Policing the Chain Gang:  
Panel Cointegration Analysis of the  
Stability of the Suffolk System, 1825-1858

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Abstract

Conventional monetary theory suggests that a closed system banking regime may lead to in-concert over-expansions of circulation by its banks. However, Selgin (2001, 2010) argues that this is unlikely as long as there are enough banks to ensure (i) routine interbank settlement and (ii) no collusion amongst banks refraining from redeeming one another’s notes. Banks effectively form a “chain gang” where in-concert expansion requires coordination that is prohibitively costly in a system with many banks. In order to test this conjecture, we examine state-level data on circulations and reserves from the Suffolk Banking System (1825 to 1858) in New England. In addition to narrative evidence on the stability of the Suffolk, panel cointegration tests provide some evidence of a long-run relationship between state-level circulations and total reserves. The estimated error-correction mechanism suggests a deviation half-life of only about one year. We argue that a cointegrating relationship between circulations and reserves, along with rapid error-correction, supports the Selgin hypothesis.

Keywords: American Free Banking, Suffolk System, Panel Data, Cointegration, Error-Correction, History of Banking, Adverse Clearings

JEL Codes: C33, E42, E51, N11
1. **Introduction**

Can a private, interbank clearing institution (or institutions) provide a feasible basis for a stable monetary order? In evaluating this question one of the greatest concerns involves the possibility of unlimited expansion of banks’ liabilities (Goodhart (1988), Lawlor and Darity (1989), Laidler (1992), and Bordo and Schwartz (1996)). Specifically, researchers have argued that such a clearinghouse will be unable to prevent over-issue by banks acting in concert. The clearinghouse may provide a check on the note issue of an individual bank through “adverse clearings” (Selgin, 1988, p. 40). However, a clearinghouse cannot do the same when banks expand uniformly (Bordo and Schwartz (1996), Gorton (1985), and Gorton and Mullineaux (1987)). If this is true then in-concert overexpansion represents a critical weakness in the free banking school of thought (e.g., Hayek (1978), Glasner (1989), White (1989), Dowd (1993), and Selgin and White (1994)).

Adverse clearings work in the following way to check individual bank note issue in a system based on a stock of outside money (traditionally specie). When an individual bank issues notes disproportionately, its debits in the clearinghouse begin to exceed its credits. As system debits and credits are settled via specie flows, the overexpanding bank finds itself drained of reserves and forced to contract its balance sheet or fail. As Goodhart (1988) argues, the clearinghouse mechanism creates a tendency for banks to increase or decrease issue in unison. The problem, however, is that this tendency may persist. During an overexpansion, each bank’s credits and debits in the clearinghouse will increase in step.

Selgin (1988, 1994, 2001), on the other hand, argues that the clearinghouse mechanism also provides a check on in-concert overexpansion. According to Selgin (2001, p. 294), “this ‘in-concert overexpansion’ doctrine is inconsistent with standard theories of the precautionary
demand for bank reserves.” An in-concert overexpansion “will involve changes in the variance of each banks’ daily net reserve loss, so that, although the expected value of that loss may not increase, its realized value will increase for roughly half of all clearing sessions” (Selgin, 2001, p. 297). The increased variance of adverse clearings will result in an increased demand for precautionary reserves, checking the in-concert expansion. Selgin (2010, p. 488) likens banks in such a clearinghouse system to members of a chain gang. They can only move forward if they do so in unison, coordinating their steps. Such coordination, however, becomes increasingly difficult because of the increase in precautionary reserve demand.

The purpose of this paper is to formally test the in-concert overexpansion doctrine using data from the Suffolk System (1825 to 1858). The Suffolk was a private clearinghouse system that served New England banks. It is of interest because numerous authors have cited it as a successful case of self-regulation (e.g., Mullineaux (1987), Dowd (1994), and Calomiris and Kahn (1996)) but this view is controversial. For example, Lake (1947, p. 1907) early on expressed the view that the Suffolk “protect[ed] the public against overissue by individual banks, but not against overissue by the system.” The Suffolk, then, provides a unique historical experiment to ask whether in-concert overexpansion is likely to occur in the absence of a modern central bank.

We examine a panel of state-level data on banks’ note issue and specie stocks under the Suffolk using panel cointegration techniques the estimation of error correction models. We find that, controlling for cross-section dependence, the unit root null cannot be rejected for note issues. We also present evidence that state-level note issues are cointegrated with both the corresponding state-level specie stocks and the aggregate (Suffolk-wide) stock of specie. Estimation of the error-correction mechanism suggests an annual adjustment rate to deviations
from the long-run relationship with aggregate specie of about 46 percent. We conclude that the available data do not lend support to the in-concert overexpansion doctrine. In particular, our findings are consistent with the image conjured by Selgin (2010): New England banks constituted a “chain gang” of whose circulations the Suffolk System effectively policed during the 1825 to 1858 time period.

2. A Brief History of the Suffolk Clearinghouse System

The Suffolk System was one of the first attempts at creating a banknote clearinghouse within the United States. In the early 1800s, due to branch banking restrictions, redemption of note issue was very costly; this was especially the case for country banks (Dowd, 1994). Banknote brokers made a living buying country banknotes (at a discount) and then redeeming them. Chartered in Boston, the Suffolk Bank entered the note brokerage market in 1818. The Suffolk Bank purchased country banknotes on the open market at a discount (typically one percent or less). Country banks could then redeem the notes at that same discount. The Suffolk Bank profited by requiring participating country banks to maintain a non-interest deposit of $5,000 with the Suffolk. (A separate zero interest deposit was required as a redemption fund.)

Over the next two years, competition led to discounts on country notes of about one half of one percent. In response to this squeeze on its profit margins, the Suffolk briefly withdrew from the note brokerage market. In 1824, the Suffolk and six other large Boston city banks attempted to drive country banknotes out of circulation in the city. Under this scheme, city banks

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1 For a full and comprehensive account of the history of the Suffolk Bank and the Suffolk System see Rice (1878). A more concise overview is found in Rolnick et al. (1998). Several basic facts are presented without citation in this section; they are drawn largely from these two sources.
2 Boston banks actually referred to notes issued by country banks as “foreign money” (Rolnick et al., 1998, p. 12).
3 The Suffolk was the second Boston bank to enter this market, the first being the New England Bank in 1814.
accumulated large numbers of country banknotes through purchases and then returned them to the country banks, *en masse*, for redemption (Rolnick et al., 1998).

Although this scheme quickly proved unsuccessful it paved the way for the introduction of a clearinghouse system. In May of 1825 the other coalition banks endorsed country banks depositing their notes with the Suffolk. However, instead of sending the notes back for redemption the Suffolk would act as a clearinghouse for participating banks. All deposits of the notes of participating banks would be cleared through debits and credits to the banks’ accounts. By 1826 several Boston banks, including a majority of the coalition banks and New England banks generally, had become part of the Suffolk System.

