NBER WORKING PAPERS SERIES

MAXIMIZING SEIGNORAGE REVENUE DURING TEMPORARY SUSPENSIONS OF CONVERTIBILITY: A NOTE

Michael D. Bordo

Angela Redish

Working Paper No. 4024

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 1992

The authors are Professor, Department of Economics, Rutgers University and Associate Professor, Department of Economics, University of British Columbia, respectively. They wish to thank Alvin Marty, Dean Taylor, Lawrence H. White, and the referees and Editor of this Journal for helpful comments. This paper is part of NBER's research programs in Development of the American Economy and Monetary Economics. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

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ABSTRACT

This note extends the theory of the revenue maximizing rate of monetary growth to the case of a temporary suspension of convertibility. It also suggests a methodology for the interpretation of monetary behavior during historical periods of inconvertibility. First we analyze the case of a government with a monopoly over currency issue. The government maximizes seignorage revenue by generating an inflation, but the terminal condition of a return to convertibility implies that the price level must drop at the point of suspension of convertibility, so that there is no discontinuity at the date of resumption. We then consider the behavior of a private banking system whose monetary liabilities are temporarily inconvertible. The model is then used to interpret monetary behaviour during the suspension of convertibility by U.S. banks in 1837/8.

Michael D. Bordo
Department of Economics
Rutgers University
New Brunswick, NJ 08903
and NBER

Angela Redish
Department of Economics
University of British Columbia
Vancouver, B.C. VGT 171
Canada

Over the last two decades economists have re-examined the question of what rate of monetary expansion maximizes the present value of seignorage revenue. Typically the problem is framed in terms of finding the seignorage maximizing rate of monetary expansion by a government with a monopoly over the issue of high powered money, given that the government can credibly announce that it will immediately begin issuing money at that rate. Although there has been increased concern about setting appropriate initial conditions (Auernheimer, 1974, 1983; Marty 1978) the literature has always examined cases in which there are no terminal conditions. This note extends the theory of the revenue maximizing rate of monetary growth to the case of a temporary suspension of convertibility.[1]

This extension has relevance because there are a range of problems, particularly in economic history, where terminal conditions were significant, that is, where a fiat money was only issued for a temporary period.[2] Indeed, the gold standard of the 19th and early 20th centuries survived in part because it permitted the temporary suspension of the convertibility of note issues. The more famous examples include: the U.S. in 1837-38 and 1862-79; Britain in 1797-1821, 1914-25, and Canada in 1838-9, 1914-25. In each case a characteristic of the issue of fiat money was the expectation that at some future date the gold standard would be resumed (Bordo and Kydland, 1990).

In addition to extending the theory of the revenue maximizing rate of monetary growth to the case of a temporary suspension of convertibility, our analysis suggests a methodology for the interpretation of monetary behavior during historical episodes of inconvertibility. There have been few careful analyses of such behaviour. Calomiris (1988) models the behaviour of the competitive U.S. banking system during the Greenback period, but this case is made idiosyncratic by the requirement that bank notes be 111% backed by government bonds. Smith and Smith (1990)

[1] A more general analysis would give the government more than one policy instrument - for example, income taxes and tariffs in addition to seignorage - and determine jointly the optimal setting for each policy instrument. We restrict our analysis to the simpler task of finding the optimal rate of seignorage under the assumption that the instruments are independent. (On optimal revenue maximization see Mankiw (1987) and for an historical application, Bordo and White (1991)).

[2] Money which is only temporarily inconvertible could be called credit money rather fiat money. We use the term fiat money because the money issues we are dealing with seem closer to fiat money than to the more usual types of credit money.

examine the 1914-1925 suspension of convertibility in the U.K., but they argue that for this period the date of resumption was endogenous and the money supply process exogenous. Our model makes the opposite assumptions. More typically, economic historians have relied on happenstance to explain monetary behaviour during temporary suspensions of convertibility (e.g. Temin, 1969).

