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Money Supply Announcements and Market Reactions in an Open Economy

REACTIONS IN MONEY, BOND, AND FOREIGN EXCHANGE markets induced by the Federal Reserve's weekly money supply announcement have been extensively documented and interpreted. The most consistent finding has been that short-term interest rates tend to increase (decrease) in response unexpectedly high (low) week-to-week monetary growth. Most researchers have sought to account for this and other empirical regularities by positing a certain view of market perceptions of central bank behavior. For example, the policy anticipations school argues that it is the real component of interest rates that increases after positive money surprises,[1] since market participants believe the Fed will seek to counteract these demand-based shocks in the coming weeks.[2] This view is strengthened by the tendency (observed in some sample periods) for the value of the dollar to also increase after positive surprises.[3]

[1]As a verbal abbreviation, I will often speak of typical reactions to positive surprises. There is no intention to imply any asymmetries (i.e., responses to negative surprises which are not equal in absolute value and of opposite sign to those of positive). In fact, in the clearest test for such asymmetries (for three-month U.S. T-bill reactions), Belongia and Kolb (1984) were unable to reject the null that responses to positive and negative surprises were symmetrical.

[2]These are shocks to the money multiplier since the corresponding level of the monetary base is announced the previous week. This is true in both Canada and the United States, where, in both cases, money supply announcements are weekly.

[3]A conflicting view, the expected inflation hypothesis, argues that interest rates increase because the inflation premium is increasing. Thus market participants expect the Fed to accommodate (at least partially) money surprises by raising monetary growth rates. Not all see the phenomenon as reflecting market perceptions of the central bank's reaction function. For example, Siegel (1985) has

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This line of research has been extended by examining market reactions induced by non-U.S. money supply announcements—in particular, for the United Kingdom (Smith and Goodhart 1985 and Goodhart and Smith 1985) and for Canada (Deaves 1989). Consistent with U.S. findings, there is evidence that, at least for some sample periods, the domestic currency tends to appreciate in response to positive surprises. There is, however, no indication that non-U.S. short-term interest rates are affected by domestic money surprises.[4]

This paper proposes an open-economy model of the money supply announcement–financial market reaction phenomenon which may account for the apparent divergence of this recent research from U.S. experience, and at the same time identifies an additional channel of influence of money surprises on interest rates for the United States. An implication of the model is that not only the magnitude but even the sign of short-term interest rate responses to money surprises is a function of the parameters of the model. In addition, the response is more likely to be small (if not zero or negative) in the case of countries such as Canada and the United Kingdom with high ratios of imports to GNP.[5]

A policy-anticipations view of central bank behavior is imposed, or, equivalently, long-term target levels for the money supply are assumed to be unaffected by unanticipated deviations from target. Previous modeling based on this view of central bank behavior in the context of the U.S. literature has been done by Urich (1982), Nichols, Small, and Webster (1983), and Roley and Walsh (1985) for closed economies, while Engel and Frankel's (1984) model is the principal open-economy predecessor. The latter, which predicts a positive correlation between interest rate changes and money surprises, is in some respects similar to a special case of the model presented here.[6]

The paper is structured as follows. Section 1 presents the basic model. The next section derives predictions of exchange rate and interest rate reactions induced by monetary innovations. Finally in section 3 brief consideration is given to the role that this model may play in explaining the stylized facts in the money supply announcements literature.

1. THE OPEN-ECONOMY MONEY MARKET MODEL UNDER POLICY ANTICIPATIONS

As a framework, a simplification of Mussa's (1982) generalization of Dornbusch's "overshooting" model (1976) is employed. The general price level at t

formulated a model that abstracts from central bank behavior and accords to monetary announcements a signaling role on the future prospects for the economy. The U.S. weekly money supply announcements empirical literature (and interpretations of it) are recently reviewed by Sheehan (1985) and Deaves (1987).

[4]Ito and Roley (1987) find that the yen/dollar exchange rate does not (for the most part) respond to Japanese money surprises. They did not test for any interest rate effects.

[5]For example, in 1987 the ratios were (according to the IMF's *International Financial Statistics*) 26.9 percent, 26.3 percent, and 10.7 percent for the United Kingdom, Canada and the United States, respectively.