Participating country banks each maintained a non-interest-bearing deposit at the Suffolk Bank of $2,000 for every $100,000 of their capital. The required deposit for participating city banks was $5,000 for every $100,000 of capital. Country banks were additionally required to hold a separate non-interest-bearing deposit as a redemption fund.

The Suffolk System remained the clearinghouse for New England banks through 1858. The beginning of the end was Massachusetts’ chartering in 1855 of the Bank of Mutual Redemption (BMR), which was to compete directly with the Suffolk for redemption services. By 1858 the BMR had raised enough capital to begin operations. Along with this competition the Suffolk faced political pressure from Massachusetts bank commissioners to retreat from a dominant position in the market. Furthermore, fueled by country banks that had never gotten over “the indignity of what can only be characterized as a bank run orchestrated by the Suffolk Bank” (Bodenhorn, 2002, p. 148), popular sentiment turned against the Suffolk. As a result the Suffolk Bank had completely exited the market for note-clearing services by 1860.4

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4 Ironically, the BMR turned out not to be a profitable operation (Rolnick et al., 1998, p. 15).
Although it effectively ended in 1858, the Suffolk System provides 33 years of data with which to evaluate the in-concert overexpansion doctrine vis-à-vis Selgin’s (1988, 1994, 2001, 2010) “chain gang” alternative. Selgin associates the following characteristics with a clearinghouse system not prone to in-concert overexpansion: (1) interbank settlements are frequent; (2) banks do not have an incentive to hold negative balances with other member banks; (3) the lending rate on interbank overnight loans is a penalty rate; (4) banks are numerous enough that deliberate collusion amongst them is prohibitively difficult. The question we now pose: was the Suffolk System characterized by (1), (2), (3) and (4)?

Between 1825 and 1831 the Suffolk System cleared bank notes with its member banks on a weekly basis. However, by 1831 the volume of notes received had increased to such an extent that the Suffolk had moved to daily clearing operations (Calomiris and Kahn, 1996, p. 775). For the entire time period clearing operations were reasonably rapid and sophisticated. By 1825 the Suffolk Bank was receiving $2 million a month in country notes; this increased to almost $9 million by 1841, $20 million in 1851, and $30 million at its peak in 1858 (Trivoli, 1979, pp. 14 & 21). As Rolnick, Smith and Weber (1998, p. 41) point out, these numbers correspond to almost half of the total circulation in Massachusetts in 1825; all of the notes in circulation in 1841 and 1851; and almost one-and-a-half times the circulation by 1858. This volume, during the entire era, was cleared on at least a weekly basis.

Also, the Suffolk had a range of penalties for banks maintaining negative balances that were increasing in the size of the balances (Dowd, 1994). An initially depleted (or continuously low) balance first resulted in “moral suasion” whereby the offending bank would be reminded of its need to maintain deposits with the Suffolk Bank. If the situation persisted the Suffolk would either severely limit that bank’s overdraft guarantee or begin sending the offending bank’s notes
As a last resort the Suffolk could expel the offender from the system (Mullineaux, 1987, p. 891). As Calmoris and Kahn (1996, pp. 773-774) point out, membership within the Suffolk System was an important signal to the public. A bank in good standing was perceived as ready and able to meet its obligations. Expulsion from the Suffolk led to an immediate discounting of a bank’s notes (Lake, 1947, p. 190).

Lake (1947) and Rolnik et al. (1998) both suggest that the Suffolk’s overnight lending rate was a penalty rate. The *Banker’s Magazine and Statistical Register* (April, 1885; pp. 724) reports that when the deposits of a member bank were insufficient to meet its obligations, the Suffolk would loan the bank sufficient funds on a short-term basis. *Hunt’s Merchants’ Magazine and Commercial Review* (Sept., 1841; pp. 261) states that the rate charged for such overnight lending was, “perhaps seven or eight per cent per annum.” The legal usury rate of interest was six percent in the state of Massachusetts, implying that the overnight rate was indeed a penalty rate.

Lastly, there is the concern that banks may collude to refrain from redemption of one another’s notes. Given a sufficient number of banks, such collusion would be prohibitively difficult to coordinate. By 1836 over 300 banks were members of the Suffolk System (Rolnick et al., 1998, p. 14). This is surely enough banks to make collusion very difficult indeed!

### 3. Data and Empirical Models

We have established that the Suffolk provided a good approximation to the type of banking system that, according to Selgin (1988, 1994, 2001), would not be prone to in-concert

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5 As an example, Whitney (1878, p. 17) notes that The Phoenix and Pacific banks, were forced to pay 2 percent interest per month, on failure to redeem their notes outstanding, until redemption was met.
overexpansion. Now we describe the data from the Suffolk System that we use to evaluate the Selgin hypothesis. We then outline the unit root and cointegration tests that we subject this data to, as well as the error-correction models that we estimate.

Our basic hypothesis is based on the Selgin (2010) chain gang analogy. Individual banks cannot expand their note issues alone; their notes outstanding should be cointegrated with their reserves (specie stocks). Furthermore, deviations from that long-run relationship should be corrected reasonably soon. Thus banks together constitute a “chain gang” where overexpansion is only possible if all banks expand in-concert. However, even in-concert expansion is unlikely to occur because the variance (though not the mean) of net reserve losses increases. As the variance increases, so will precautionary reserve demands. Consistent with this reasoning, banks’ note issues will also be cointegrated with the aggregate (clearinghouse system-wide) stock of specie. The clearing house system will effectively police the chain gang.

3.1 Data

We employ a unique dataset which compiles both the total specie and circulation of notes within the Suffolk System. We begin with data compiled for New England banks from Weber (2008) data.\(^6\) This dataset provides the most accurate and concise series of individual bank statements available. Data from Hunt’s Merchants’ Magazine and Commercial Review and the Comptroller of the Currency’s Report of 1876 are used to fill missing or incomplete observations in the Weber (2008).\(^7\) We aggregate the individual banks data into state-level data for

\(^6\) This data are freely available at [http://research.mpls.frb.fed.us/research/economists/wewproj.html](http://research.mpls.frb.fed.us/research/economists/wewproj.html).

\(^7\) These two sources were generally used to check the validity of the aggregated data from the Weber (2008) datasets. Although only minor discrepancies were detected (i.e. differences within hundreds of dollars) subsequent changes to the aggregated data used here were made such that the most contemporary data available to the times were employed. For example, when a discrepancy was detected, if the Comptroller’s Report provided a different data point, then that information was employed. If both Hunt’s and the Comptrollers Report provided two different
Massachusetts, Connecticut, Vermont, New Hampshire, Rhode Island and Maine. This constitutes an unbalanced panel of data on specie stocks and notes outstanding from 1825 to 1858 ($T \leq 34; N = 6$).