The first section analyzes the case of a government with a monopoly over currency issue. The government maximizes seignorage revenue by generating an inflation, but the terminal condition implies that the price level must drop at the point of suspension of convertibility, so that there is no discontinuity at the date of resumption. (Since resumption at the old par is anticipated with certainty, market efficiency would prevent such a discontinuity.) The second section of the paper considers the behaviour of a private banking system whose monetary liabilities are temporarily inconvertible, beginning with the case of a bank that issues interest-bearing deposits. The special cases of a note issuing bank and a bank constrained by a usury law are examined.[3] If a deposit issuing bank with monopoly power can pay interest on its deposits at an optimal rate, then it obtains no additional benefit from a temporary suspension of the requirement that deposits are convertible into specie. If the bank issues notes, its optimal policy (in the absence of usury laws) is identical to that of a government with a monopoly over currency issue. In the face of binding usury laws limiting the nominal rate of interest charged on loans, the revenue maximizing rate of inflation is lower than in the unconstrained case.

1. A Government Monopoly Over Currency Issue

It is customary in analyses of seignorage maximizing behaviour, to measure the potential seignorage as a capital sum. That is the seignorage created over a period of time is the sum of the present discounted value of instantaneous changes in the money stock. The seignorage revenue could equivalently be measured as an income flow (Johnson, 1969). That is, the seignorage revenue at a point in time is measured by the interest earned by the assets purchased with the outstanding money issues. Potential seignorage over the period is then the present discounted

[3] See Rockoff (1988) for a description of the prevalence of usury laws in the United States in the 19th century.

value of these income flows. Since the latter concept is more convenient for analyzing a temporary suspension of convertibility we begin by examining the equivalence between the two measures and then proceed to analyze the behaviour of a government with a monopoly over currency issue, during a temporary suspension of convertibility.

Consider a government that issues money and faces a demand for money function (1):[4]

$$\frac{M^d}{P} = m^d = Ae^{-b(r+\pi)} \tag{1}$$

(see Table 1 for notation). Assume initially that this is a small open economy on a fixed exchange rate, that agents have perfect foresight and that purchasing power parity implies (2):

$$P = s \cdot P^* \tag{2}$$

TABLE 1

Notation

M	nominal money balances	m	real money balances (M/P)
P	domestic price level	D	nominal deposits
π	rate of inflation ($\dot{P}/P$)	d	real deposits (D/P)
s	exchange rate	N	nominal notes
P*	world price level	n	real notes (N/P)
r	real interest rate	i	nominal interest rate (r + p)
ρ	reserve ratio	R	bank reserves

Letting the rate of inflation in the rest of the world, π_w, equal zero, the level of the money stock supplied by the government is endogenous and given by (3):

$$M = P \cdot Ae^{-b(r+\pi_0)} = P \cdot Ae^{-br} \tag{3}$$

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[4]Here we follow standard practice, (Bailey (1956), Auernheimer (1974)) and assume that all factors other than the nominal interest rate, such as the level of real income, are virtually unchanging and can be subsumed into the constant term.

Assume now that the government suspends convertibility and chooses a path for money issues that maximizes seignorage revenue. Using the interest flow calculation, the potential seignorage revenue (S_i) is given by (4):

$$S_i = \int_0^\infty \{i \cdot M/P\}\, e^{-rt}\, dt \qquad (4)$$
$$= \int_0^\infty (r+\pi) A e^{-b(r+\pi)} e^{-rt}\, dt$$
$$= (1 + \frac{\pi}{r})\, A e^{-b(r+\pi)}$$

That is, the seignorage revenue is the sum of the present discounted value of the instantaneous real value of nominal interest earnings on the assets backing the money stock outstanding. The capital flow calculation asserts that

$$S_k = \int_0^\infty \frac{dM/dt}{P}\, e^{-rt}\, dt + \frac{M}{P}\Big|_{t=0} \qquad (5)$$

Since, $\frac{dM/dt}{P} = m\pi = Ae^{-b(r+\pi)} \bullet \pi$, and $\frac{M}{P}\Big|_{t=0} = Ae^{-b(r+\pi)}$, equation (5) can be rewritten

$$S_k = \int_0^\infty Ae^{-b(r+\pi)}\ \pi\, e^{-rt} dt + Ae^{-b(r+\pi)}$$
$$= Ae^{-b(r+\pi)}\, (1 + \frac{\pi}{r})$$

Note that for the equivalence ($S_i = S_k$) to hold, the expression $\frac{M}{P}\Big|_{t=0}$ must be included in equation (5) because the interest flow calculation includes interest not only on increments to the money stock but also on the amount outstanding at the beginning of the period.

