Money Demand and Seignorage Maximization before the End of the Zimbabwean Dollar

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Stephen Matteo Miller and Thandinkosi Ndhlela. "Money Demand and Seignorage Maximization before the End of the Zimbabwean Dollar." Mercatus Working Paper, Mercatus Center at George Mason University, Arlington, VA, February 2019.

Abstract

Unlike most hyperinflations, during Zimbabwe's recent hyperinflation, as in Revolutionary France, the currency ended before the regime. The empirical results here suggest that the Reserve Bank of Zimbabwe operated on the correct side of the inflation tax Laffer curve before abandoning the currency. Estimates of the seignorage-maximizing rate derive from a short-run structural vector autoregression framework using monthly parallel market exchange rate data computed from the ratio of prices from 1999 to 2008 for Old Mutual insurance company's shares, which trade in London and Harare. Dynamic semi-elasticities generated from orthogonalized impulse response functions indicate that the monthly seignorage-maximizing rate equaled 108 to 118 percent, generally exceeding monthly inflation.

JEL codes: E31, E41, E42, E58, E62, E65

Keywords: Cagan's Paradox, hyperinflation, money demand, seignorage maximization, structural vector autoregression

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Acknowledgments

We thank Kurt Schuler; David Beckworth; Scott Sumner; Warren Coats; Tyler Cowen; Tracy Miller; Pok-sang Lam; participants at the 2018 Western Economic Association meetings, especially our discussant, Ari Aisen; participants at the Dykhouse Program Workshop Series at South Dakota State University, especially Joe Santos and Zhiguang Wang; and participants at the 2016 Southern Economic Association meetings. Any remaining errors should be attributed to us.

This paper can be accessed at https://www.mercatus.org/publications/monetary-policy/money-demand-and-seignorage-maximization-end-zimbabwe-dollar.

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1. Introduction

With widespread unofficial dollarization through currency substitution and the note-printing capacity of the Reserve Bank of Zimbabwe (RBZ) on its last legs after July 1, 2008, the official dollarization in early 2009 signaled the end of Zimbabwe's hyperinflation.[1] Miller (2016) shows how such a delayed end might arise by deriving a Hotelling (1931) type of optimal-stopping-time rule to extract all remaining seignorage before abandoning the currency based on Brennan and Buchanan's (1980, 1981) notion of a Leviathan monetary authority. In that sense, the delayed end to Zimbabwe's hyperinflation may have had more in common with the Revolutionary French hyperinflation (see Sargent and Velde 1995; White 1995), as each regime outlived its currency. Typically, the opposite happens (see Paldam 1994; Bernholz 2003).

Irrespective of how Zimbabwe's hyperinflation ended, what happened before then reflects the fiscal dominance of monetary policy. Given the dwindling tax base owing to a collapsing economy and inability to increase borrowing from abroad, the regime relied on the RBZ to generate seignorage to fund quasi-fiscal activities (QFAs), essentially central bank activities that could be undertaken by the fiscal authority via expenditures, subsidies, or taxes (see Munoz 2007; McIndoe-Calder 2018). Munoz (2007) observes that

[1] For Giesecke & Devrient's press release announcing the end of its dealings with the RBZ, see Giesecke & Devrient (2008). For a summary of how the note-printing infrastructure deteriorated in the final months, see *Los Angeles Times* (2008); we thank Pok-sang Lam for bringing this reference to our attention. For the announcement of the subsequent official dollarization, see BBC (2009).

QFAs were used in efforts to buy back bonds, to subsidize credit, to absorb foreign exchange losses arising from preferential exchange rates offered to state-owned enterprises, and to restructure the financial system. Mawowa and Matongo's (2010) descriptive account suggests that the RBZ's activities were also used to keep the regime in power by paying soldiers to threaten and intimidate those wanting to buy foreign currency in the parallel market, even as the regime itself allegedly bought foreign currency in that market. In what follows, we therefore examine the optimality of seignorage extraction by the RBZ at monthly frequencies through March 2008, when the sample ends.

The standard approach to estimating the seignorage-maximizing rate comes from Cagan (1956), who suggests starting with an estimate of the semielasticity of some measure of the (natural log of) real balances with respect to some measure of inflation. The negative inverse of the semielasticity equals the seignorage-maximizing rate. Studies since Cagan (1956) tend paradoxically to find that the magnitude of the semielasticity is too small (typically less than -1), such that measured inflation exceeds the seignorage-maximizing rate. However, Mladenovic and Petrovic (2010) find that measured inflation rates almost always lay below the seignorage-maximizing rate during the Serbian experience in the early 1990s. Similarly, our short-run semielasticities suggest that the RBZ operated on the correct side of the Laffer curve through March 2008, as inflation rates were below the estimated seignorage-maximizing rate for most of our sample. Only toward the end does measured inflation approach the seignorage-maximizing rate.

