Journal of International Economic
Integration 7(1), Spring 1992, 80—101

Monetary Growth Volatility and Asset Prices in a Two-Country Cash-in-Advance Model*

Marcelo Bianconi
Tufts University

Abstract

This paper contributes to the existing literature in the cash-in-advance asset-pricing general equilibrium model for open economies by showing that if one allows for a variable velocity of circulation in the domestic and/or foreign economy, the responses of assets, currencies, and relative prices to changes in the conditional variance of the domestic and/or foreign monetary growth process are critically different from the case where the velocities of circulation are constant.

I. Introduction

This paper examines the response of asset and relative prices to changes in the conditional variance of the future monetary growth stochastic process which is exogenously given. The model I use is the basic cash-in-advance (*c-i-a*) asset-pricing model in the version presented by Svensson [1985b] which is a direct extension of Lucas [1982, 1984]. In turn, the model is related to the recent paper by Hodrick [1989] who examined the empirical relevance of changes in the conditional variance of the exogenous driving processes on exchange rates and other endogenous prices.[1] However, I introduce some modifications in order to study the interac-

* I thank Michael Murphy and two anonymous referees for helpful comments and the useful comments and editorial suggestions of the co-editor, E. Kwan Choi. Any remaining errors are my own.

1. Hodrick [1989] finds that the exogenous conditional variances do not explain movements in US exchange rates for Japan, West Germany, and UK. However, this seems to be due to temporal

tion of information processing, monetary uncertainty and the portfolio choice of the representative individual, which I believe is the important contribution of this paper. I follow the stochastic structure suggested by Giovannini [1989], with the additional possibility of a variable velocity of circulation. The contribution of the analysis is that it shows theoretically the comovements of exchange rates, currencies, and asset prices in the presence of alternative information processing and monetary volatility. In this sense, the paper is a direct extension of Svensson [1985b] who studied temporary and permanent changes in the level of the monetary growth rate.

There are several motivations for this study. First, the now extensive literature which models time-varying moments assigns an important role for explicit effects of changes in conditional second order moments on the maximizing behavior of agents (an extensive survey of empirical applications is found in Bollerslev, *et al* [1990]).

Second, the Svensson [1985b] model, in its closed economy version (as in Lucas [1984] and Svensson [1985a]), has been subject to several empirical tests. Hodrick, Kocherlakota, and Lucas [1989] calibrate the model with the U.S. post WWII time series data and find that the liquidity constraint is almost always binding, or alternatively velocity is constant most of the time. Giovannini and Labadie [1989] also calibrate the same model using a larger sample with a constant velocity assumption. They find that the model predicts a high covariance between ex-ante returns on stocks and nominal bonds. Finn, Hoffman, and Schlagenhauf [1990] test the Euler equations of the same model (using a GMM procedure) and find that it is the only one, in the class of *c-i-a* monetary models, in which monetary effects improve the explanation of asset returns.

Third, Engle, Ito, and Lin [1990] test volatility in the foreign exchange daily market (the U.S. and Japan) under alternative information processing and different market locations. They define two alternative hypothesis: the heat wave where market volatility in one location is not affected by volatility in another location; and the meteor shower where each market's volatility is affected by other markets changes in volatility. They find evidence in favor of the meteor shower hypothesis. Ito, Engle,

---

aggregation problems since conditional variances show little variation on a monthly basis, see Bollerslev, et al [1990].

and Lin [1990] find that stochastic policy coordination does not account for the volatility spillovers, which is evidence that information processing may be one of the main determinants behind volatility spillovers.

My model assigns a decisive role to information processing through the signal that the individual receives with respect to the level and the uncertainty of the monetary growth rate. I consider states in which the domestic representative agent does not observe foreign signals, the heat wave hypothesis; and states in which the representative agent has complete knowledge of domestic and foreign signals, the meteor shower hypothesis. Then, I show how these signals affect the agent's relative demands for domestic and foreign currencies and stocks. Some of the issues related to monetary uncertainty have been addressed by Stulz [1984], but he assumed a money in the utility function framework. I confirm one of his main findings that a change in purchasing power risks affects the exchange rate between the two currencies.

If the current empirical evidence mentioned above is taken into account, the important results of my analysis concern states where the information processing leads to the meteor shower hypothesis with constant velocities of circulation, consistent with Engle, Ito, and Lin [1990] and Hodrick, Kocherlakota, and Lucas [1989]. If the monetary volatility in the two countries is expected to increase, I show that the comovements of the exchange rate with currencies and asset demands may go in any direction. If the monetary volatility in both countries is expected to go in opposite directions, I show a clear pattern of joint movements between the exchange rate and currency and stock prices. In all cases, a clear pattern of comovements between currencies and stocks is obtained.

The paper is organized as follows. Section II specifies the basic model while section III presents the equilibrium. Section IV spells out the stochastic structure. Section V is where the experiments of increased monetary growth volatility are examined in detail. Section VI presents some concluding remarks.

II. Two-Country Macroeconomic Structure

Consider a discrete time stochastic two-country model of a monetary economy inhabited by households, firms, and government. Each country's firm produces one non-storable good, freely traded internationally, at an exogenous constant

level. Also, asset markets are fully integrated. Domestic (d) economy variables are unstarred while foreign (f) economy variables are starred. The model follows closely the setup of Svensson [1985b]:

i) Households: every period, a representative household solves a choice-theoretic problem in order to optimally allocate his/her total wealth between consumption of the domestic and foreign good, stock holdings of the domestic and foreign firm, and holdings of the domestic and foreign currencies. The problem of the representative domestic household is (the foreign representative household problem is symmetric)

$$\text{Max } E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^d, c_t^{*d}) \{c_t^d, c_t^{*d}, M_{t+1}^d, M_{t+1}^{*d}, z_{t+1}^d, z_{t+1}^{*d}, x_{t+1}^d, x_{t+1}^{*d}\}_{t=0}^{\infty} \quad (1a)$$