Consider, now, the problem of a government that suspends convertibility only temporarily, from time 0 until time T. The seignorage revenue is now given by (6),[5]

$$S_i' = \int_0^T \{(i \cdot M)/P\}\, e^{-rt}\, dt \qquad (6)$$

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[5] An identical result is obtained, somewhat less elegantly, by using the capital sum approach to measuring seignorage.

$$S_k' = \int_0^T \frac{dM}{P} e^{-rt}\ dt + \frac{M}{P}\Big|_{t=0} + \frac{M}{P}\Big|_{t=T} e^{-rT}$$

$$= Ae^{-b(r+\pi)}(1-e^{-rT})\left[1+\frac{\pi}{r}\right]$$

To find the revenue-maximizing rate of inflation, we take the derivative of (6) with respect to π and set it equal to zero:

$$\frac{\partial S_i'}{\partial \pi} = (1-e^{-rT})\ Ae^{-b(r+\pi)}(-b(1+\frac{\pi}{r})+\frac{1}{r}) = 0$$

or, $$\pi^* = \frac{1}{b} - r. \qquad (7)$$

The optimal level of nominal money balances at all times is jointly determined by the optimal rate of inflation, the interest elasticity of the demand for real balances and a terminal constraint on the price level. Assuming that the world price level is constant over this period, then at $t = T$, $P = s \cdot P^*$, and $m^d = Ae^{-br}$. Since all agents are assumed to have perfect foresight, there can be no discrete change in the price level at $t = T$.

If the seignorage maximizing rate of inflation during the period is higher than zero, then at $t = T$, the level of real money balances will discretely rise and with no discrete change in the price level, the level of nominal money balances must also rise. At $t = 0$, the level of real money balances must fall as must the price level, and these imply a path for nominal money balances. Consider a simple example where $b = 5$, $r = .05$. If we define units such that $T=1$, and before $t = 0$, $m = M = P = 1$, then $A = 1.284$. During the suspension the seignorage maximizing rate of inflation is 15 %, so if the suspension lasts one year, the price level will fall at $t = 0$ from 1.0 to 0.86. The level of real balances will fall from 1.0 to 0.47 (= 1.284 exp (-1.0)), and the level of nominal balances at $t = 0$ falls from 1.0 to 0.41. These paths are illustrated by the solid lines in Figures 1-3. The revenue from this policy would be 0.09215, in contrast to a revenue of 0.05 from a policy of zero inflation.

The result is in contrast with that of Friedman (1971). Friedman ignored any possible changes in the money stock at the date of the new policy and found that to maximize seignorage the government should set $\pi = 1/b$. This assumption of zero revenue at the onset of the policy is only consistent if the price level rose at $t = 0$, causing real balances to fall. This behaviour is illustrated by the dashed line marked F'71 in Figures 1-3.

Auernheimer (1974) (and subsequently Marty 1978) argued that a jump in the price level at $t = 0$, implies that the government is dishonest. They impose the assumption that the price level does not jump discretely at $t = 0$, and the solution to the model then implies that the level of nominal money balances must fall discretely at $t = 0$. Since the higher the inflation rate the greater the initial loss of seignorage, they find that the optimal rate of inflation is lower than Friedman suggested, that is $\pi = (1/b) - r$. This solution is illustrated by the dashed line marked A'74 in Figures 1-3.

Our solution for the optimal rate of inflation is the same as in the Auernheimer model, however, as Figures 1-3 illustrate the levels of the nominal variables behave very differently. Since both models predict the same inflation rate, the drop in real money balances is the same. However, in our model the price level falls at $t = 0$ so that nominal balances decline to a greater extent than in Auernheimer's model. We have assumed that the initial suspension of convertibility is unanticipated, while the date of, and parity at, resumption, is perfectly anticipated. These are clearly extreme assumptions, but the model captures the important elements of some historical episodes.