We aggregate to the state-level because (i) we want to examine note issue in relation to reserves system-wide and (ii) panel unit root tests and some panel cointegration tests require allowance of a reasonable number of lagged observations. Although total specie and circulation for Massachusetts is available from 1825 to 1858, for the other states this is not necessarily the case. For Vermont a complete series does not begin until 1836.\(^8\) New Hampshire is missing data for both 1827 and 1828.\(^9\) Rhode Island has complete data except for one year: 1836.\(^{10}\) Connecticut only has data available beginning in 1834 and, finally, Maine has a complete set beginning in 1831, but excluding 1833. While we could attempt analysis of an unbalanced, bank-level data for the permitted years for each state, this would invariably give us many individual banks series with a very small number of yearly observations. This would severely constrain our unit root and cointegration tests.

A limitation of our data is that it is impossible to determine exactly which banks were members of the Suffolk. However, Calomiris and Kahn (1996) note that in 1825 the majority of data points, then the information from Hunt’s was employed. Further, the inclusion of this data also allowed us to fill in some of the missing annual aggregate data found in the Weber (2008) dataset for various states.

\(^8\) Although data on circulation is available as far back as 1827, subsequent specie data is no longer available. An independent search revealed that state banking reports at the time lumped specie into a category with various other assets of each bank, and thus makes it impossible to ever determine with any certainty the actual specie held.

\(^9\) This missing data are attributed to the fact that no banking commission had been established within the state at that time. As such, statewide bank audits were only made by special request of the legislature. It would appear that no such requests were ever made for those two years.

\(^{10}\) There is no clear reason as to why this is the case. However, the only data that seems to remain are two individual bank statements within the state for the year 1836. Because there is only one missing observation in the case of this state, we ultimately interpolate to fill it in. We judged the cost involved with “making up” the one observation was significantly less than the benefit to preserving all the Rhode Island specie and note observations on either side of 1836.
New England banks were already members. Furthermore, by 1836 there were almost 300 member banks – nearly all New England banks (Rolnick et al., 1998, p. 14). By 1838 there were over 300 member banks (Trivoli, 1979, p. 14). Also, since the Suffolk, as the dominant clearinghouse for the entire period, promptly returned notes from nonmember banks for redemption, it is reasonable to assume that all New England banks were affected by the Suffolk’s standards and practices.11

Table 1 presents summary statistics on our state-level and New England total specie and notes time series. (Observation numbers of the New England totals correspond to the minimum observation numbers across individual states, e.g., 22 for Connecticut.) Summary statistics for notes and specie are for thousands of dollars although natural logs are taken for both notes and specie series in the econometric analyses. Figure 1 plots the time series of the logged note and specie values for each state and figure 2 plots the state-level reserve ratios (specie divided by notes). The results of conventional Augmented Dickey-Fuller (ADF) unit root tests for each of the state-level specie and notes series are reported in Table 2. In no case can the unit root null hypothesis be rejected at the ten percent significance level or better.

Strictly speaking, Selgin’s theory implies a stable relationship between specie stocks and the product of note issues and velocity (i.e., nominal spending). In terms of data, this would amount to note redemptions. This might lead us to incorrectly reject the chain gang hypothesis if, for example, note issues persistently rose (relative to specie) during the Suffolk era while velocity persistently fell. We can explore this possibility by examining Trivoli’s (1979) estimates of Suffolk note redemptions. These estimates are only for the aggregate and only for the years 11 Legislation in Vermont and Massachusetts, passed in 1842 and 1843, respectively, created a strong set of incentives for their banks to enter the Suffolk System. Specifically, Vermont taxed any nonmember bank ten percent on its operating capital. Massachusetts prohibited any state bank from paying out the notes of other banks, thus effectively requiring that all notes be cleared through the Suffolk System. We also know from Knox (1900, p. 333) that, by 1848 there were only two banks in the Maine that did not maintain accounts with the Suffolk.
1841 to 1842 and 1844 to 1858. This constrains our cointegration tests to focusing on note issues. However, figure 3 plots (the logs of) aggregate Suffolk redemptions and note issues. The two series have very similar trends through most of the period. In 1854 the most notable divergence between the two series occurs and redemptions increase markedly to a plateau while note issues contract. This would imply a period of decreasing money demand (increasing velocity) and a contracting money supply. This episode of divergence is inconsistent with an in-concert overexpansion.

3.2 Panel Unit Root Tests

The small number of observations for each state implies that the power of the ADF tests reported in Table 2 is very low. Therefore we will report the results of panel unit root tests.

We first consider a widely-used test introduced by Levin et al. (2002). This test is straightforward; based on a conventional ADF test. The specification is,

\[ \Delta y_{it} = \alpha y_{i,t-1} + \sum_{j=1}^{p} \beta_j \Delta y_{i,t-j} + \varepsilon_{it}, \]

where \( i \) denotes the cross-section unit, \( t \) is the time period and, in this context, the \( y_{it} \)s are the (logs of) notes and specie series.\(^{12}\) The error term is denoted by \( \varepsilon_{it} \). The null hypothesis is that there is a unit root (\( \alpha = 0 \)) and the null is tested against the one-sided alternative (\( \alpha < 0 \)). Levin et al. (2002) recommend replacing \( y_{it} \) and \( \Delta y_{it} \) with measures free of deterministic components and serial correlation. This is achieved by, for each cross-section, regressing both \( y_{it} \) and \( \Delta y_{it} \) on \( p \) lags of \( \Delta y_{it} \). The resulting estimated coefficient vectors are \( \hat{\lambda}_i \) and \( \hat{\theta}_i \) respectively. Next, define the variables,\(^{12}\)

\(^{12}\) Constants and time trends are suppressed in the exposition of all tests in this section. However, they are included in the actual tests reported on in section 4.
\[ \bar{y}_{i,t-1} = y_{i,t-1} - \sum_{j=1}^{p} \hat{\lambda}_{ij} \Delta y_{i,t-j} ; \]

\[ \Delta \bar{y}_{it} = \Delta y_{it} - \sum_{j=1}^{p} \hat{\theta}_{ij} \Delta y_{i,t-j} . \]

These two measures are then standardized by dividing by the standard error from a regression of (3.1), for each cross-section (denoted by \( \hat{\sigma}_i \)), using the unmodified data on \( y_{it} \) and \( \Delta y_{it} \):

(3.2) \[ \bar{y}_{i,t-1}^* = \bar{y}_{i,t-1} / \hat{\sigma}_i ; \]

(3.3) \[ \Delta \bar{y}_{it}^* = \Delta \bar{y}_{it} / \hat{\sigma}_i . \]

Finally, the panel unit root test statistic is based on a pooled regression using the modified variables defined by (3.2) and (3.3):

(3.4) \[ \Delta \bar{y}_{it}^* = \alpha_{i,t-1}^* + \eta_{it} . \]

While Levin et al.'s (2002) test provides a solid baseline, we also utilize a test proposed by Im et al. (2003). This test is also based on a conventional ADF test but, unlike Levin et al.'s (2002) test, allows for cross-section unit-specific roots. Specify for each cross-section unit, \( i \),

(3.5) \[ \Delta y_{it} = \alpha_i y_{i,t-1} + \sum_{j=1}^{p} \beta_{ij} \Delta y_{i,t-j} + \varepsilon_{it} , \]

The null hypothesis is that there is a unit root (\( \alpha_i = 0 \) for all \( i \)). A separate OLS regression of (3.5) for each cross-section unit is run. The panel test statistic is then based on the average of \( t \)-statistics from the cross-section unit ADF tests.