To obtain our estimates, we start with Mladenovic and Petrovic's (2010) approach to estimating the demand for money. Their approach relates real balances, defined as currency in circulation, to inflation by combining Cagan's (1956) specification with Frenkel's (1976) monetary model of the exchange rate (MMER). The MMER in turn relies on purchasing power parity (PPP), which relates the exchange rate between two countries' currencies with the ratio of their price levels; in addition, Mladenovic and Petrovic (2010) use daily black-market exchange-rate data to measure inflation. Intuitively, if exchange rate determination happens in the money market as the MMER suggests, holding the other country's price level fixed, a country that experiences a currency depreciation should subsequently experience a rise in prices. Accordingly, during a hyperinflation, assuming the reference country experiences ordinary rates of inflation, the rate of exchange-rate depreciation should approximately equal the rate of domestic inflation.

With that in mind, we measure the rate of inflation by applying PPP to impute the parallel market rate implied by the share prices of the Old Mutual insurance company, whose shares trade in London and Harare, Zimbabwe. To obtain measures of real balances, we deflate the monetary base and currency in circulation by the Old Mutual (OM) rate. Our sample extends from October 1999 through March 2008, as the daily Old Mutual series was sparsely reported after the first week of April, while the RBZ stopped reporting the monetary series after June.

To estimate the semielasticity of real balances with respect to the parallel market rate of inflation, we could in principle apply the same co-integration techniques used in Mladenovic and Petrovic (2010). However, we find that our exchange-rate depreciation measure of inflation is not co-integrated with either real currency in circulation or the real monetary base. We therefore estimate the semielasticities using short-run structural vector autoregressions (SVARs) in levels after accounting for structural breaks in the intercept and trend, which generates stationary model residuals. When we exclude the structural breaks, the model generates similar estimates of the semielasticity but is unstable, and the residuals exhibit nonstationarity. The lack of co-integration could be consistent with Sims, Stock, and Watson's (1990) observation that using co-integration methods to transform models to stationary form with integrated data series may be unnecessary.

Our estimate of the monthly semielasticity of the real monetary base with respect to inflation using the SVAR equals –0.85. Following Cagan (1956), the negative inverse of that semi-elasticity equals the monthly seignorage-maximizing rate of 118 percent. Similarly, our estimate of the monthly semielasticity of real currency in circulation with respect to inflation equals –0.93, the negative inverse of which equals the monthly seignorage-maximizing rate of 108 percent. Dynamic semielasticities generated from orthogonalized impulse response functions (OIRFs) and cumulative OIRFs also suggest that the response dies out after the initial unanticipated inflation shock. We describe our data, report our estimates of the seignorage-maximizing rate, and discuss our results before concluding.

2. The Road to the Zimbabwe Dollar's End

2.1. The Old Mutual Parallel Market Rate, Monthly Real Balances, and Seignorage

For Zimbabwe, aggregate price index data quality poses a challenge for measuring inflation and estimating money demand and seignorage in the period leading up to and during the hyperinflation. According to Coomer and Gstraunthaler (2011) and Ndhlela (2011), International Monetary Fund staff observed that in a bid to quell urban unrest from rising prices, the Mugabe regime imposed price controls in a militaristic fashion. The price controls applied at times to as much as 70 percent of the goods covered by the Consumer Price Index (CPI).[2] We show later that the timing of these reported price controls coincides with the odd behavior observed for inflation and the associated real values of the monetary base and currency in circulation. Accordingly, we use an alternative measure to the CPI.