2. Private Bank Behaviour

The above analysis examined the behaviour of a revenue-maximizing government during a short run issue of inconvertible currency. We turn now to the behaviour of a private banking system in similar circumstances. This behaviour is of interest both because of its historical relevance and because of recent interest in the operation of private banking systems. The literature on the operation of private banking systems has focussed on the determinants of the supply of money in such a regime, both with and without the constraint of convertibility. We examine the determinants of the money stock by a private banking system during a temporary suspension of convertibility.

We assume the same conditions as in Part 1: this is a small open economy, and the suspension of convertibility is unanticipated, although the announced date of resumption and the parity at resumption are both believed; adjustments occur instantaneously. We begin by examining the behaviour of a deposit issuing bank facing a downward sloping demand curve for its deposit liabilities. This assumption is motivated by the fact that each bank's deposit liabilities are a differentiated product, and the bank has some local monopoly power in the geographic area in which it operates. We assume, however, that the bank operates on the infinitely elastic portion of the demand curve for its loanable funds.

Consider the bank's behaviour under the constraint that its deposits must be convertible on demand into gold and that the rate of inflation is zero. Let the nominal interest rate on deposits be $i_d \equiv r + \pi$. The bank faces a demand function for deposits (8),

$$\frac{D^d}{P} \equiv d = Ae^{-b(i-i_d)} \qquad (8)$$

where $(i - i_d)$ measures the opportunity cost of holding bank deposits. Since $\pi = 0$, $i = r$, $i_d = r_d$, $d = Ae^{-b(r-r_d)}$ The bank is assumed to hold gold reserves $R = \rho D$, and to make loans L at the interest rate i.[6] The price level in this economy is constrained by (2) so that the bank's problem is to choose r_d to maximize its profits. The objective function is given by (9):

$$\underset{r_d}{\text{Max}}\ V = \int_0^\infty \frac{1}{P}(i \cdot L - i_d \cdot D)e^{-rt}dt \qquad (9)$$

Substituting $L = D - R$, $i = r$, and $i_d = r_d$, this can be rewritten,

$$\underset{r_d}{\text{Max}}\ V = \int_0^\infty \left\{r(1-\rho) - r_d\right\} Ae^{-b(r-r_d)}\, e^{-rt}\, dt \qquad (10)$$

and the solution to the bank's problem is then to set r_d such that (11) holds:

$$br\,(1-\rho) - r_d\, b = 1 \qquad (11)$$

[6] In the early nineteenth century there were no required reserves, but this simplification allows us to ignore the problem of modelling the bank's choice of an optimal reserve ratio.

or, if we define η_r and η_d as the interest elasticity and own interest elasticity of the demand for deposits respectively,

$$\eta_r (1-\rho) + \eta_d = -1 \tag{12}$$

That is, the bank sets r_d such that the sum of the adjusted elasticities equals -1.

Since the bank can choose r_d to maximize its profits, it does not need the alternative instrument of inflation to maximize its seignorage revenue, and thus the behaviour of the bank will not change if the requirement of convertibility were removed, temporarily or permanently. (See also Marty (1978; 446, f2). In the case where the money stock comprised (government issued) notes, r_d was implicitly restricted to zero, so that the only way that the government could obtain the optimal real rate of return on its liabilities was by changing the rate of inflation.[7]

We turn now to the analysis of a special case of historical relevance: the behaviour of a note-issuing bank with and without the constraint of a usury law that limits the interest rate that the bank can charge on its loans. The significant distinction between note and deposit liabilities is that banks do not pay interest on their notes.[8] Therefore, in the absence of a usury law, the bank's problem is identical to that of a deposit-issuing bank, with the constraint that $r_d = 0$.