While the Im et al. (2003) test allows for cross-section unit-specific roots, it suffers in the present context by not allowing for cross-section dependence (as does Levin et al. (2002) test). We are examining state banking systems linked together under the Suffolk System – a situation where dependence across cross-section units is likely. Among available alternatives, Sul (2009)
proposes a test that not only accommodates cross-section dependence but, also, exhibits high power for panels where $T > N$. With only six New England states relative to the 1825 to 1858 times period, $T > N$ is an apt characterization of our data.

Sul (2009) begins with a common factor structure,

$$ y_{it} = \lambda_i F_t + y_{it}^0 $$

Where $\lambda_i$ is a $k \times 1$ vector of factor-loading coefficients that describe the effects of the $k \times 1$ vector of common factors, $F_t$; and $y_{it}^0$ is an idiosyncratic error. The panel variable, $y_{it}$, is stationary if and only if both $F_t$ and $y_{it}^0$ are stationary. There are, therefore, two sequential tests to be applied.

The first is a feasible generalized least squares (FGLS) unit root test that incorporates a recursive mean adjustment (RMA) to control for the common factors. This test is focused on the $y_{it}^0$ component and the RMA is based on the adjustment,

$$ c_{i,t-1} = \frac{1}{t-1} \sum_{s=1}^{t-1} y_{is} $$

Then consider the autoregressive model,

$$ y_{it} - 2c_{i,t-1} = \rho_i \left( y_{i,t-1} - 2c_{i,t-1} \right) + \sum_{j=1}^{p} \phi_j \Delta y_{i,t-j} + \varepsilon_{it} $$

The null hypothesis is a unit root ($\rho_i = \rho = 1$ for all $i$) and the test has a one-tailed alternative ($\rho_i = \rho < 1$ for all $i$). The specification, (3.8) is estimated by FGLS with cross-section weights and Sul (2009, p. 124) provides critical values for the associated $t$-statistics.

If the unit root null is rejected in the FGLS-RMA model, Sul (2009) suggests proceeding to examine the common factors, $F_t$. The common factors are approximated using the cross-section average of $y_{it}$ relative to the RMA. Define,
and then consider the model,

$$\bar{y}_t - 2c_{i,t-1} = \rho_i (\bar{y}_{t-1} - 2c_{i,t-1}) + \sum_{j=1}^{p} \phi_j \Delta \bar{y}_{t-j} + \varepsilon_t.$$  

Again, the null hypothesis is a unit root ($\rho_i = \rho = 1$ for all $i$) and the test has a one-tailed alternative ($\rho_i = \rho < 1$ for all $i$).

### 3.3 Panel Cointegration Tests

We examine the possibility of cointegration, conditional on notes and specie series being non-stationary, using the test statistics described in Pedroni (1999, 2004). Perdoni’s tests are derived from the Engel and Granger (1987) cointegration test; based on the following model:

$$y_{1,it} = \varphi_i y_{2,it} + \varepsilon_{it},$$

where $y_{1,it}$ and $y_{2,it}$ are both assumed to be integrated of order one. In the absence of cointegration, the error term ($\varepsilon_{it}$) from (3.11) is non-stationary.

Consider the following model of the residuals from an estimation of (3.11):

$$\hat{\varepsilon}_{it} = \alpha_i \hat{\varepsilon}_{i,t-1} + \sum_{j=1}^{p} \beta_j \hat{\varepsilon}_{i,t-j} + \nu_{it}.$$  

The relevant null is $\alpha_i = 1$ and corresponds to no cointegration between $y_{1,it}$ and $y_{2,it}$. Pedroni derives several test statistics associated with this null. We report results based on all of them below.

### 3.4 Error-Correction Model
We argue that cointegration of note issues and reserves constitutes evidence against the in-concert overexpansion doctrine. In-concert overexpansion implies that a “chain gang” of banks, acting together, can “escape” from the clearinghouse policing mechanism. Cointegration implies that this cannot occur. A binding relationships anchors the chain gang to the specie stocks within the clearinghouse system. However, cointegration is a long-run relationship and one may object that in the long run we are all dead! In other words, there may indeed be a long-run relationship between inside money and reserves yet in-concert over-expansions are short-run episodes where note issues manage to “run away” from their golden anchor. To what extent such episodes are economically important depends on how quickly the clearinghouse system corrects deviations from the long-run equilibrium relationship.

We begin informally by examining, at the state-level, how the ratios of note issues to specie stocks evolve over time relative to the series means. Since we are concerned primarily with the in-concert overexpansion hypothesis, we also report the correlations of these deviation series across New England states.

More formally, we explore the error-correction mechanism by first estimating an OLS fixed effects regression of (3.11) above. The residuals, $\hat{e}_{\mu}$, are collected. If $y_{1,\mu}$ and $y_{2,\mu}$ are cointegrated then the residual series are stationary. The residuals are then included as regressors in an error correction model,

$$
\Delta y_{1,\mu} = y_{1,0} + \alpha_1 \Delta y_{1,\mu-1} + \ldots + \alpha_p \Delta y_{1,\mu-p} + \beta_1 \Delta y_{2,\mu-1} + \ldots + \beta_p \Delta y_{2,\mu-p} + \rho \hat{e}_{1,\mu-1} + u_{\mu}.
$$

The parameter, $\rho$, is of interest and represents the speed of correction to deviations from the long-run relationship. The model, (3.13) is estimated using OLS with fixed effects.
4. Results

We begin with an examination of state level (logs) note issues and specie. The individual ADF tests reported in Table 2 uniformly fail to reject the unit root null. Here we report results from the Im et al (2003) and Sul (2009) panel unit root tests in order to better utilize variation in data from the Suffolk System taken as a whole.

4.1 Results from Panel Unit Root Tests

Table 3 reports the results from the panel unit roots tests described in Section 3.2. All tests require specification of lag numbers \( p \). Invariably the Schwarz information criterion (SIC) is decreasing in the number of lags up through \( p = 14 \) or higher. With a total number of years of 34, and with three states having at most 25 yearly observations, such a lag structure is implausible. In lieu of a reasonable lag structure pinned down by the SIC, we report results for each test assuming both \( p = 2 \) and \( p = 4 \) years.

All tests assume both constants and linear time trends. In all series depicted in Figure 1 there is at least the suggestion of an upward trend or “drift”. This would be expected for expanding economies. The trends and/or drifts do not strike one as homogenous across the states and all tests estimate cross-section unit-specific time trends.

The baseline Levin et al. (2002) tests never reject the unit root null. Regardless of whether the variable being considered is notes or specie; and regardless of one or two lags being assumed, there is no evidence against assuming that the series are non-stationary.