[6]In Engel and Frankel interest rates and the exchange rate are linked through open interest parity

(P_t), measured as a logarithm, is a weighted average of domestic money prices of domestic goods and foreign goods:

$$P_t = \sigma p_t + (1 - \sigma)(e_t + p_t^*) , 0<\sigma<1 \tag{1}$$

where p_t = log of domestic money price of domestic goods;
p_t^* = log of foreign price level;
e_t = log of exchange rate, defined as the price of a unit of foreign money in terms of domestic;
σ = expenditure share on domestic goods.

Since the object is to investigate how asset prices deviate from their steady-state levels in response to domestic information of a transitory nature, it will be harmless to assume that all foreign magnitudes, including the price level, are constant, and that domestic steady-state variable values are constant.[7] If market participants hold a policy-anticipations view, then they believe that any demand-based money surprises will eventually be counteracted by the monetary authority (hereafter MA). If domestic goods prices are somewhat sticky in response to new information (even without counteractive monetary policy), then it may be a reasonable approximation to assume that the domestic price level can be treated as constant.[8] Normalizing the foreign price level at unity, equation (1) can be rewritten as

$$P_t = \sigma p + (1 - \sigma)e_t \, . \tag{1a}$$

Note that only one of P_t and e_t is independent. Forward differencing of (1a) yields

$$DP_t = (1-\sigma)De_t \tag{1b}$$

where $Dx_t = x_{t+1} - x_t$.

Money demand, open interest parity, and the Fisher equation have standard forms:

(as here). As will become clear, I go one crucial step further by incorporating the exchange rate (via import prices) in the general price level, which then feeds back into the monetary sector (through money demand).

[7]Foreign constant variables and domestic steady state variable values will be indicated by the relevant variable symbols without a time subscript. Steady-state growth in variables (such as monetary expansion and inflation) could readily be incorporated, and all asset price changes could then be viewed as deviations from trend.

[8]Many models of price adjustment allow for gradual movement of the price level toward its level in a world without any price inflexibility. In the model presented here the gap between these two gradually diminishes in any case (except perhaps, as will be shown, for an initial phase when it could potentially widen).

$$m_t^d = k_t + P_t - \eta i_t = m_t\,, \quad \eta>0 \tag{2}$$

$$i_t = i^* + E_t(De_t)\,, \tag{3}$$

$$i_t = r_t + E_t(DP_t)\,, \tag{4}$$

where m_t^d, m_t = log of nominal money demand, supply;
i_t = domestic single-period nominal interest rate[9];
η = interest elasticity;
k_t = real money demand shift component;
i^* = foreign nominal interest rate (assumed constant);
r_t = real ex ante rate of interest.

Substituting (3) and (1b) into (2) allows derivation of the following first-order difference equation:

$$P_t - (1/c)E_t(DP_t) = w_t \tag{5}$$

where $c = (1 - \sigma)/\eta$;
$w_t = m_t - k_t + \eta i^*$.

Using recursive substitution, it is straightforward to show that its solution is a weighted average of the current and expected future values of w_t:

$$P_t = \sum_{j=0}^{\infty} c[1/(1+c)]^{j+1} E_t(w_{t+j})\,. \tag{6}$$

Thus specification of the $E_t(w_{t+j})$ path, or, equivalently, the expected paths of money demand and supply are sufficient to derive current and expected future values for the general price level and [by (1a)] for the exchange rate. Current and expected future interest rates are then determined from (2), and ex ante real interest rates from (4).

Next the monetary process is specified.[10] There are two reasons why the MA is not able to exercise perfect monetary control, even if it desired to do so: shocks to money demand and a lag in information. Shocks to money demand occur through the real money demand shift component. It is assumed that

$$k_t = k + u_t \tag{7}$$

[9] Arguably the demand for money function would more normally have as its cost argument a longer-term interest rate (e.g., a thirteen-week Treasury bill rate) than the span from one money supply announcement to another. Deaves (1987) makes this adjustment and no substantive results change.

[10] The stochastic nature of money demand and the reaction function of the monetary authority share common features with those of Roley and Walsh (1985). For this reason, interest rate predictions for the zero import special case (with $\sigma=1$) are similar to those of Roley and Walsh.

where k = steady-state shift factor level;
$u_t = \rho u_{t-1} + \epsilon_t, 0 < \rho < 1,$

and ϵ_t is white noise. Thus shocks to money demand are both transitory and persistent.[11]

Because of an information lag, the MA becomes aware of demand shocks only after they take place. Until this time under most operating procedures some temporary central bank accommodation of unobservable money demand shocks occurs. In fact, this accommodation will be total under an interest rate instrument. This procedure will be assumed here.