subject to

$$\begin{aligned} M_{t+1}^d/P_t + f_t M_{t+1}^{*d}/P_t + (Q_t^d/P_t) z_{t+1}^d + (Q_t^{*d}/P_t) z_{t+1}^{*d} + (R_t^d/P_t) x_{t+1}^d \\ + (R_t^{*d}/P_t) x_{t+1}^d \leq (M_t^d/P_t - c_t^d) + (f_t/P_t)\{M_t^{*d} - F_t^* c_t^{*d}\} + (Q_t^d/P_t + y_t) z_t^d \\ + [(Q_t^{*d}/P_t) + (f_t/P_t) P_t^* y_t^*] z_t^{*d} + [(R_t^d/P_t + (\omega_t - 1)\tau_t/P_t] x_t^d \\ + [(R_t^{*d}/P_t) + (\omega_t^* - 1)\tau_t^*/P_t] x_t^{*d} \end{aligned} \quad (1b)$$

$$c_t^d \leqq M_t^d/P_t \quad (1c)$$

$$c_t^{*d} \leqq M_t^{*d}/P_t^* \quad (1d)$$

$$z_o^d = z_o^{*d} = x_o^d = x_o^{*d} = (1/2);\ M_o^d > 0,\ M_o^{*d} > 0 \text{ given} \quad (1e)$$

where

$0 < \beta < 1$ is a constant discount factor common to both countries

E_o = expectation operator conditional on information at t = 0 with respect to the probability distribution of $\{c_t^d, c_t^{*d}\}_{t=0}^{\infty}$ to be defined below

c_t^d = real consumption of the domestic good by domestic residents at time t

c_t^{*d} = real consumption of the foreign good by domestic residents at time t

P_t = domestic good price level at time t

P_t^* = foreign good price level at time t

Q_t^d = domestic money price of domestic stock (share) at time t

Q_t^{*d} = domestic money price of foreign stock (share) at time t

M_t^d = nominal money holdings of domestic currency by domestic residents at time t

M_t^{*d} = nominal money holdings of foreign currency by domestic residents at time t

R_t^d ≡ 1 = domestic money price of domestic currency at time t

R_t^{*d} = domestic money price of foreign currency at time t

z_t^d = quantity of perfectly divisible stock (share) of domestic firm held by domestic resident at time t

z_t^{*d} = quantity of perfectly divisible stock (share) of foreign firm held by domestic resident at time t

x_t^d = quantity of perfectly divisible claim on domestic money held by domestic resident at time t

x_t^{*d} = quantity of perfectly divisible claim on foreign money held by domestic resident at time t

y_t ≡ y = constant domestic real output equal to domestic dividend rate

y_t^* ≡ y^* = constant foreign real output equal to foreign dividend rate

ω^t = gross rate of domestic monetary growth at time t

ω_t^* = gross rate of foreign monetary growth at time t

$(\omega_t - 1)\tau_t$ = lump sum domestic monetary transfer (tax) at time t

$(\omega_t^* - 1)\tau_t^*$ = lump sum foreign monetary transfer (tax) at time t

f_t = nominal exchange rate defined as units of domestic currency per unit of foreign currency

$U(.,.)$ = utility function, common to both countries, with $U_1(.,.) > 0$, $U_2(.,.) > 0$, $U_{11}(.,.) < 0$, $U_{22}(.,.) < 0$, $U_1(0,.) = U_2(.,0) = \infty$, $U_1(\infty,.) = U_2(.,\infty) = 0$

The representative household problem, the sequence of markets, and the information constraints are identical to Svensson [1985a, b], that is, the goods market opens in the beginning of the period and the asset market opens in the end of the period, with the monetary transfer received after the goods market closes. In turn, it implies that once a decision at period t to carry a certain amount of cash balances to $t+1$ is made, it is irreversible in the sense that, when facing the goods market in period $t+1$, the consumer can spend no more than that amount; also the foreign exchange can only be transacted on the asset market so that ad-

od.[2] The household budget constraint (1b) shows that dividends on domestic and foreign stocks and currencies plus any cash not spent in the consumption of domestic and foreign goods are carried to the next period and allocated into currencies, stocks, and claims to transfers. (1c) is the cash-in-advance constraint for the domestic good, (1d) is the cash-in-advance constraint for the foreign good, and (1e) are the initial conditions;

ii) Government: the role of the domestic and foreign government is to transfer (tax) at the stochastic gross rate of growth of money ω_t *and* ω_t^*according to the roles

$$\tau_{t+1} = \omega_t \tau_t; \tag{2a}$$

$$\tau_{t+1}^* = \omega_t^* \tau_t^*; \tag{2b}$$

where $\tau_t(\tau_t^*)$ is the domestic (foreign) monetary transfer. The state of the *world* economy in period t is defined as $s_t = (\omega_t, \omega_t^*)$ and it is a Markov process which evolves according to the transition $Pr\{\omega_{t+1} \leq \omega', \ \omega_{t+1}^* \leq \omega^{*\prime} \mid \omega_t = \omega, \omega_t^* = \omega^*\} = H(\omega', \omega^{*\prime}, \omega, \omega^*)$ and $H(.,.,.,.)$ has joint conditional density (assumed to exist) $h(\omega', \omega^{*\prime}, \omega, \omega^*)$.

III. Macroeconomic Equilibrium

Let us focus on the perfectly pooled equilibrium for quantities as in Lucas (1982) and Svensson (1985b), given by[3]

Goods Market Equilibrium,

$$c_t^d = c_t^f = y/2 \tag{3a}$$

$$c_t^{*d} = c_t^{*f} = y^*/2$$

Money Market Equilibrium,

2. In this setup, goods cannot be traded for goods, only currency can buy goods. In turn, the real exchange rate is not exactly the relative price of goods. All transactions are assumed in the sellers currency such that the money demands are well defined.

3. In order for risk to be perfectly pooled we need the vector of assets which include the claims on domestic and foreign monetary transfers [as in (1)]. If the utility function is homothetic, as in Stockman and Dellas [1989], then the equilibrium may be written as $hc_t^d + (1-h)c_t^f = y$ where $0 < h < 1$ is a parameter determined by the initial distribution of wealth.

$$(M_{t+1}/2) = (\tau_{t+1}/2) = M^d_{t+1} = M^f_{t+1} = (\omega_t \tau_t/2) = (\omega_t M_t/2) \tag{3b}$$
$$(M^*_{t+1}/2) = (\tau^*_{t+1}/2) = M^{*d}_{t+1} = M^{*f}_{t+1} = (\omega^*_t \tau^*_t/2) = (\omega^*_t M^*_t/2)$$

Assets Market Equilibrium,

$$z^d_t = z^{*d}_t = x^d_t = x^{*d}_t = z^f_t = z^{*f}_t = x^f_t = x^{*f}_t = (1/2) \tag{3c}$$

where $M_t(M^*_t)$ is the domestic (foreign) total money stock.