Turning to the Im et al. (2003) results, where cross-section unit-specific roots are permitted, the test does not reject the presence of a unit root given either \( p = 2 \) or \( p = 4 \). The same is true for note issues given \( p = 2 \). However, when four lags are assumed, the unit root null
is rejected at the 5 percent significance level. If differences in roots across cross-section units are important and the appropriate lag length is four years then, for the case of note issues, the evidence weighs in favor of the stationarity alternative. However, if heterogeneous roots are not important, then the Levin et al (2002) non-rejections for both two and four lags is compelling.

Finally, we turn to the results of tests based on the Sul (2009) model. Cross-section dependence is, again, likely to be important for a clearinghouse system where adverse clearings check the note issues of individual banks vis-à-vis other clearinghouse members. Those same adverse clearings operate through interbank specie flows, so cross-section dependence is likely for reserves as well. Therefore we place the most confidence in these results. As described in Section 3.2 above, there are two tests involved: (i) a test of the idiosyncratic component of each series and (ii) a test of the common factors.

The first test, (i), is the FGLS-RMA test and results are labeled as such in Table 3. Concerning the idiosyncratic component a unit root is not rejected for note issues for either \( p = 2 \) or 4. Since a series is stationary if and only if both its components are stationary, this represents no evidence for the stationarity of note issues. However, whereas with the Im et al. (2003) test the uncertain result involved the stationarity of note issues, in the case of the FGLS-RMA test it is the specie series where an ambiguous result is found. For \( p = 2 \), the unit root null is rejected at the one percent significance level; for \( p = 4 \) there is no rejection at standard levels of significance.

Furthermore, for the test involving the common factors (i.e., the ADF-RMA results in Table 3), there is an unambiguous result across variables and lag assumptions: a unit root is rejected at the one percent significance level. This is irrelevant to note issues, at least to the extent that we cannot reject the unit root null for the idiosyncratic component. However, it means
that we cannot dismiss the ambiguity involved with the idiosyncratic component of specie stocks.

Determining whether or not state-level note issues and specie stocks are governed by unit root processes is important for moving ahead to a cointegration analysis. Obviously, results from such an analysis are, at best, difficult to interpret and, at worst, spurious if the series are stationary. Our view is that, given our baseline Levin et al. (2002) results that uniformly do not reject a unit root, the more important deviation from that baseline is the presence of cross-section dependence. Conditional on that, the greater uncertainty involves the presence of a unit root in the specie series. For specie stocks we have a stronger prior in favor of a unit root. These reserves are largely governed by the supplies of precious metals. Alternatively, it is the note issues that, according to the in-concert overexpansion doctrine, we might expect to “run way” from their “golden fetters”, embarking on an upward trend. The Sul (2009) test does not reject the unit root null for notes with either lag specification, so we tentatively move on the cointegration tests. However, we acknowledge that the results of those tests must be interpreted as conditional on the non-stationarity of both note issues and specie.

4.2 Results from Panel Cointegration Tests.

Table 4 reports the results of cointegration tests based on the Pedroni (1999, 2004) test statistics. (Of these, only the ADF-based test statistics require specification of lags; for those we report, again, for both $p = 2$ and $p = 4$.) For several of the test statistics, we also report “weighted” versions where, as suggested by Pedroni (2004), the weights incorporated into the test statistics are the cross-section unit-specific long-run conditional variances.
We report results from cointegration tests of (i) state-level note issues and state-level specie stocks and (ii) state-level note issues and the aggregate (Suffolk-wide) specie stock. Results from the former set of tests, (i), we interpret as relevant to whether or not banks under the Suffolk System constituted a “chain gang”. The results of the later set of tests, (ii), we interpret as speaking to whether or not the Suffolk effectively “policed” the chain gang, i.e., prevented them from overexpanding in-concert.

While there is clearly heterogeneity across the test statistics, in several cases the no-cointegration null is rejected for state-level notes and state-level specie stocks at the ten percent significance level or better. What is more striking is that for a considerable majority of test statistics (9 out of 14), the no-cointegration null is rejected at the ten percent level or better. In six of those cases, rejection is at better than the one percent level.

In both the case of state-level specie stocks and the aggregate specie stock, the ADF-based test statistics are notable for not rejecting the no-cointegration null hypothesis. Especially for the aggregate specie stock in relation to state-level note issues, the non-ADF-based test statistics are uniform in rejecting the no-cointegration null.

Overall, conditional on note issues and specie stocks being non-stationary, we interpret the Table 4 results as supportive of both banks constituting a chain gang and the Suffolk effectively policed that chain gang. In other words, adverse clearings checked individual banks from expanding their note issues relative to other Suffolk System banks; also, under the clearinghouse system, in-concert overexpansion was also checked. If we are to interpret based on the Selgin (2001, 2010) hypothesis, this “policing” was effective due to the increase in precautionary reserve demands that would have occurred during an incipient in-concert expansion under the Suffolk.
4.3 Results on Error-Correction Mechanisms

If in-concert overexpansion was checked by the Suffolk, how *quickly* was it checked? In other words, we present evidence above of a long-run relationship between note issues and specie stocks. When note issues deviated from the long-relationship, how quickly did the Suffolk correct those errors?

We begin by illustrating in Figure 4 how notes to specie ratios evolved for each state during the Suffolk era. For all states except Massachusetts and Maine a time trend is statistically significant and positive. However, only for New Hampshire and Rhode Island can the trend be considered economically significant. The Massachusetts time trend is not statistically significant and Maine’s is negative.13 Eyeballing the deviation series for Massachusetts, Vermont, Connecticut, and Maine (where the trends are not significant or economically small), “large” deviations from the mean appear to have been short-lived in most cases. Furthermore, Table 5 reports the correlations of the deviation series across New England states. The cross-correlations are typically low (i.e., less than 0.600) and never greater than 0.716. If economically important in-concert overexpansion occurred during the Suffolk era, we would expect these cross-correlations to be higher.

The analysis of the deviations in Figure 4 is admittedly more or less subjective. Table 6 reports the more formal results of estimating error-correction models of state-level note issues, (3.13), using the residuals from the cointegrating relationship, (3.11). Changes in state-level note issues are related to their own lagged values and (a) lagged changes in state-level specie stocks or (b) lagged changes in the total specie stock in the Suffolk. In line with the unit root and

13 These remarks are based on regressing the natural log of the ratio of note issues to specie stocks on a constant and time trend. Only for New Hampshire and Rhode Island are the time trend coefficients greater than 0.020 (0.070 and 0.052 respectively). Maine’s time trend is negative and significant (-0.016).
cointegration tests above, we report results for both $p = 2$ and $p = 4$ lags. We also report results for a lag structure suggested by minimizing the Schwarz criterion (SIC), i.e., $p = 1$ for the state-level specie model and $p = 3$ for total specie model.