Based on the information available to it, the MA plans to "set" single-period interest rates so as to achieve its target path for the money supply. To correspond with Canadian and U.S. institutional practice, it is assumed that the money supply is calculated with a two-period (that is, two-week) lag. Thus the MA learns of the level of the money supply at $t-2$ just before setting interest rates at t. It then revises its planned future single-period interest rate settings so as to counteract any surprises at a rate of λ percent per period:

$$T_t(m_{t+j}) - T_{t-1}(m_{t+j}) = (1-\lambda)^{j+1}[E_t(m_{t-1}) - T_{t-1}(m_{t-1})], j = 0,1,2,... \quad (8)$$

where $T_t(m_{t+j})$ = target money stock for $t+j$ based on information known to MA at t.

It is assumed that $0 \leq 1-\lambda < \rho$. In other words, the MA acts in such a way that the money supply reverts to target levels more quickly than it would otherwise "unwind."[12]

It should be stressed that the model is not based on any informational advantage. As soon as the monetary authority gathers the data (at the beginning of week t), it releases the money supply figure. The stochastic nature of money demand, the money supply target path and its adjustment to new information are common knowledge. Therefore, any changes in asset prices that take place will be consistent with the plans of the monetary authority and are simply market anticipations of these plans.

2. MARKET REACTIONS TO MONEY SURPRISES

To simplify the analysis, assume that the economy, beginning in the constant steady state at $t-3$, experiences a shock to money demand at $t-2$. Unknown to

[11]Since the shocks are weekly, it is probable that they would possess a high degree of serial correlation.

[12]If $\lambda=1$, the target levels of the money stock do not change, and the shock would be totally reversed in the next period. In all other cases temporary partial accommodation is implied. The reason that $\rho \leqslant 1-\lambda$ has been disallowed is as follows. In the case of the strict inequality (which always includes $\lambda=0$ since $\rho<1$), the implication is that the MA illogically compounds a surprise. As for the equality, by allowing the surprise to "unwind" at its own rate, the MA would have no role in the monetary process. In the strict context of the model this would actually be optimal, as there would be

the MA until t, it is at first accommodated. When at t the surprise is observed, the MA revises its planned interest rate settings so as to counteract it over time. The market becomes aware of this with the announcement at t of the money supply at $t-2$. Thus the general price level, the exchange rate, and interest rates are perturbed from their initial levels (P, e, and i, respectively). The forward-looking analysis will be simplified by assuming perfect foresight, with all error terms except for the original being set equal to zero.[13] Eventually the system converges to its original steady state. The object is to examine the impact of the shock on current levels of (and the path of) the endogenous variables before the reestablishment of long-term equilibrium.

Given the stochastic nature of money demand and the reaction function of the MA, and the fact that the system began in the steady state, (8) can be rewritten as

$$m_{t+j} - m = (1-\lambda)^{j+1}[\rho\epsilon_{t-2}], \qquad j=0,1,2,... \tag{8a}$$

where m = constant steady state level of money supply.

To calculate the immediate change in the general price level (as well as its future path) after the announcement, notice that [using (7) and (8a)] the following perceived shift in the path of w_t has taken place:

$$\begin{aligned} \Delta w_{t+j} &= \Delta m_{t+j} - \Delta k_{t+j} + \Delta\eta i^* ; \\ &= (1-\lambda)^{j+1}(\rho\epsilon_{t-2}) - \rho^{j+1}(\rho\epsilon_{t-2}) ; \\ &= \rho\epsilon_{t-2}[(1-\lambda)^{j+1} - \rho^{j+1}] ; \qquad j=0,1,2,... \end{aligned} \tag{9}$$

At t, just prior to the announcement, the general price level will still be at P (that is, $P_t^b = P$ where b denotes "before the announcement"), as the public will have no reason to expect that a monetary disturbance has taken place. After the announcement, the general price level will shift to P_t^a (where a denotes "after the announcement"). Its change (j=0) and the expected change in its path (j>0) is [from (6) and (9)]

$$\Delta P_{t+j} = P^a_{t+j} - P^b_{t+j} = P^a_{t+j} - P ;$$

no price level or interest rate consequences, but the model ignores the formation of inflation expectations, and the public's observation of an increase in monetary expansion might lead to revisions in future expected inflation, which is after all what a policy of targeting is designed to prevent.