To estimate inflation, we first impute parallel market exchange rates from daily data by applying absolute PPP, or the law of one price, to Old Mutual insurance company share prices. Old Mutual shares trade in London and Harare, as well as in several other markets.[3] While the approach might seem crude, RBZ staff regularly monitored the rate, and RBZ governor Gono acknowledged that people relied on this measure as he attempted to shut down the Zimbabwe Stock Exchange to prevent people from uncovering the inflation rate by applying relative PPP to Old Mutual prices.[4]

To compute this measure of the parallel market rate, we collect stock price data for each market from July 15, 1999, following Old Mutual's demutualization, through April 8, 2008, when Datastream stopped reporting the series.[5] Keeping observations when both prices appear, we get a sample of 2,094 daily closing prices. Datastream

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[2] This behavior of the CPI contrasts with Cavallo's (2013) observation that the short-term nature of price controls in Argentina contributed only to higher CPI inflation volatility rather than to lower inflation rates.
[3] We thank Kurt Schuler for bringing this measure of the parallel market rate to our attention. See *Economist* (2007) for an early discussion of this measure of inflation, which Hanke and Kwok (2009) adopt. McIndoe-Calder (2018) uses an alternative measure for the part of her sample that coincides with the one used here that is based on black market rates reported by the local Zimbabwean firm Techfin.
[4] See Hanke and Kwok (2009, 361–62) for a quote from Governor Gono on November 20, 2008, as the RBZ statements have since been removed. Similarly, in Revolutionary France, White (1995), Sargent and Velde (1995), and Bernholz (2003) each report that government officials blamed speculators on the hyperinflation.
[5] We thank Petra Sjostedt at Old Mutual for providing us with the post-April data and for information about the recording of the Harare share prices. We do not include the later observations, as the data series has large gaps from May through September 2008 and from November 2008 through February 2009.

reports the Harare price in Zimbabwe dollars (Z$) and the London price in pence, which we convert to British pounds (£) by dividing by 100. We also collect daily pound/US dollar (£/US$) rates along with the share price series to impute the Old Mutual parallel market rate (OM rate) as

$$e_{M,t} = 1{,}000 \times \frac{Z\$(t)}{US\$(t)} = 1{,}000 \times \frac{Old\ Mutual\ Harare\ (Z\$(t))}{\frac{Old\ Mutual\ London\ (in\ pence\ of\ \pounds(t))}{100}} \times \frac{\pounds(t)}{US\$(t)}. \qquad (1)$$

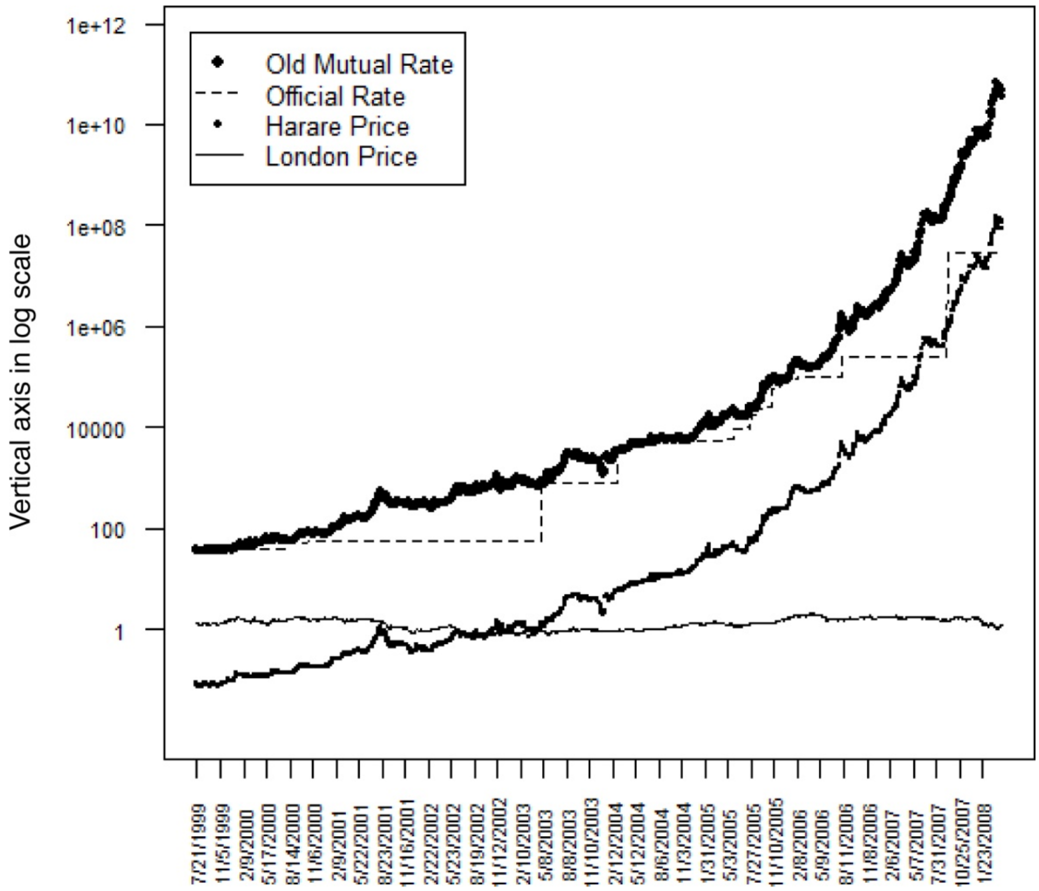
We convert the implied Z$/£ rate into a Z$/US$ rate, since the US dollar is more relevant in Zimbabwe because the RBZ began pegging to it in 1999. We multiply our OM rate by 1,000 to keep it roughly in line with the official rate at the beginning of the sample, defined as the midpoint between the bid-ask quotes that we collect from OANDA.[6] We also multiply the official rate again by 1,000 from August 4, 2006, until the end of the sample, since the currency was redenominated by eliminating three zeros.[7]