Estimates of the error-correction parameter, $\rho$, are never significant when $p$ is equal to 2. However, in both regressions with 4 lags the $\rho$ estimate is statistically significant and negative: note issues are corrected in periods following deviations from the long-run relationship with reserves. This also is the case for both models when the lag structure is chosen according to the SIC.

In the state-level specie case, the significant point estimates are -0.164 ($p = 4$) and -0.095 ($p = 2$). They imply, respectively, a half-life of deviations of about 4 years or 7 years. On the other hand, when significant for the total specie model, the $\rho$ estimate is considerably larger in absolute value: -0.459 for $p = 4$ and -0.504 for $p = 3$. Either estimate implies a deviation half-life of just about a year (or a single observation in our time series). In relation to system-wide reserves, this would have represented error correction of considerable speed. Also, since the Suffolk’s performance is being evaluated as a clearinghouse system it is the adjustment to the system-wide reserves that seem most interesting. If we take the error-correction estimates at face value, they suggest that the Suffolk not only policed its chain gang of banks but also did so promptly; before economically important overexpansion could occur.

5. Did the Suffolk Prevent Overexpansion? Some Supporting Evidence

We interpret our results as supporting the Selgin (2001, 2010) “chain gang” hypothesis. Is such an interpretation consistent with the historical record? Here we provide some informal
supporting evidence from the Suffolk’s performance during the US banking panic of 1837.\textsuperscript{14} This informal evidence, we believe, complements and strengthens our interpretation of the more formal results reported above.

Following the panic, the Suffolk (along with many banks nationwide) suspended specie payments. Leading up to the panic, questionable expansions in lending and decreases in banks’ reserve ratios occurred. For example, by April of 1836 there were 44 banks that had overdrawn their accounts at the Suffolk (Whitney, 1878, p. 25). Certainly the Suffolk was not immune from national inflations and contagion from resulting crises. However, more telling is the performance of the Suffolk and New England banks relative to other banks in the US.

We know that in the five years following the 1837 panic 194 of the 729 then-chartered US banks failed, or just under 27 percent (Rousseau, 2002, p. 457). In New England following the crisis, between 11 (White, 1989, p. 330) and 32 (Knox, 1900, p. 362) Massachusetts banks failed. Not a single Connecticut bank failed (Trivoli (1979, p. 22); Knox (1900, p. 380)) and only one Rhode Island bank failed (Knox, 1900, p. 372). For New Hampshire we know that the total number of banks in that state fell from 28 in 1837 to 17 in 1845 (Knox, 1900, 340). Much of this decrease was presumably due to the panic. Although the number of bank failures that occurred as a direct result of the panic in Maine and Vermont is unknown, the Annual Report of the Comptroller of the Currency (1876) showed that in 1837 there were 53 banks in Maine and 19 banks in Vermont. In 1842, five years after the panic, there were 40 banks in Maine and 17 banks in Vermont. As far as the total number of banks in the Suffolk as of 1837, 300 seems to be

\textsuperscript{14} The other major panic that occurred during the Suffolk’s existence was that of 1857. However, the Bank of Mutual Redemption chartered in 1855 and by 1857 the Suffolk was being pressured by bank commissioners to withdraw from a dominant position in the market. The panic hit in September of 1857; by October of 1858 the Suffolk had issued a circular stating that “[t]he time has arrived to surrender our agency in the system as heretofore conducted” (Lake, 1947, p. 201). In none of the accounts that we read was the panic mentioned as an important determinant of the Suffolk’s decision.
a reasonable estimate (Rolnick et al. (1999, p. 14); Trivoli (1979, p. 14)). If we take 59 banks out of 300, that is less than 20 percent of Suffolk banks.\textsuperscript{15} By this measure the Suffolk fared well relative to the nation as a whole.

Also, in a comparison of Massachusetts banks to Pennsylvania banks (with no Suffolk-like clearinghouse), Smith and Weber (1999, p. 656) report that in the years following the panic, net note creation as a ratio of percent of balance sheets fell dramatically from above 0.25 to about 0.10 in 1840; “[n]et note issue by Massachusetts banks, in contrast, remained roughly constant during this period.” A reasonable interpretation is that the Suffolk allowed Massachusetts banks to keep lending while banks lacking such a clearinghouse system found themselves in a marked contraction of credit.

Finally, we can also report some anecdotal evidence on the performance of the Suffolk during and following the 1837 panic. On May 12\textsuperscript{th} of 1837 the Suffolk (along with banks in New York, Philadelphia, and elsewhere) suspended payment in specie but by May 29\textsuperscript{th} the president of the Suffolk wrote: “In regard to resuming specie payments, I can only say that we are ready to commence again today, and intend to remain in this condition till [sic] others so are ready” (Whitney, 1878, p. 28). By April of 1838, “[c]onfidence was restored – so much so that during the first week of resumption [of specie payments] no bank in Boston was called upon for over $500 in specie on any one day, and in many banks more specie was deposited than was paid out” (Whitney, 1878, p. 30). Former US comptroller of the currency, John Jay Knox (1900, p. 382), concluded in his \textit{A History of Banking in the United States} that the “Suffolk Bank system of redemption imposed a salutary check upon excessive circulation and made it impossible for the

\textsuperscript{15} Here we are counting all of the decrease in NH, ME and VT banks as failures and assuming the higher number (32) of Massachusetts bank failures. Thus, even this maximum bound would suggest that the percentage of bank failures in New England was still below the national average.
banks to sustain as large note issues as they were legally entitled to[,] was far more effectual and rational than any law could have effected.”

We surely do not do justice above to the Suffolk experience with the panic of 1837. A thorough historical analysis is far beyond the present scope (and a worthy subject of future research). Our purpose has only been to frame the results of our econometric analysis; to ensure that our interpretation of those findings is plausible given the historical record.

6. Concluding Discussion

A longstanding debate amongst monetary theorists considers the stability of a monetary system under a private note clearing regime. While there is broad consensus that adverse clearings would check any individual bank from overexpanding its note issue under such a clearinghouse system, numerous authors argue that in-concert overexpansion by banks would not be checked.

However, Selgin (2001, 2010) argues that during an incipient in-concert overexpansion, the demands for precautionary reserves would increase. This would cause banks to curb their note issues. An increase in precautionary demands occurs during an in-concert overexpansion because, while average net clearings do not change, the variance of net clearings increases. To use Selgin’s (2010) analogy, banks operating within this type of note clearing regime represent a chain gang where an overexpansion can occur only if all banks move forward together. However, the clearinghouse system effectively polices the chain gang.

Until now this theoretical debate has relied on historical narratives to support either claim. While a wealth of data has been integrated into these narratives, there has been no attempt to complement the narratives with formal econometric treatments of the data. In order to fill this void, we have proposed a test of the in-concert overexpansion hypothesis vis-à-vis the Selgin
(2001, 2010) alternative through cointegration techniques and the estimation of error correction. We have compiled a unique panel of state level data from the Suffolk Banking System which operated in New England between 1825 and 1858. Not only are this data a rich source of evidence on the working of an actual private clearinghouse banking system; the Suffolk System also closely approximated the necessary assumptions of Selgin’s theory: (1) rapid note redemption, (2) penalization of member banks for holding negative balances with one another and (3) a penalty rate charged on interbank lending.