[13]The following equations describe the money market up to t:

At $t-3$: $m = P + k - \eta i$ (steady state);
At $t-2$: $m + \epsilon_{t-2} = P + k + \epsilon_{t-2} - \eta i$ (shock accommodated);
At $t-1$: $m + \rho\epsilon_{t-2} = P + k + \rho\epsilon_{t-2} - \eta i$(shock again accommodated; $\epsilon_{t-1} = 0$).

It would be straightforward to repeat the analysis in terms of a fully stochastic world (with the appropriate substitution of expectations).

$$= \sum_{i=0}^{\infty} c[1/(1+c)]^{i+1} \Delta w_{t+j+i} \; ;$$

$$= c\rho\epsilon_{t-2} \left[\frac{(1-\lambda)^{j+1}}{(1+c)} \sum_{i=0}^{\infty} \left[\frac{(1-\lambda)}{(1+c)} \right]^{i} - \frac{\rho^{j+1}}{(1+c)} \sum_{i=0}^{\infty} \left[\frac{\rho}{(1+c)} \right]^{i} \right] ;$$

$$= c\rho\epsilon_{t-2} \left[\frac{(1-\lambda)^{j+1}}{(1+c-(1-\lambda))} - \frac{\rho^{j+1}}{(1+c-\rho)} \right] , \qquad j=0,1,2,\ldots \tag{10}$$

Note that, if the surprise is positive, the current level of the general price level will decline.[14] Also it is clear that $P_{t+\infty} = P$. There may in fact be, depending on the magnitudes of λ and ρ, additional falls in the price level (after the initial decline). Eventually, if not immediately, the general price level must "turn around" and asymptotically reach P, its steady-state level.[15]

Implied movements in the spot and forward exchange rates are [from (10) and (1a)

$$\Delta e_{t+j} = e^{a}_{t+j} - e^{b}_{t+j} = e^{a}_{t+j} - e \; ;$$

$$= (1/(1-\sigma))c\rho\epsilon_{t-2} \left[\frac{(1-\lambda)^{j+1}}{[1+c-(1-\lambda)]} - \frac{\rho^{j+1}}{(1+c-\rho)} \right] ;$$

$$= (\rho/\eta)\epsilon_{t-2} \left[\frac{(1-\lambda)^{j+1}}{[1+c-(1-\lambda)]} - \frac{\rho^{j+1}}{(1+c-\rho)} \right] , \qquad j=0,1,2,\ldots \tag{11}$$

A zero import special case is derived by setting $\sigma=1$ (implying $c=0$):[16]

$$\Delta e_{t+j} = (\rho/\eta)\epsilon_{t-2} \left[\frac{(1-\lambda)^{j+1}}{[1-(1-\lambda)]} - \frac{\rho^{j+1}}{(1-\rho)} \right] , \qquad j=0,1,2,\ldots \tag{11Z}$$

In response to a positive surprise the value of the domestic currency unequivocally rises (that is, e_t falls). Over time it too asymptotically returns to its initial steady-state value. This is true for both the general model and the zero import special case.[17]

[14]This immediately follows from $\rho > 1 - \lambda$.

[15]For example, if η=.5, σ=.5, λ=.5, and ρ=.965, the general price level will continue to fall for several more periods, after which it begins to climb toward its steady-state level. After thirteen weeks it is approximately equal to its postannouncement level. See Deaves (1987) for a simulation using these parameter values.

[16]Note that the existence of an exchange rate is still valid in the zero import case because of international capital movements, and the possibility that the country may be exporting without importing at all. Also, in this case $\Delta P_{t+j} = 0$, since the general price level is equivalent to the price of domestic goods which is fixed by assumption. In fact equation (6) is not defined for this case.

[17]In the zero import case the linkage between the (now constant) general price level and the exchange rate is terminated. Exchange rate movements are determined *purely* from interest parity.