The demand for notes is given by equation (13),

$$N^d / P \equiv n = Ae^{-bi} \tag{13}$$

[7] The predictions of this model of the behaviour of a bank with monopoly power can be contrasted with the predictions by Klein (1974) for the behaviour of competitive banks issuing an inconvertible currency in a perfect foresight world. Klein argues that as long as the free rider problem is solved by banks having to maintain the reputation of their brand of money, the banks will have zero economic profits, and will be indifferent to the rate of inflation (in terms of their money). This conclusion anticipates Fama (1980) who similarly argues that competition will minimize the interest rate spread earned by the banks as financial intermediaries. Klein characterizes this as a metastable equilibrium. His result relies on free entry and competition amongst banks. In our model, the bank has monopoly power (not as a result of its issue of brand name deposits) because of economies of scale and limitations on entry into the industry which confer a degree of local monopoly power to banks. The assumption that the bank is a monopolist affects the equilibrium in our model through two routes. On the one hand, the monopolist earns profits at all times, but on the other hand, because there is no free rider problem, these are invariant to the inflation rate.

[8] See White (1987) for a discussion of why this is so.

Under a convertible regime the bank sets[9]

$$N = P \bullet Ae^{-bi} = P \bullet Ae^{-br} \tag{14}$$

Removal of the requirement of convertibility gives the bank a degree of freedom and the bank's problem becomes,

$$\underset{\pi}{\text{Max}}\ V = \int_0^T \left(\frac{1}{P} \bullet i \bullet L\right) e^{-rt}\, dt \tag{15}$$

Since during the period of inconvertibility we assume R = 0, we can rewrite

$\left(\frac{1}{p} \bullet i \bullet L\right) = \left(\frac{1}{p} \bullet i \bullet N\right) = Ae^{-b(r+\pi)} \bullet (r + \pi)$. The bank's problem is identical to that of the government in equation (6) and the solution is given by equation (7). Again, the rate of inflation is used to drive a wedge between the real and nominal rates of return on notes.

Finally, we turn to the case of a note-issuing private bank that is constrained by usury laws that impose a maximum nominal rate of interest that banks can charge on loans, say

$$i \leq i_u \tag{16}$$

The bank's problem is to maximize profits, given by (15) subject to the constraint (16). The optimal rate of inflation is found by forming the Lagrangean (17):

$$L = (r + \pi)\, Ae^{-b\pi} + \lambda(i_u - (r + \pi)) \tag{17}$$

and the Kuhn-Tucker conditions for an optimum are,

$$\frac{\partial L}{\partial \pi} = Ae^{-b\pi}(1 - b \bullet i) - \lambda = 0 \tag{18}$$

$$\lambda \bullet (i_u - (r + \pi)) = 0 \tag{19}$$

$$\lambda \geq 0,\ (i_u - i) \geq 0. \tag{20}$$

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[9] This is obviously a simplification of the bank's problem. A more complex model would allow the bank to undertake costly actions that would influence the demand for its notes (eg. open branches or open for longer hours) and give it at least one margin on which to operate.

If the usury law is binding, $\lambda > 0$, condition (19) states that the optimal rate of inflation will be $(i_u - r)$. The intuition is straightforward. The bank's profits depend on the number of loans it makes and the real rate of interest it can charge. A bank issuing convertible notes (in the absence of usury laws) can earn the real rate of interest on a level of note issue constrained by (14). The removal of the constraint of convertibility enables the bank to set p to maximize the amount of notes issued, which will maximize the amount of loans on which the bank earns the interest rate r. The bank earns the real interest rate by charging a nominal interest rate $i^* = r + \pi^*$.

The usury law constrains the bank's ability to set the inflation rate to maximize the amount of loans, but if the usury rate is greater then the real rate of interest this does not affect the bank's ability to earn the rate 'r' on its loans. The bank sets $\pi = i_u - r$, and $i = i_u$. Let us continue the example of Section (2), and impose a usury law prohibiting interest rates greater than 6%. The unconstrained solution was a nominal interest rate of 20%, a rate of inflation of 15%, and seignorage revenue equal to 0.09. Under usury laws, the banks would not profit from an inflation rate of 15%, as restricting the nominal interest rate to 6% would imply a negative real interest rate. The banks would maximize profits by generating a 1% inflation, and thus charging a nominal interest rate of 6% would yield a real interest rate of 5%. The revenue from this policy would be 0.0557, less than that of the unconstrained case (R = 0.09) but more than from a policy of zero monetary expansion (R = 0.04877). The bank earns less profits than in the absence of usury laws because it cannot make the optimal quantity of loans.

