector to the stable eigenvector S′S. Thus, while regime I persists, the dynamic adjustment to shocks is more complex than the version of the model described in Part 2 of the Appendix.

4. Section 3 model when the relevant interest rate in the real economy is the expected average after-tax real rate over a time period of length T

This Part of the Appendix examines how the models in Section 3 are altered if the relevant interest rate in the real domestic economy at time t* is the expected average after-tax real interest rate in the period $t^* \leq t \leq t^* + T$, rather than the short-term after-tax real rate at time t*. For ease of notation, define the real after-tax interest rate in regime I as r^I ($r^I \equiv i\,[1 - \tau] - Dp$) and in regime II as r^{II} ($r^{II} \equiv r^*\,[1 - \tau]$). Then, while regime I persists, the expected average real after-tax interest rate over a time period of length T, $\langle r \rangle$, is

$$\begin{aligned} \langle r \rangle &= \frac{1}{T}\int_0^T \{r^I t + r^{II}(T - t)\}\, \varepsilon\, e^{-\varepsilon t}\, dt \; + \; r^I e^{-\varepsilon T} \\ &= r^{II} + (r^I - r^{II})\frac{1 - e^{-\varepsilon T}}{\varepsilon T} \qquad \text{(A7)} \\ &\approx r^I + (r^{II} - r^I)\frac{\varepsilon T}{2} \quad \text{when } \varepsilon T \text{ is small.} \end{aligned}$$

Then, equation (3) should be replaced by

$$y = -\gamma \langle r \rangle + \delta\,(e - p), \qquad \gamma, \delta > 0 \quad \text{(IS curve)} \qquad (3^*)$$

where $\langle r \rangle$ is given by equation (A7). It follows that, while steady inflation persists, the equilibrium is again given by equations (12), (13) and (14) but with $f(\varepsilon) = \frac{1 - e^{-\varepsilon T}}{T}$ replacing ε. Since $f(\varepsilon) \geq 0$, and $\frac{df(\varepsilon)}{d\varepsilon} > 0$, this specification makes no qualitative difference to the results.

The regime I equilibrium continues to be characterized by a domestic short-term pre-tax (after-tax) real interest rate higher (lower) than the comparable world rate, and by an over-valued domestic real exchange rate.

REFERENCES

Alesina, A., Gruen, D.W.R. and Jones, M.T. (1990), 'Fiscal adjustment, the real exchange rate and Australia's external imbalance', Centre for Economic Policy Research Discussion Paper No. 233, A.N.U.

Ball, L. (1990), 'Why does high inflation raise inflation uncertainty?', NBER Working Paper No. 3224.

Buiter, W.H. and Miller, M. (1981), 'Monetary policy and international competitiveness: the problems of adjustment', *Oxford Economic Papers,* Sept., 143 - 175.

Buiter, W.H. and Miller, M. (1982), 'Real exchange rate overshooting and the output cost of bringing down inflation', *European Economic Review,* **18,** 85–123.

Dominguez, K. and Frankel, J.A. (1990), 'Does foreign exchange intervention matter? Disentangling the portfolio and expectations effects for the Mark', NBER Working Paper No. 3299.

Feldstein, M. (1976), 'Inflation, income taxes and the rate of interest: a theoretical analysis', *American Economic Review,* **66,** 809–820.

Feldstein, M., Green, J. and Sheshinski, E. (1978), 'Inflation and taxes in a growing economy with debt and equity finance', *Journal of Political Economy,* **86,** S53–S70.

Frankel, J.A. (1985), 'The dazzling dollar', *Brookings Papers on Economic Activity,* **1,** 199–217.

Frankel, J.A. (1988), 'Recent estimates of time-variation in the conditional variance and in the exchange risk premium', *Journal of International Money and Finance,* **7,** 115–125.

Frankel, J.A. and Engel, C.M. (1984), 'Do asset-demand functions optimize over the mean and variance of real returns? A six-currency study', *Journal of International Economics,* **17,** 309–323.

Froot, K.A. and Frankel, J. A. (1989), 'Forward discount bias: Is it an exchange risk premium?', *Quarterly Journal of Economics,* **CIV,** 139–161.

Gordon, J. M. (1986), 'The J-curve effects', *Economic Record,* **62,** special issue, 82–88.

Horton, T. and Wilkinson, J. (1989), 'An analysis of the determinants of imports', Research Discussion Paper 8910, Reserve Bank of Australia.

Liviatan, N. (1980), 'Anti-inflationary monetary policy and the capital import tax', Warwick Economic Research Paper, No. 171.

Smith, J. and Gruen, D.W.R. (1989), 'A random walk around the $A: expectations, risk, interest rates and consequences for external balance', Research Discussion Paper 8906, Reserve Bank of Australia.