Next interest rate reactions are considered.[18] After the announcement, the current level of the weekly interest rate, which the MA intends to set, and expected future levels will be clear to the public. Thus both the current weekly rate and longer-term rates will immediately change in such a way as to clear the money market given P_t^a and the expected levels of the money supply and demand shift factor. In the appendix it is shown that current and future single-period and multiperiod interest rate changes are[19]

$$\begin{aligned}\Delta i_{t+j} &= i_{t+j}^a - i_{t+j}^b = i_{t+j}^a - i\,;\\ &= (\rho/\eta)\epsilon_{t-2}\left[c\left[\frac{(1-\lambda)^{j+1}}{[1+c-(1-\lambda)]} - \frac{\rho^{j+1}}{(1+c-\rho)}\right]\right.\\ &\qquad \left. + [\rho^{j+1}-(1-\lambda)^{j+1}]\right], \qquad j=0,1,2,\ldots \end{aligned} \tag{12}$$

$$\begin{aligned}\Delta i_{k,t+j} &= i_{k,t+j}^a - i_{k,t+j}^b = i_{k,t+j}^a - i\,;\\ &= (\rho/k\eta)\epsilon_{t-2}\left[c\left[\frac{(1-\lambda)^{j+1}[1-(1-\lambda)^k]}{\lambda[1+c-(1-\lambda)]} - \frac{\rho^{j+1}(1-\rho^k)}{(1-\rho)(1+c-\rho)}\right]\right.\\ &\qquad \left. + \left[\frac{\rho^{j+1}(1-\rho^k)}{(1-\rho)} - \frac{(1-\lambda)^{j+1}[1-(1-\lambda)^k]}{\lambda}\right]\right],\\ &\qquad j=0,1,2,\ldots;k=1,2,3,\ldots, \end{aligned} \tag{13}$$

where $i_{k,t}$ = k-period interest rate at t.

Setting $c=0$ for the zero import special case, we have

$$\Delta i_{t+j} = (\rho/\eta)\epsilon_{t-2}\,[\rho^{j+1} - (1-\lambda)^{j+1}], \qquad j=0,1,2,\ldots \tag{12Z}$$

$$\begin{aligned}\Delta i_{k,t+j} &= (\rho/k\eta)\epsilon_{t-2}\left[\frac{\rho^{j+1}(1-\rho^k)}{(1-\rho)} - \frac{(1-\lambda)^{j+1}[1-(1-\lambda)^k]}{\lambda}\right],\\ &\qquad j=0,1,2,\ldots;k=1,2,3,\ldots\end{aligned} \tag{13Z}$$

For the general case, the direction of these interest rate movements is indeterminate and depends on the relevant parameter values. To see this, consider the current single-period rate reaction. It is apparent that it is made up of two terms $c\{[(1-\lambda)/(1+c-(1-\lambda))] - \rho/(1+c-\rho)\}$ and $\rho-(1-\lambda)$ (whose sum is multiplied

[18]Note that, as is appropriate for an open economy, monetary forces drive the exchange rate and interest yields accommodate themselves appropriately. The monetary authority can only "set" nominal interest rates if the settings are consistent with the implied differences between money supply and demand and the value of the exchange rate.

[19]Note that, for simplicity, I am assuming the unbiased expectations theory of the term structure to be appropriate. Also, long-term interest rates are expressed as arithmetic rather than geometric averages of short-term rates.

by the product of ρ/η, which is positive, and the surprise). Since $\rho > 1-\lambda$, the first term is negative and the second positive. Only the second term, which constitutes an "anticipated counteraction" effect, is present for zero import economies (since $c=0$ implies that the first term is zero). This effect leads to increases (decreases) in interest rates in response to positive (negative) surprises, as the public anticipates future monetary tightening (loosening). The first term, a "price level" effect, works in the direction of interest rate decreases (increases) after positive (negative) surprises.[20] The more the general price level (driven by the exchange rate) falls (rises), the more real balances rise (fall). For this reason interest rates, through money demand, are pushed lower (higher).[21]

3. CONCLUDING REMARKS

A brief recapitulation of the predictions of the open-economy model under policy anticipations is in order. To concentrate on movements in spot variables (rather than expected paths), the formulation presented here suggests that, in response to positive money surprises, the value of the domestic currency tends to increase. This is true for both the general model and the zero import special case. Interest rates movements are another matter. For the zero import case, under policy anticipations, they will always increase in anticipation of future central bank tightening. In the general case, however, changes in interest rates may be positive, zero, or negative depending on parameter values and maturity.