The solution of problem (1), and its foreign counterpart, together with (2)-(3) yields a stochastic stationary rational expectations equilibrium[4] More precisely, the definition of equilibrium consists of a set of initial conditions, the stochastic structure, the money supply rules, the endogenous choice variables in (1), and prices of goods and assets all of which satisfy: i) given the pricing functions and the money supply rules, the usual first order conditions solve the agent's maximization problem (1) for consumption, money holdings and asset holdings and the subjective probabilities are equal to the objective probabilities for all $t=1, 2,\ldots$; ii) the competitive markets for goods, money and shares clear according to (3a)-(3c) for all $t=1, 2,\ldots$; iii) the transversality conditions at infinity are satisfied for all $t=1, 2,\ldots$.

Since the stochastic growth problem can be solved independently of the asset pricing problem, the goods prices and marginal values of wealth and money can be solved independently of the asset prices. In particular, the domestic and foreign endogenous purchasing power of money, $1/P_t$ and $1/P^*_t$, the domestic and foreign marginal utilities of real wealth, λ_{1t} *and* λ^*_{1t} [or the multiplier on the wealth constraint (lb)], and the domestic and foreign marginal utilities of real money balances, λ_{2t} and λ^*_{2t} and [or the multiplier on the liquidity constraint (lc)], are explicity solved as in Svensson (1985b).

If $h_{t-1}(M_o) \leq (y/\beta E[1/P_{t+1}|.])$ for all possible realizations of $E[.|.]$[5], where $h_{t-1}(M_o) = M_o \prod_{j=0}^{\infty} \omega_{t-1-j}$ is the history of past domestic growth rates which de-

4. Existence results for closed economy versions of the Lucas [1982] model may be found in Townsend [1987] and Lucas and Stokey [1987].

5. The expressions relating the current money stock to the discounted nominal output represent the borderline functions discussed in Svensson [1985a, b].

termines the current domestic money stock, then the liquidity constraint (1c) is binding almost surely (a. s.) such that

$$1/P_t = y/h_{t-1}(M_0) \tag{4a}$$

$$\lambda_{1t} = [\beta\ U_1(y/2,\ y^*/2)\ h_{t-1}(M_0)/y]\ E[1/P_{t+1}\,|\,.] \tag{4b}$$

$$\lambda_{2t} = U_1(y/2, y^*/2) - [\beta U_1(y/2, y^*/2)\, h_{t-1}(M_0)/y] E[1/P_{t+1}|\,.] > 0. \tag{4c}$$

If $h_{t-1}(M_o) > (y/\beta E[1/P_{t+1}\,|.])$ for all possible realizations of $E[.\,|.]$, then the liquidity constraint (1c) is nonbinding a. s. such that

$$1/P_t = \beta E[1/P_{t+1}\,|\,.] \tag{4d}$$

$$\lambda_{1t} = U_1(y/2,\ y^*/2) \tag{4e}$$

$$\lambda_{2t} = 0. \tag{4f}$$

Note that (4d) shows that the cash-in-advance constraint for domestic currency will bind in any state in which the expected gross rate of inflation is greater than the discount factor (the same result applies to the foreign economy).[6] The marginal utility of foreign real money balances held by domestic residents, λ_{3t}[or the multiplier on liquidity constraint (1d)], is given by

$$\lambda_{3t} = (\lambda^*_{1t}/\lambda_{1t})^{-1}\ \lambda^*_{2t} \qquad \text{for } \lambda^*_{2t} > 0 \text{ a. s.} \tag{4g}$$

$$\lambda_{3t} = 0 \qquad \text{for } \lambda^*_{2t} = 0 \text{ a. s..} \tag{4h}$$

The end-of-period (*forward*) nominal exchange rate is directly obtained from the first order conditions of problem (1) yielding

$$f_t = (\lambda^*_{1t}/P^*_t)/(\lambda_{1t}/P_t) \tag{5a}$$

6. The basic result of Hodrick, Kocherlakota, and Lucas [1989] is that for any discount factor in the range of 0.9 and 1.06 [and plausible coefficient of relative risk aversion], the annual US data process predicts expected inflation greater than the discount factor almost always.

while the terms of trade (foreign good in terms of domestic good for next period consumption) is

$$f_t P_t^* / P_t = (\lambda_{1t}^* / \lambda_{1t}) \tag{5b}$$

The price of the domestic stock,[7] in terms of the domestic good, is (symmetric formulas for the foreign economy also hold)

$$Q_t^d / P_t = (\beta y / \lambda_{1t}) \sum_{j=0}^{\infty} \beta^j E[\lambda_{1t+1+j} \mid .] \tag{4i}$$

while the price of the foreign stock, in terms of the domestic good, is

$$Q_t^{*d} / P_t = (\beta y^* / \lambda_{1t}) \sum_{j=0}^{\infty} \beta^j E[\lambda_{1t+1+j}^* \mid .] \tag{4j}$$