In the case where $i_u < r$, the bank is constrained by the usury law even under the convertible regime. The bank's level of notes (and loans) is still given by (14) but its profits are reduced (relative to no usury law) because it earns less interest on outstanding loans.[10] Removing the constraint that notes be convertible allows this bank to generate a deflation which allows the bank to earn the real rate of interest on its loans. If we continue the above example, setting $i_u = 3$ %, the bank's optimal strategy, given by (19) is to set $\pi = -2$ %, and $i = 3$ %.

[10] The loans would have to be rationed.

3. Historical Experience

As noted in the Introduction there were many temporary suspensions of convertibility by gold standard economies. Few, however, satisfy the restrictive assumptions of our model. Suspensions can typically be divided into two categories: those that are a response to war-time emergencies and those that are a response to financial panics. In the former case the date of resumption is usually not known with certainty. Indeed the record of Parliamentary and Congressional debate, and other governmental action, in both British and American experiences with war-time suspension, suggests that even the inevitability of resumption at the original parity may have been at times an open question.[11] In the latter case, the suspensions were usually so short that the data only capture the disequilibrium conditions that generated the suspension.

The suspension of convertibility by the U.S. banks in May 1837 comes closest to satisfying the model's assumption. Usury laws limited the interest rate charged by New York banks to 7% (Rockoff, 1988) so it is the final version of our model that is applicable. The episode was brief - in New York exactly one year. By early 1838 the resumption of convertibility was widely anticipated since failure to resume would void the banks' charters. The proximate cause of the suspension was a level of money stock higher than that consistent with adherence to the gold standard, leading to a run on the banks.[12]

The available monthly data showing the behaviour of nominal variables are presented in Table 1. In the early months of the suspension the effects of the financial panic are clear - interest rates on commercial paper rose to 32% and the premium on gold rose to 10-12%. Contrary to the predictions of our model, the price level and money supply did not increase instantaneously with the onset of suspension. This occurred because the level of note issues could not be instantaneously reduced in a costless fashion as our model assumed. The sharper decrease in note issues than in the price level may reflect the fact that both the public and the banking system had

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[11] See Bordo and Kydland (1990). Recent literature linking resumption to expectations about monetary policy includes Calomiris (1989) for the Greenback episode and Smith and Smith (1990) for Britain's return to gold in 1925.

[12] The underlying cause of the crisis has been attributed to many factors including Andrew Jackson and the Bank War, and the tightening of credit markets in London. See, for example, Temin (1969) and Gayer et al, (1975).

Table 1

The Behaviour of Nominal Variables: 1837-38

	Prices[13]	Exchange Rate[14]	Interest rate[15]	Price of Gold[16]	Notes Issues by New York banks[17]
May 1837	102	1.3%	32	5-10%	N/A
June 1837	102	3.1%	6		15,422
July 1837	103	7.6%	7.5	10-12%	15,278
Aug. 1837	103	9.3%	7.5		15,472
Sept. 1837	98	10.4%	6.5		14,191
Oct. 1837	101	4.0%	6.5	5-5.5%	15,531
Nov. 1837	106	5.8%	9		15,469
Dec. 1837	108	4.0%	10	4.5-5%	14,154
Jan. 1838	107	0.2%	11	2.5-3%	12,432
Feb. 1838	103	-0.5%	12	2.5-3%	11,664
March 1838	101	-1.9%	18		
April 1838	100	-4.4%	12		11,220
May 1838	100	-2.65	7		11,058

increased their holdings of specie relative to notes.

The behaviour in the second half of the suspension period is closer to the predictions of our model. Our model predicts that the exchange rate will be at a discount that decreases as resumption gets nearer. This is consistent with the observed discount on the U.S. dollar. Similarly the model predicts that the nominal interest rate will exceed its "gold standard level" during the suspension.