Several tests reject the no-cointegration null hypothesis for (i) state-level note issues and state-level specie stocks and (ii) state-level note issues and the aggregate (i.e., Suffolk System-wide) specie stock. We interpret (i) as supportive of the view that banks under the Suffolk-System represented a chain gang in the sense that the principle of adverse clearings prevented individual banks from expanding their note issue in increasing proportion to both their reserves and the note issues of other banks. Additionally, (ii) suggests that the chain gang was effectively policed by the Suffolk System. In addition to banks’ note issues being cointegrated, the aggregate of reserves in the system provided an anchor to aggregate note issues.

Furthermore, while cointegrating relationships are long-run relationships, the results from estimating error-correction models suggest that deviations from long-run equilibrium were short-lived. Deviations from the long-run equilibrium of note issues and Suffolk-wide reserves may have, all else equal, been halfway corrected within a year. The fact that the error-correcting relationship is stronger to Suffolk-wide specie than state-level reserves suggests that the Suffolk was most effective as a clearinghouse system preventing in-concert overexpansion from occurring.
Our analysis is not definitive. For example, creating a panel amenable to existing unit root tests and cointegration techniques led us to focus observations at the level of New England states rather than individual banks. There are clearly additional insights to be had by further study at the level of individual banks. Also, the reported results from panel unit root and cointegration tests are by no means without ambiguity. However, we believe that we have provided an interesting approach that can be fruitfully applied to available data from other historical clearinghouse system episodes. Furthermore, we believe that we have provided a baseline for further examinations of the Suffolk System.
References:

Banker’s Magazine and Statistical Register. Various Years.


*Hunt's Merchants Magazine and Statistical Review*. Various Years.


Department, Federal Reserve Bank of Minneapolis.


## Tables

Table 1  
Summary statistics for note issues and specie stocks (thousands of $s) and reserve ratios (specie divided by notes) under the Suffolk, 1825-1858.

<table>
<thead>
<tr>
<th></th>
<th>MA</th>
<th>VT</th>
<th>NH</th>
<th>CT</th>
<th>RI</th>
<th>ME</th>
<th>Total</th>
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<td>Notes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>15,021</td>
<td>2,415</td>
<td>1,845</td>
<td>5,084</td>
<td>2,739</td>
<td>2,610</td>
<td>27,870</td>
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<tr>
<td>Std. dev.</td>
<td>6,076</td>
<td>1,128</td>
<td>881</td>
<td>2,733</td>
<td>1,244</td>
<td>1,326</td>
<td>12,049</td>
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<tr>
<td>Maximum</td>
<td>26,544</td>
<td>4,764</td>
<td>3,678</td>
<td>11,220</td>
<td>5,522</td>
<td>5,318</td>
<td>50,823</td>
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<td>Minimum</td>
<td>7,650</td>
<td>848</td>
<td>916</td>
<td>1,920</td>
<td>1,251</td>
<td>1,106</td>
<td>14,130</td>
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<tr>
<td>Specie</td>
<td></td>
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<tr>
<td>Mean</td>
<td>3,527</td>
<td>135</td>
<td>226</td>
<td>620</td>
<td>392</td>
<td>455</td>
<td>7,651</td>
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<tr>
<td>Std. dev.</td>
<td>2,070</td>
<td>46</td>
<td>148</td>
<td>294</td>
<td>126</td>
<td>301</td>
<td>3,040</td>
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<tr>
<td>Maximum</td>
<td>11,092</td>
<td>209</td>
<td>790</td>
<td>1,207</td>
<td>733</td>
<td>1,164</td>
<td>16,675</td>
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<tr>
<td>Minimum</td>
<td>1,136</td>
<td>51</td>
<td>127</td>
<td>119</td>
<td>243</td>
<td>137</td>
<td>3,701</td>
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<tr>
<td>Reserve Ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mean</td>
<td>0.249</td>
<td>0.060</td>
<td>0.133</td>
<td>0.133</td>
<td>0.160</td>
<td>0.168</td>
<td>0.290</td>
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<tr>
<td>Std. dev.</td>
<td>0.151</td>
<td>0.019</td>
<td>0.096</td>
<td>0.047</td>
<td>0.083</td>
<td>0.042</td>
<td>0.098</td>
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<tr>
<td>Maximum</td>
<td>0.791</td>
<td>0.109</td>
<td>0.475</td>
<td>0.279</td>
<td>0.373</td>
<td>0.252</td>
<td>0.628</td>
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<tr>
<td>Minimum</td>
<td>0.126</td>
<td>0.035</td>
<td>0.056</td>
<td>0.049</td>
<td>0.062</td>
<td>0.097</td>
<td>0.214</td>
</tr>
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<tbody>
<tr>
<td>First year</td>
<td>1825</td>
<td>1836</td>
<td>1829</td>
<td>1837</td>
<td>1825</td>
<td>1834</td>
<td>1837</td>
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<td>Observations</td>
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<td>23</td>
<td>30</td>
<td>22</td>
<td>34</td>
<td>25</td>
<td>22</td>
</tr>
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</table>

*Notes:* data are natural log transformation of note issues and specie stocks.
Tables (cont.)

Table 2
Unit root tests on (logs of) state-level note issues and state-level specie stocks.

<table>
<thead>
<tr>
<th>Notes</th>
<th>ADF statistic</th>
<th>Lags</th>
<th>Specie</th>
<th>ADF statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA</td>
<td>-2.864</td>
<td>0</td>
<td></td>
<td>-2.861</td>
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<tr>
<td>VT</td>
<td>-2.406</td>
<td>4</td>
<td></td>
<td>-1.959</td>
</tr>
<tr>
<td>NH</td>
<td>-2.224</td>
<td>0</td>
<td>6</td>
<td>-0.975</td>
</tr>
<tr>
<td>CT</td>
<td>-2.101</td>
<td>8</td>
<td>3</td>
<td>-2.708</td>
</tr>
<tr>
<td>RI</td>
<td>-2.775</td>
<td>0</td>
<td>3</td>
<td>-2.491</td>
</tr>
<tr>
<td>ME</td>
<td>-2.304</td>
<td>3</td>
<td>3</td>
<td>-2.722</td>
</tr>
</tbody>
</table>

Notes: all tests include trends and intercepts. Null hypothesis is a unit root(s). Rejection at the 10, 5, and 1 percent significant levels denoted by, respectively, “*”, “**”, “***”. Lag length chosen according to SIC with maximum of 8 lags considered.

Table 3
Panel unit root tests on (logs of) note issues and specie stocks.