IV. Stochastic Structure

Let us present a stochastic structure consistent with the assumption that the liquidity constraint does or does not bind each period. In each country and each period, agents receive a signal $\gamma_t \in \{0, 1\}$ and $\gamma_t^* \in \{0, 1\}$ affecting the probability that the constraint will bind in the following period.[8] Assume first that ω_t and ω_t^* are stochastically independent such that the joint density function may be written as $h(\omega_t, \omega_t^*) = d(\omega_t) f(\omega_t^*)$. Then, I restrict the distribution function of the state in each country, $D(\omega', \omega)$ and $F(\omega', \omega)$, in the following manner:

$$\begin{aligned} D(\omega_{t+1}, \phi_t) &= Pr(\omega_{t+1} \leq \omega' \mid \phi_t = \phi) \\ &= \alpha_t [\gamma_t D_{0g}(\omega_{t+1}) + (1-\gamma_t) D_{0b}(\omega_{t+1})] \\ &\quad + (1-\alpha_t)[\gamma_t D_{1g}(\omega_{t+1}) + (1-\gamma_t) D_{1b}(\omega_{t+1})] \end{aligned} \tag{6a}$$

with $\phi_t = (\alpha_t, \gamma_t)$ (6b)

$$Pr(\alpha_{t+1} = 1) + Pr(\alpha_{t+1} = 0) = 1 \tag{6c}$$

$$Pr(\gamma_{t+1} = 1) + Pr(\gamma_{t+1} = 0) = 1 \tag{6d}$$

7. Solutions for the stock prices in (4i)-(4j) are well behaved (no bubbles).

8. In essence, I am substituting the two distributions that Giovannini [1989] used in his closed economy with four distributions for each country to be defined below.

ω_t and α_t iid. and stochastically independent (6e)

ω_t and γ_t iid. and stochastically independent (6f)

α_t and γ_t iid. and stochastically independent (6g)

$$\int \omega_{t+1}\ dD_{0g}(\omega_{t+1}) = \int \omega_{t+1} dD_{1g}(\omega_{t+1}) = E(\omega_g) \tag{6h}$$

$$dD_{1g}(\omega_{t+1}) = MPS(\omega_{t+1}) + dD_{0g}(\omega_{t+1}) \tag{6i}$$

$$\int \omega_{t+1}\ dD_{0b}(\omega_{t+1}) = \int \omega_{t+1} dD_{1b}(\omega_{t+1}) = E(\omega_b) \tag{6j}$$

$$dD_{1b}(\omega_{t+1}) = MPS(\omega_{t+1}) + dD_{0b}(\omega_{t+1}) \tag{6k}$$

$$\begin{aligned} \text{and } F(\omega^*_{t+1},\ \phi^*_t) &= Pr(\omega^*_{t+1} \leq \omega^{*\prime} \mid \phi^*_t = \phi^*) \\ &= \alpha^*_t[\gamma^*_t F_{0g}(\omega^*_{t+1}) + (1-\gamma^*_t) F_{0b}(\omega^*_{t+1})] \\ &\quad + (1-\alpha^*_t)[\gamma^*_t F_{1g}(\omega^*_{t+1}) + (1-\gamma^*_t) F_{1b}(\omega^*_{t+1})] \end{aligned} \tag{7}$$

which is restricted in an identical manner as (6). $MPS(\omega_{t+1})$ is a mean preserving spread of the distribution in the sense of Rothschild and Stiglitz [1970]. The transition probabilities governing ω and ω^* are given by one of four distributions, each depending on draws of α_t and γ_t, α^*_t and γ^*_t, , which are independent zero or one random variables. For the domestic economy (and symmetrically for the foreign economy), if $\gamma_t = 1$, the distribution of the state is bounded by $h_{t-1}(M_o) \leqq (y/\beta E[1/P_{t+1}|.)$ almost surely (a.s.) for all possible realization of $E[.|.]$, and is given by $\alpha_t D_{og} + (1-\alpha_t) D_{1g}$ such that D_{1g} is a MPS of D_{og} according to (6h)-(6i). If $\gamma_t = 0$, the distribution of the state is bounded by $h_{t-1}(M_o) > (y/\beta E[1/P_{t+1}|.])$ a.s. for all possible realizations of $E[.|.]$, and is given by $\alpha_t D_{ob} + (1-\alpha_t) D_{1b}$ such that D_{1b} is a MPS of D_{ob} according to (6j)-(6k). α_t equal to zero or one then basically determines one of the four functions D as the distribution function. Therefore, given the equilibrium (4)-(5), the stochastic structure (6)-(7) generates a probabilistic model which signals to the agent: i) whether the cash-in-advance constraint will be binding next period and; ii) the degree of risk of the drawing of the state reflecting the ordering *low* and *high* risk. The sig-

nal γ corresponds to a certain range of levels of the monetary growth rate while the signal α corresponds to the degree of risk of the monetary growth rate within a given range of levels. Note that the distribution function of $\omega_{t+1}(\omega^*_{t+1})$ is independent of the realization of the current state, $\omega_t(\omega^*_t)$, and the current realization may be interpreted as a temporary disturbance which does not change the probability distribution of the future states as in Svensson [1985a].

We shall examine two example economies: one consistent with $\gamma_t = 1$; and the other consistent with $\gamma_t = 0$; however, one must also compute the probabilities that the cash-in-advance constraints in all future periods be binding or not. In order to avoid this complication and to focus on the distinction of the two basic example economies, we truncate the states of the world for all other $s \neq t$ such that $\gamma_s = 1$ a.s. and $\gamma^*_s = 1$ a.s..[9]

V. Domestic and Foreign Monetary Growth Volatility

In the domestic (foreign) economy, at every t, we have a known state $\omega_t(\omega^*_t)$, and a vector of innovations $\phi_t(\phi^*_t)$. At period $t+1$, $\omega_{t+1}(\omega^*_{t+1})$ is realized and observed and new information about the future state, $\omega_{t+2}(\omega^*_{t+2})$, contained in $\phi_{t+1}(\phi^*_{t+1})$ arrives. We can specify the set on which $E[\,.\,|\,.\,]$ is conditioned with elements of ϕ_t and/or ϕ^*_t. When information is conditioned only on ϕ_t, we associate this with the heat wave hypothesis [recall Engle, Ito, and Lin [1990] and when the information is conditional on both, ϕ_t and ϕ^*_t, we associate it with the meteor shower hypothesis.