Our analysis stands in contrast with the standard description of the period. The recovery of the real economy in 1838 is usually ascribed to the easing of credit market conditions in England, and Temin (1969; 149) argues that this also explains exchange rate behaviour. "The exchange rate between pounds and dollars fell back toward the gold par as a result of the British demand for dollars, and it became possible for the American banks to re-establish the parity between specie and bank obligations". We argue that it was the level of the money stock that determined the exchange

[13] Weighted index of general wholesale commodity prices (1834-42 = 100) (Smith and Cole, 1935, 158).
[14] The premium over par is calculated assuming that par is £1 = $4.8665. (Smith and Cole, 1935, 190).
[15] Commercial Paper Rates - the end of the month where given (Smith and Cole, 1935, 192).
[16] Temin (1969; 118).
[17] Schwartz (no date) Table III.

rate (while the level of the money stock in turn was determined by exogenously given expectations of resumption, and by profit maximizing behaviour by the banks.)

4. Conclusion

In this paper we argue that the level of the money stock determines the behaviour of the nominal variables, e.g. the price level, and exchange rate, during temporary suspensions of convertibility. We build a model of money supply for the simplest case where the suspension is of known duration, starts from an initial equilibrium, and where the money issuer wishes to maximize seignorage revenue. In such a world the money issuer will generate an inflation, but resumption at the old parity implies that the money issuer must start by reducing nominal balances (and hence prices) below the level implied by the gold standard.

The simplifying assumptions restrict the applicability of our model, however, we contrast our analysis with that of Temin for the suspension of convertibility by US banks in 1837-8. We argue that Temin's analysis is incomplete and find that the data provide some support for our model, particularly in the second half of the period.

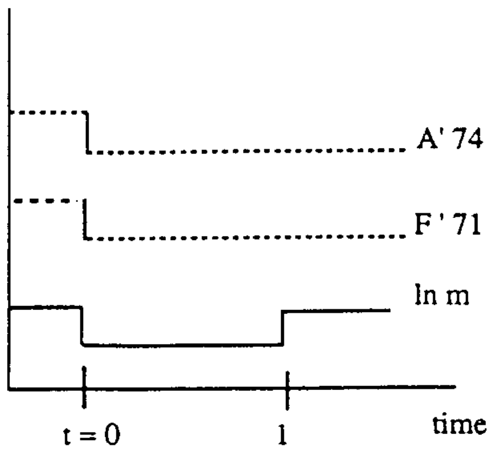

Figure 1: Real Money Balances

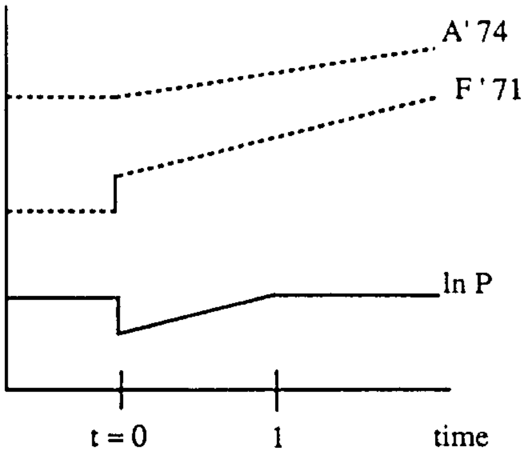

Figure 2: Prices

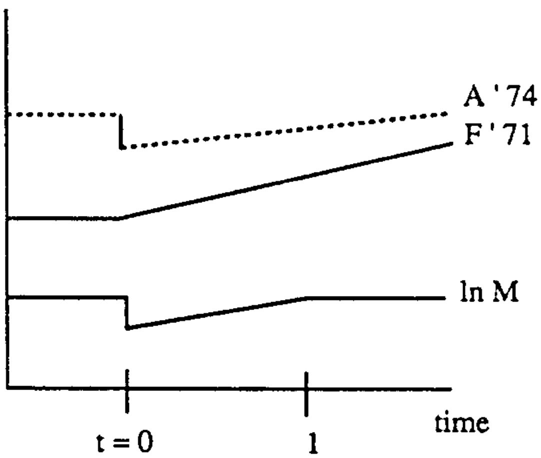

Figure 3: Nominal Money Balances

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