<table>
<thead>
<tr>
<th>Test statistics</th>
<th>Notes</th>
<th>Specie</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF (Levin et al. (2002))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 lags</td>
<td>2.277</td>
<td>2.085</td>
</tr>
<tr>
<td>4 lags</td>
<td>4.758</td>
<td>3.496</td>
</tr>
<tr>
<td>ADF (Im et al. (2003))</td>
<td></td>
<td></td>
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<tr>
<td>2 lags</td>
<td>-0.962</td>
<td>0.712</td>
</tr>
<tr>
<td>4 lags</td>
<td>-1.962**</td>
<td>0.461</td>
</tr>
<tr>
<td>FGLS-RMA (Sul (2009))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 lags</td>
<td>2.200</td>
<td>-7.156***</td>
</tr>
<tr>
<td>4 lags</td>
<td>5.000</td>
<td>-1.167</td>
</tr>
<tr>
<td>ADF-RMA (Sul (2009))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 lags</td>
<td>-22.166***</td>
<td>-25.823***</td>
</tr>
<tr>
<td>4 lags</td>
<td>-16.311***</td>
<td>-13.173***</td>
</tr>
</tbody>
</table>

Notes: all tests include trends and intercepts. Null hypothesis is a unit root(s). Rejection at the 10, 5, and 1 percent significant levels denoted by, respectively, “*”, “**”, “***”.
<table>
<thead>
<tr>
<th>Test Statistics</th>
<th>State-level notes; State-level specie (Weighted)</th>
<th>State-level notes; total specie (Weighted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel $v$-stat</td>
<td>0.734</td>
<td>2.416***</td>
</tr>
<tr>
<td>Panel $\rho$-stat</td>
<td>-1.966**</td>
<td>-3.021***</td>
</tr>
<tr>
<td>Panel $t$-stat</td>
<td>-4.546***</td>
<td>-3.782***</td>
</tr>
<tr>
<td>Panel ADF-stat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 lags</td>
<td>-0.412</td>
<td>-0.129</td>
</tr>
<tr>
<td>4 lags</td>
<td>-0.558</td>
<td>-1.546*</td>
</tr>
<tr>
<td>Group $\rho$-stat</td>
<td>-0.553</td>
<td>-1.374*</td>
</tr>
<tr>
<td>Group $t$-stat</td>
<td>-3.568***</td>
<td>-3.051***</td>
</tr>
<tr>
<td>Group ADF-stat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 lags</td>
<td>0.507</td>
<td>0.409</td>
</tr>
<tr>
<td>4 lags</td>
<td>-0.281</td>
<td>-0.086</td>
</tr>
</tbody>
</table>

Notes: all tests include trends and intercepts. Null hypothesis is no cointegration. Rejection at the 10, 5, and 1 percent significant levels denoted by, respectively, “*”, “**”, “***”. “Weighted” refers to statistics weighted by member-specific long-run conditional variances.
Table 5
Correlations of state-level notes to specie ratio deviations from means

<table>
<thead>
<tr>
<th></th>
<th>MA</th>
<th>VT</th>
<th>NH</th>
<th>CT</th>
<th>RI</th>
<th>ME</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA</td>
<td>1.000</td>
<td>0.366</td>
<td>0.358</td>
<td>0.634</td>
<td>0.705</td>
<td>-0.259</td>
</tr>
<tr>
<td>VT</td>
<td>0.366</td>
<td>1.000</td>
<td>0.562</td>
<td>0.602</td>
<td>0.543</td>
<td>-0.350</td>
</tr>
<tr>
<td>NH</td>
<td>0.358</td>
<td>0.562</td>
<td>1.000</td>
<td>0.333</td>
<td>0.555</td>
<td>-0.304</td>
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<tr>
<td>CT</td>
<td>0.634</td>
<td>0.602</td>
<td>0.333</td>
<td>1.000</td>
<td>0.716</td>
<td>0.039</td>
</tr>
<tr>
<td>RI</td>
<td>0.705</td>
<td>0.543</td>
<td>0.555</td>
<td>0.716</td>
<td>1.000</td>
<td>-0.194</td>
</tr>
<tr>
<td>ME</td>
<td>-0.259</td>
<td>-0.350</td>
<td>-0.304</td>
<td>0.039</td>
<td>-0.194</td>
<td>1.000</td>
</tr>
</tbody>
</table>

*Notes:* series are computed by taking the natural log of the notes to specie ratio then subtracting the sample mean of that logged ratio.
Table 6
Estimates of error-correction mechanism for state-level (logs of) note issues

<table>
<thead>
<tr>
<th>Error-correction parameter ($\rho$)</th>
<th>State-level specie</th>
<th>Total specie</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 lags</td>
<td>-0.076</td>
<td>-0.164</td>
</tr>
<tr>
<td></td>
<td>(0.048)</td>
<td>(0.128)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.121</td>
<td>0.234</td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td>1.853</td>
<td>1.699</td>
</tr>
<tr>
<td>SIC</td>
<td>0.199</td>
<td>0.239</td>
</tr>
<tr>
<td>4 lags</td>
<td>-0.164$^{**}$</td>
<td>-0.459$^{**}$</td>
</tr>
<tr>
<td></td>
<td>(0.128)</td>
<td>(0.188)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.163</td>
<td>0.335</td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td>1.837</td>
<td>2.025</td>
</tr>
<tr>
<td>SIC</td>
<td>0.270</td>
<td>0.216</td>
</tr>
<tr>
<td>1 lag (SIC)</td>
<td>-0.095$^{**}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.149</td>
<td></td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td>1.865</td>
<td></td>
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<tr>
<td>SIC</td>
<td>0.136</td>
<td></td>
</tr>
<tr>
<td>3 lags (SIC)</td>
<td></td>
<td>-0.504$^*$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.147)</td>
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<tr>
<td>$R^2$</td>
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<tr>
<td>Durbin-Watson</td>
<td>1.818</td>
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</tr>
<tr>
<td>SIC</td>
<td>0.157</td>
<td></td>
</tr>
</tbody>
</table>

Notes: estimates come from fixed-effects estimation of (3.13). Rejection at the 10, 5, and 1 percent significance levels denoted by, respectively, ‘*’, ‘**’, ‘***’. Standard errors are in parentheses.
Figures

Massachusetts

Vermont

New Hampshire

Connecticut

Rhode Island

Maine

Note: solid lines are note issues; broken lines are specie stocks.

Fig. 1. State-level note issues and specie stocks under the Suffolk.
Figures (cont.)

Massachusetts

Vermont

New Hampshire

Connecticut

Rhode Island

Maine

Fig. 2. State-level reserve ratios (specie divided by notes) under the Suffolk.
Figures (cont.)

Note: solid line and left scale are note issues; broken line and right scale are note redemptions.

Fig. 3. Suffolk (logs of) total note issues and note redemptions.
Figures (cont.)

Note: series are computed by taking the natural log of the notes to specie ratio then subtracting the sample mean of that logged ratio.

Fig. 4. State-level deviations from the mean notes to specie ratio.