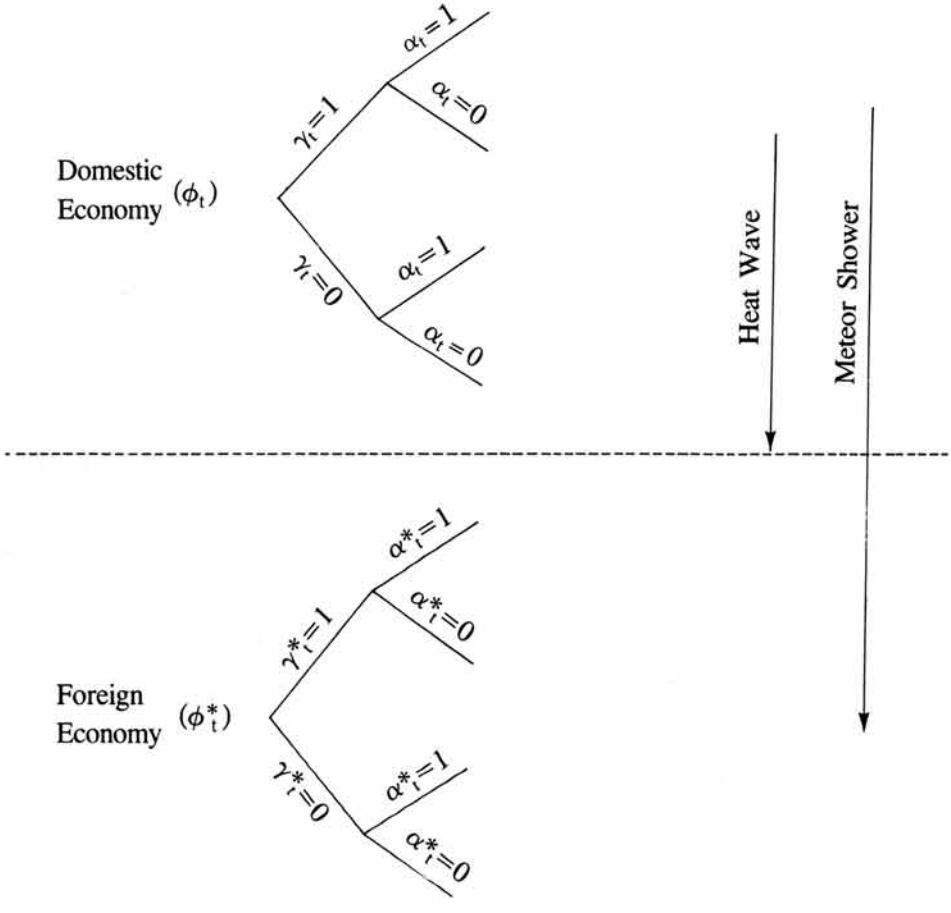
Figure 1, depicts the event tree economy. In the heat wave hypothesis we have four possible nodes and I consider, in case 1, the general solution when $\gamma_t = 1$ and, in that state, I analyze the effects of increased future domestic monetary volatility on the endogenous prices, i.e. $\alpha_t = 1$ versus $\alpha_t = 0$. Then, case 2 is when $\gamma_t = 0$ and in this alternative state I analyze the effects of increased

9. In turn, we need the following restrictions on the state $\gamma_t = 0$; at most, $\omega_t h_{t-1}(M_o) > [y/\beta E[1/P_{t+2}|.]]$ for all possible realizations of the expectation on the RHS a.s., while $h_s(M_o) \leqq [y/\beta E[1/P_s|.]]$ for all other $s = t$ and all possible realizations of $E[.|.]$ a.s., and let $E[1/\omega_{t+1}|.] > [1/\beta]$ for all possible realizations of the expectation on the LHS a.s. [same restrictions apply to the state in the foreign economy]. There is an appendix to this paper [available upon request] that proves the sufficiency of the conditions above, and the results of Tables 1-3.

future monetary volatility on the endogenous prices. In essence, I assume that the heat wave hypothesis implies that if there is an increase in future domestic monetary volatility, $\alpha_t = 1$ versus $\alpha_t = 0$, it has no spillovers on the foreign monetary volatility, α^* is constant, or alternatively domestic residents do not observe the current α^* (and γ^*). In the meteor shower hypothesis, for each of the four nodes in the domestic economy (see Figure 1) I also have to consider the additional four nodes of the foreign economy, giving a total of sixteen possible states of the world. The strategy is to analyze the states combining the alternatives of γ_t and γ_t^* with the alternatives of α_t and α_t^*.

What are the effects of increased future money growth volatility on the en-

Figure 1
Event Tree Economies



dogenous variables? For the domestic (or foreign) prices in (4a)-(4f) the effects of increased future domestic (or foreign) monetary volatility, $\alpha_t = 1$ versus $\alpha_t = 0$ (or $\alpha_t^* = 1$ versus $\alpha_t^* = 0$), hold conditionally and unconditionally upon each other country's innovation vector. This is because these solutions are not a function of each other's state[10] In turn, we can analyze the effects of increased domestic (or foreign) future monetary volatility on those prices as if the economies were closed. But, this is part of the analysis in Bianconi [1992]. The key aspect is that when $\gamma_t = 1$, which implies $\lambda_{2t+1} > 0$, increases in future domestic monetary volatility have an effect on asset holdings implying a portfolio shift away from money and into stocks and bonds. This effect is reversed when $\gamma_t = 0$, which implies $\lambda_{2t+1} = 0$, or, there is a portfolio shift away from stocks and bonds and into money.

In the open economy, what happens to relative prices such as the nominal exchange rate, the terms of trade, the marginal utility of foreign (domestic) real and nominal balances held by domestic (foreign) residents, the foreign stock prices in terms of the domestic good held by domestic residents?

A. Information Conditional upon Domestic Innovations or the Heat Wave Hypothesis

Consider an experiment where the information set is conditioned only upon domestic innovations, ϕ_t. The effect of increased future domestic monetary volatility on the domestic (or foreign) relative prices may be obtained from (4)-(5). Table 1 summarizes the results.

In case 1, the current nominal exchange rate is unchanged with the current innovation. The expected values for $t+1$ and $t+2$, however, are affected. The nominal exchange rate is expected to appreciate both for $t+1$ and $t+2$. The terms of trade is expected to turn in favor of the domestic country. The key to understand these results is to notice that the purchasing power of domestic money, $1/P$, is expected to increase only for period $t+2$. Since holding domestic cash is riskier, there is a portfolio shift by domestic residents away from domestic currency

10. This is also true in Svensson's [1985b] experiments where output is held constant, however, it would not be true if endowments were stochastic as in Lucas [1982].