Goodhart and Smith (1985) showed that, for the United Kingdom during a 1977–83 sample period, changes in the value of the pound were positively correlated with positive money surprises, while Deaves (1989) showed a similar result for Canada during a 1978–79 sample period. In both cases, however, three-month T-bill yields were not significantly affected. In light of the model presented here, and the fact that the United Kingdom and Canada have high imports to GNP ratios, these results need not be surprising. Empirical differences in short-term interest rate responses between the latter two nations versus the United States may thus be attributable to different parameter values. The "price level" effect, though present in the United States, is simply dominated by the "anticipated counteraction" effect.

[20]As pointed out by an anonymous referee, the magnitude of the "price level" effect is likely to be altered by the consideration of various factors abstracted from in my analysis. For example, this effect will be greater if domestic price flexibility (i.e., instantaneous inflexibility followed by gradual adjustment toward equilibrium levels) is allowed, since the rising value of the domestic currency will put downward pressure on the domestic price level causing the general price level to fall even further after positive surprises. Also, future real income increases induced by positive surprises will tend to further lower prices.

[21]As shown in Deaves (1987), investigating real interest rate movements provides an important clue on the direction of nominal rate movements. In fact it can be shown that changes in k-period real rates of interest move in the same direction as changes in expected movements in the general price level from t to $t+k$ $(\Delta P_{t+k} - \Delta P_t)$, which implies that nominal rates move in the same direction as both the real rate and the inflation premium.

APPENDIX: DERIVATION OF INTEREST RATE REACTIONS

First the immediate change in the single-period rate is derived. Consider how perceptions of the elements of the money demand and supply change after the announcement:

$$\Delta m_t = \Delta k_t + \Delta P_t - \eta \Delta i_t$$

$$\Rightarrow (1-\lambda)\rho\epsilon_{t-2} = \rho^2\epsilon_{t-2} + c\rho\epsilon_{t-2}\left[\frac{(1-\lambda)}{(1+c-(1-\lambda))} - \frac{\rho}{(1+c-\rho)}\right] - \eta\Delta i_t$$

$$\Rightarrow \Delta i_t = (\rho/\eta)\epsilon_{t-2}\left[c\left[\frac{(1-\lambda)}{[1+c-(1-\lambda)]} - \frac{\rho}{(1+c-\rho)}\right] + [\rho - (1-\lambda)]\right].$$

It is straightforward to generalize this to derive the path of single-period interest rates which gives us (12):

$$\Delta i_{t+j} = (\rho/\eta)\epsilon_{t-2}\left[c\left[\frac{(1-\lambda)^{j+1}}{[1+c-(1-\lambda)]} - \frac{\rho^{j+1}}{(1+c-\rho)}\right] + [\rho^{j+1}-(1-\lambda)^{j+1}]\right], \quad j=0,1,2,\ldots \tag{12}$$

Equation (13) is derived from (12). We begin with current multiperiod rates:

$$\Delta i_{k,t} = (1/k)\sum_{j=0}^{k-1}\Delta i_{t+j};$$

$$= (\rho/k\eta)\epsilon_{t-2}\left[c\left[\sum_{i=0}^{k-1}\frac{(1-\lambda)^{i+1}}{[1+c-(1-\lambda)]} - \sum_{i=0}^{k-1}\frac{\rho^{i+1}}{(1+c-\rho)}\right] + \left[\sum_{i=0}^{k-1}\rho^{i+1} - \sum_{i=0}^{k-1}(1-\lambda)^{i+1}\right]\right];$$

$$= (\rho/k\eta)\epsilon_{t-2}\left[c\left[\frac{(1-\lambda)(1-(1-\lambda)^k)}{\lambda(1+c-(1-\lambda))} - \frac{\rho(1-\rho^k)}{(1-\rho)(1+c-\rho)}\right] + \left[\frac{\rho(1-\rho^k)}{1-\rho} - \frac{(1-\lambda)(1-(1-\lambda)^k)}{\lambda}\right]\right].$$

To derive the expected path of multiperiod rates, note tat all summations now are indexed from $i=j$ to $j+k-1$. Consider the third summation, for example:

$$\sum_{i=j}^{j+k-1} \rho^{i+1} = \rho^{j} \sum_{i=0}^{k-1} \rho^{i+1} .$$

Thus (13) clearly holds. The zero import equations (12Z) and (13Z) are derived by setting $c=0$.

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