Table 1

Effects of Future Domestic Monetary Growth Volatility on Endogenous Relative Prices Heat Wave Hypothesis
($\alpha_t=1$ *versus* $\alpha_t=0$)

	Case 1. $\gamma_t=1$ a.s. $\rightarrow \lambda_{2t+1}>0$	Case 2. $\gamma_t=0$ a.s. $\rightarrow \lambda_{2t+1}>0$
f_t	(0)	(−)
$E[f_{t+1,\ t+2} \mid \phi_t]$	(−)	(−)
$f_t P_t^*/P_t$	(0)	(−)
$E[f_{t+1} P_{t+1}^*/P_{t+1} \mid \phi_t]$	(−)	(0)
λ_{3t}	(0)	(+)
$E[\lambda_{3t+1} \mid \phi_t]$	(+)	(0)
λ_{3t}/P_t	(0)	(+)
$E[\lambda_{3t+1,\ t+2}/P_{t+1,\ t+2} \mid \phi_t]$	(+)	(+)
Q_t^{*d}/P_t	(0)	(−)
$E[Q_{t+1}^{*d}/P_{t+1} \mid \phi_t]$	(−)	(0)

Note: (+) → *increase,* (−) → *decrease,* (0) → *unchanged.*

and into domestic stocks which bids up the current price of domestic stocks.

However, the domestic resident may also diversify its portfolio through holdings of foreign assets. The expected (higher) purchasing power of domestic currency increases the demand, by domestic residents, for foreign currency because it is expected to provide an additional purchasing power in terms of foreign goods since the terms of trade is turning in favor of the domestic country. Consequently, the domestic demand for foreign stocks decreases. To see this, consider the effects on the marginal utility of foreign real and nominal balances held by domestic residents, λ_3 and λ_3/P. The demand for real foreign balances is expected to increase for $t+1$ while the demand for nominal foreign balances is expected to increase for $t+1$ and $t+2$ all by domestic residents. The current price of foreign stocks in terms of the domestic good is unchanged but its expected value for $t+1$ decreases, implying that the domestic demand for foreign stocks decreases. There-

fore, in this case, the exchange rate is expected to appreciate and a portfolio shift away from domestic money and foreign stocks and into domestic stocks and foreign money is observed.

In case 2, the current exchange rate is affected by increases in future domestic monetary volatility, it appreciates. This is because domestic money is expected to yield a positive return at $t+1$ (in order to induce the nonbinding domestic cash-in-advance constraint in $t+1$) or, alternatively, holding domestic money at $t+1$ provides a higher discounted value in terms of future consumption since there is no expected liquidity services gain in relaxing the liquidity constraint in $t+1$, or $E[\lambda_{2t+1} | \gamma_t = 0] = 0$. The expected value for the nominal exchange rate for $t+1$ and $t+2$ also decreases, or it is expected to appreciate. In turn, the current terms of trade turns in favor of the domestic country while its expected value for $t+1$, $t+2, \ldots$ is unchanged. The intuition for the result here is that there is a current portfolio shift into domestic money and away from domestic stocks. Still, domestic residents will shift into foreign currency since the current marginal liquidity value of foreign currency held by domestic residents, λ_{3t}, increases (current and expected future nominal foreign balances provide a higher expected liquidity value). Also, there is a decrease in the relative demand for foreign stocks since the current price of foreign stocks in terms of the domestic good, Q_t^{*d} / P_t, decreases.

In comparing cases 1 and 2 in Table 1, a key aspect is that in case 1, the current nominal and real exchange rates, the current liquidity value of foreign currency, and the current price of foreign stocks are unchanged while in case 2 they are not. Contrasting, in case 1, the expected values of the real exchange rate, the liquidity value of foreign currency, and the price of foreign stock respond immediately while in case 2 they do not. Therefore, the results are distinct with respect to the composition of the individual's portfolio in terms of domestic assets. In case 1 the individual shifts out of domestic money and into domestic stocks while in case 2 he/she shifts into domestic money and out of domestic stocks. But, in both cases, the composition of the portfolio in terms of foreign assets is affected in an equivalent way. In essence, this is because the individual is neutral to changes in the volatility of foreign monetary growth, a characteristic of the heat wave hypothesis.

B. Information Conditional upon Domestic and Foreign Innovations or the Meteor Shower Hypothesis

Consider states of the world where monetary volatility in the domestic economy is combined with monetary volatility in the foreign economy and the signals γ and γ^*, and α and α^* are also combined (see Figure 1). Let us analyze the possible states of the world dividing it into four basic possibilities all summarized in Tables 2-3. Across Tables 2-3 I assume a benchmark case where both distributions spread out the same amount, or $\omega \simeq \alpha^*$ in distribution.[11]

Table 2, case 1, indicates a state where velocities in both countries are expected to be constant (equal to one) and the monetary growth volatility is expected to increase in both countries. Notice that due to the assumption of identical distributions, the results on nominal and real relative prices have a flavor of countries *leaning against the wind*, i.e. prices are fully stabilized. If the outcome of this state is due to policy coordination among the countries, the exchange rate movements are naturally stabilized. However, holdings of foreign (domestic) currency by domestic (foreign) residents are affected because $\lambda_3(\lambda_3^*)$ is related to $\lambda_2^*(\lambda_2)$ almost by definition.[12]

Intiutively, at first, domestic residents decrease their relative demand for domestic and foreign currency while increasing their demand for domestic and foreign stocks (a symmetric result emerges for foreign residents). But, the price of foreign stocks is expected to decrease for $t+1$. That is because the marginal utility of foreign currency for $t+2$ is expected to increase. Higher monetary volatility in both currencies leads the domestic individual to shift the composition of his/her portfolio, first, away from both currencies and into both stocks (in the first period). But, in the second period, foreign stock holdings become too expensive (foreign currency is expected to yield a higher liquidity value) and the individual decreases his/her relative demand for foreign stocks in favor of foreign currency. One interesting aspect of this state is that even though the relative prices are stabilized, the relative demands for assets are not.

---

11. Relaxing this assumption alters some of the results in states where the domestic and foreign exogenous processes spread in the same direction.

12. λ_3 is the marginal utility of fM^*/P while λ_2^* is the marginal utility of M^*/P^*. Therefore, $\lambda_3 = (P/fP^*)\lambda_2^*$ almost by definition. This is essentially equation (4g).

Table 2

Effects of Future Domestic and Foreign Monetary Growth Volatility on Endogenous Relative Prices Meteor Shower Hypothesis

(α_t=1 *versus* α_t=0)

(α^*_t=1 *versus* α^*_t=0)

	Case 1. $\gamma_t=1$ a.s. $\rightarrow \lambda_{2t+1}>0$ $\gamma_t^*=1$ a.s. $\rightarrow \lambda^*_{2t+1}>0$	Case 2. $\gamma_t=0$ a.s. $\rightarrow \lambda_{2t+1}=0$ $\gamma_t^*=0$ a.s. $\rightarrow \lambda^*_{2t+1}=0$
f_t	(0)	(0)
$E[f_{t+1},\ {}_{t+2} \mid \phi_t, \phi_t^*]$	(0)	(0)
$f_tP_t^*/P_t$	(0)	(0)
$E[f_{t+1}P^*_{t+1}/P_{t+1} \mid \phi_t, \phi_t^*]$	(0)	(0)
λ_{3t}	(0)	(−)
$E[\lambda_{3t+1} \mid \phi_t, \phi_t^*]$	(−)	(0)
λ_{3t}/P_t	(0)	(−)
$E[\lambda_{3t+1}/P_{t+1} \mid \phi_t, \phi_t^*]$	(−)	(0)
$E[\lambda_{3t+2}/P_{t+2} \mid \phi_t, \phi_t^*]$	(+)	(+)
Q_t^{*d}/P_t	(+)	(−)
$E[Q^{*d}_{t+1}/P_{t+1} \mid \phi_t, \phi_t^*]$	(−)	(0)

Note: (+) → *increase,* (−) → *decrease,* (0) → *unchanged.*

Table 2, case 2, indicates the state where velocities in both countries are expected to be variable and the monetary growth volatility is expected to increase in both countries. The main result is that the portfolio shift goes in opposite direction as compared to the previous case. The liquidity value of currencies is expected to be zero and individuals prefer currency holdings because it is expected to yield a positive rate of return. Therefore, in this case individuals in both countries shift away from stocks and into currencies.

The results on the relative prices in Table 2 depend on the assumption with respect to the relative intensities of the monetary volatilities in both countries. In these states, the country in which monetary volatility is greater will experiment an ap-

preciation in the value of its currency and the terms of trade turns in its favor.[13] Why is this? The reason is that the exchange rate in this context is the ratio of the marginal utilities of wealth. Higher monetary volatility in the foreign country relative to the domestic country implies that the marginal utility of wealth in the foreign country is expected to be greater relative to the marginal utility of wealth in the domestic country. This affects the valuation of the foreign assets in terms of the domestic good and the foreign stock becomes more attractive in the current period. It also gives some theoretical support to Engle, Ito, and Lin [1990] and Ito, Engle, and Lin [1990] that the volatility of the exchange rate is explained by the meteor shower hypothesis and agents' information processing, but not by stochastic policy coordination. Note also that the comovements of the exchange rate with the currencies and asset prices could go in either direction. This is because the greater uncertainty in the monetary growth rate in both countries implies a clear pattern for currencies and asset demands, however, the movements in the exchange rate will depend upon the relative intensities of uncertainty.

Table 3 summarizes states where the volatility of money growth in the two countries is expected to move in opposite directions. In the domestic economy, monetary volatility is expected to increase and in the foreign economy it is expected to decrease. Countries may be thought of as *leaning with the wind*, i.e. the movements in relative prices are exacerbated. Because in these cases the foreign exogenous process reinforces the channels on which the relative prices are affected, almost all of the results qualitatively match those of Table 1 above.

In case 3, both velocities of circulation are constant. The nominal exchange rate is expected to appreciate for $t+1$ and $t+2$ and the terms of trade is expected to turn in favor of the domestic country for $t+1$. In the domestic economy, holding domestic currency is riskier which leads to a relative decrease in the demand for domestic currency. However, in the foreign economy, holding foreign currency is safer which leads to an increase in the domestic consumer relative demand for foreign currency. The domestic consumer, in this case, decreases its holdings of domestic money and foreign stocks (foreign stock prices fall) in favor of a higher relative demand for domestic stocks and the (expected) less risky foreign currency. The advantage of foreign currency for the domestic consumer lies on its relative higher

13. These results are consistent with the exchange rate results in Table 1, case 1 above (for individual countries), as well as with Hodrick [1989], page 443.

Table 3

Effects of Future Domestic and Foreign Monetary Growth Volatility on Endogenous Relative Prices Meteor Shower Hypothesis
($\alpha_t=1$ *versus* $\alpha_t=0$)
($\alpha^*_t=0$ *versus* $\alpha^*_t=1$)

	Case 3. $\gamma_t=1$ a.s. $\rightarrow \lambda_{2t+1}>0$ $\gamma_t^*=1$ a.s. $\rightarrow \lambda_{2t+1}^*>0$	Case 4. $\gamma_t=0$ a.s. $\rightarrow \lambda_{2t+1}=0$ $\gamma_t^*=0$ a.s. $\rightarrow \lambda_{2t+1}^*=0$
f_t	(0)	(−)
$E[f_{t+1},\ {}_{t+2} \mid \phi_t, \phi_t^*]$	(−)	(−)
$f_tP_t^*/P_t$	(0)	(−)
$E[f_{t+1}P_{t+1}^*/P_{t+1} \mid \phi_t, \phi_t^*]$	(−)	(0)
λ_{3t}	(0)	(+)
$E[\lambda_{3t+1} \mid \phi_t, \phi_t^*]$	(+)	(0)
λ_{3t}/P_t	(0)	(+)
$E[\lambda_{3t+1}/P_{t++1} \mid \phi_t, \phi_t^*]$	(+)	(0)
$E[\lambda_{3t+2}/P_{t+2} \mid \phi_t, \phi_t^*]$	(+)	(+)
Q_t^{*d}/P_t	(−)	(−)
$E[Q_{t+1}^{*d}/P_{t+1} \mid \phi_t, \phi_t^*]$	(−)	(0)

Note: (+) → *increase,* (−) → *decrease,* (0) → *unchanged.*

expected purchasing power, since the terms of trade is expected to turn in favor of the domestic country.

In case 4, both velocities of circulation are expected to be variable. Now, the domestic consumer has an incentive to increase its holdings of foreign currency immediately since it is expected to provide more purchasing power and a positive rate of return. In his/her choice of domestic assets, domestic currency is also expected to provide a positive rate of return and the individual increases its relative demand for domestic currency. In this case, the domestic consumer decreases its holdings of domestic and foreign stocks relative to a higher demand for domestic and foreign currencies.

Notice that the only qualitative difference between case 1 in Table 1 and case

3 in Table 3 is that in the latter the current price of foreign stocks (in terms of the domestic good) decreases while it is unchanged in the former. The reason is that, with the meteor shower hypothesis, the additional information about the foreign monetary volatility is computed in the present discounted value of the asset price.[14]

VI. Concluding Remarks

The response of currency, asset, and relative prices to changes in the conditional variance of money growth is shown to depend upon the signal the individual receives with respect to the future velocity of circulation being constant or variable. One important aspect of the results is that it provides a theoretical account of the joint behavior of exchange rates, currencies, and asset prices.

In accordance with the current empirical evidence of Hodrick, Kocherlakota, and Lucas [1989], Engle, Ito, and Lin [1990], and Ito, Engle, and Lin [1990], the main results of the paper concern Table 2, case 1, and Table 3, case 3. In the former, because monetary uncertainty in both countries increases, the most important result is that the comovements of the exchange rate with currencies and asset demands may go in any direction. One cannot expect to find a clear correlation between movements in the exchange rate and prices of currencies and stocks. In the latter case, when monetary uncertainty in both countries go in opposite direction, a clear pattern of joint movements between the exchange rate and currency and stock prices is obtained. Specifically, if the monetary uncertainty in the domestic country increases while in the foreign country it decreases, the exchange rate appreciates, the relative demand for domestic stocks and foreign currency increases, and the demand for domestic currency and foreign stocks currency increases, and the demand for domestic currency and foreign stocks decreases. In all cases, a clear pattern of comovements between currencies and stocks is obtained, which confirms the empirical results of Finn, Hoffman, and Schlagenhauf [1990], i.e. monetary effects improve the explanation of asset returns in this class of models.

14. Alternative cases may also be studied in the same fashion as the ones already analyzed. Insights in those additional cases are minor and available from the author upon request.

References

Bianconi, M. [1992], "Monetary Growth Innovations in a Simple Cash-in-advance Asset-pricing Model," *European Economic Review* (forthcoming).

Bollerslev, T., R.Y. Chou, N. Jayaraman, and K.F. Kroner [1990], "ARCH Modeling in Finance: A Selective View of the Theory and Empirical Evidence, with Suggestions for Future Research," Unpublished Manuscript. Northwestern University, March.

Engle, R.F., T. Ito, and W-L. Lin [1990], "Meteor Showers or Heat Waves? Heteroskedastic Intra-daily Volatility in the Foreign Exchange Market," *Econometrica* 58(3): pp. 525-42.

Finn, M.G., D.L. Hoffman, and D.E. Schlagenhauf [1990], "Intertemporal Asset-pricing Relationships in Barter and Monetary Economies: An Empirical Analysis," *Journal of Monetary Economics* 25: pp. 431-51.

Giovannini, A. [1989], "Uncertainty and Liquidity," *Journal of Monetary Economics* 23: pp. 239-58.

Giovannini, A. and P. Labadie [1989], "Asset Prices and Interest Rates in Cash-in-advance Models," NBER Working Paper Series No. 3109, September. *Journal of Political Economy* (forthcoming).

Hodrick, R.J. [1989], "Risk, Uncertainty, and Exchange Rates," *Journal of Monetary Economics* 23: pp. 433-59.

Hodrick, R.J., N. Kocherlakota, and D.J. Lucas [1989], "The Variability of Velocity in Cash-in-advance Models," NBER Working Paper Series No. 2891, March. *Journal of Political Economy* (forthcoming).

Ito, T., R.F. Engle, and W-L. Lin [1990], "Where Does the Meteor Shower Come From? The Role of Stochastic Policy Coordination," NBER Working Paper Series No. 3504, October.

Lucas, R.E. [1982], "Interest Rates and Currency Prices in a Two-Country World," *Journal of Monetary Economics* 10: pp. 335-59.

Lucas, R.E. [1984], "Money in a Theory of Finance," *Carnegie-Rochester Conference Series on Public Policy* 21: pp. 9-46.

Lucas, R.E. and N. Stokey [1987], "Money and Interest in a Cash-in-advance Economy," *Econometrica* 55, (3): pp. 491-513.

Rothschild, M. and J.E. Stiglitz [1970], "Increasing Risk: A Definition," *Journal of Economic Theory* 2: pp. 225-43.

Stockman, A.C. and L.E.O. Svensson [1987], "Capital Flows, Investment, and Exchange Rates," *Journal of Monetary Economics* 19: pp. 171-201.

Stockman, A.C. and H. Dellas [1989], "International Portfolio Nondiversification and Exchange Rate Variability," *Journal of International Economics* 26: pp. 271-89.

Stulz, R.M. [1984], "Currency Preferences, Purchasing Power Risks, and the Determinants of Exchange Rates in an Optimizing Model," *Journal of Money, Credit, and Banking* 16: pp. 302-16.

Svensson, L.E.O. [1985a], "Money and Asset Prices in a Cash-in-Advance Economy," *Journal of Political Economy* 93, (5): pp. 919-44.

Svensson, L.E.O. [1985b], "Currency Prices, Terms of Trade, and Interest Rates: A General Equilibrium Asset-pricing Cash-in-advance Approach," *Journal of International Economics* 18: pp. 17-41.

Townsend, R. [1987], "Asset Return Anomalies in a Monetary Economy," *Journal of Economic Theory* 41: pp. 219-47.