Figure 1 depicts the daily closing Harare and London prices, the imputed OM rate based on the calculation in equation (1), and the daily official rates in log scale. We get similar results if we calculate a Z$/£ rate by leaving out the £/US$ rate, but we do not report the results to simplify the graph. The trend in the OM rate arises from the upward trend in the Harare prices reflecting the inflationary environment, while London prices exhibit no apparent trend. Moreover, the parallel market rate exhibits characteristics of a floating exchange rate, while the official rate exhibits behavior that reflects extensive efforts by the RBZ to control the exchange rate market (see Munoz 2007; Coomer and

[6] We use data from http://www.oanda.com/currency/historical-rates, but these data are no longer available.
[7] While the official date of the redenomination was July 31, OANDA recorded the change on August 4.

Gstraunthaler 2011; and Ndhlela 2011). Much like the graphs depicted in Reinhart and Rogoff (2004), the official rate appears to adjust systematically to the parallel rate.

Figure 1. Daily Z$/US$ OM and Official Daily Midpoint Exchange Rates, as well as Harare and London Old Mutual Closing Prices, July 15, 1999–April 8, 2008



Given that our monetary aggregates get reported at the end of each month, to compute monthly rates of inflation from the daily OM rate, we compute the natural log of the last observed daily rate in the current month, $e_{M,t}$, relative to that in the previous month. For low rates of inflation in the United States, $\pi_{US,t}$, relative PPP suggests we can estimate the OM rate of inflation as

$$\pi_{OM,t} = \ln e_{M,t}/e_{M,t-1} + \pi_{US,t} \approx \ln e_{M,t}/e_{M,t-1}. \quad (2)$$

To show why the OM rate may serve as a better measure of inflation than the CPI, we also generate monthly estimates of inflation based on the CPI. The International Financial Statistics (IFS) reported year-on-year inflation after our sample ends but stopped reporting the CPI series in September 2007. However, because the IFS did report year-on-year inflation, we can use it to impute CPI levels from October 2007 through March 2008 by rearranging the formula for year-on-year inflation as follows:

$$CPI_t = CPI_{t-12}\left(1 + \frac{\pi_{CPI,t}^{yoy}}{100}\right).$$

Appendix A1 shows tests of stationarity, which indicate that the series for inflation as well as both measures of real balances are integrated of order 1. However, using the Bai and Perron (1998, 2003) method, we also find three structural breaks in each real-balances series and one structural break in the OM rate of inflation series. The break dates and the 99 percent confidence are reported in table 1. While our sample begins in October 1999, the hyperinflation is primarily associated with RBZ governor Gideon Gono's tenure, which began in December 2003 (see Mawowa and Matongo 2010; Coomer and Gstraunthaler 2011). The breakpoint in the real monetary base in November 2003 and the breakpoint in real currency in September 2003 would be consistent with RBZ activities changing with the arrival of Governor Gono. The OM rate inflation series exhibits a structural break in April 2006, several months before the currency was devalued.

Table 1. Bai-Perron Structural Breakpoint Break Dates

	Lower bound of 99 percent confidence interval	Break date	Upper bound of 99 percent confidence interval
Monetary base	June 2002	August 2002	September 2002
	May 2003	November 2003	January 2004
	January 2005	August 2005	November 2005
Currency	September 2001	October 2001	January 2002
	July 2003	September 2003	November 2003
	June 2005	August 2005	April 2006
Inflation	August 2004	April 2006	June 2006

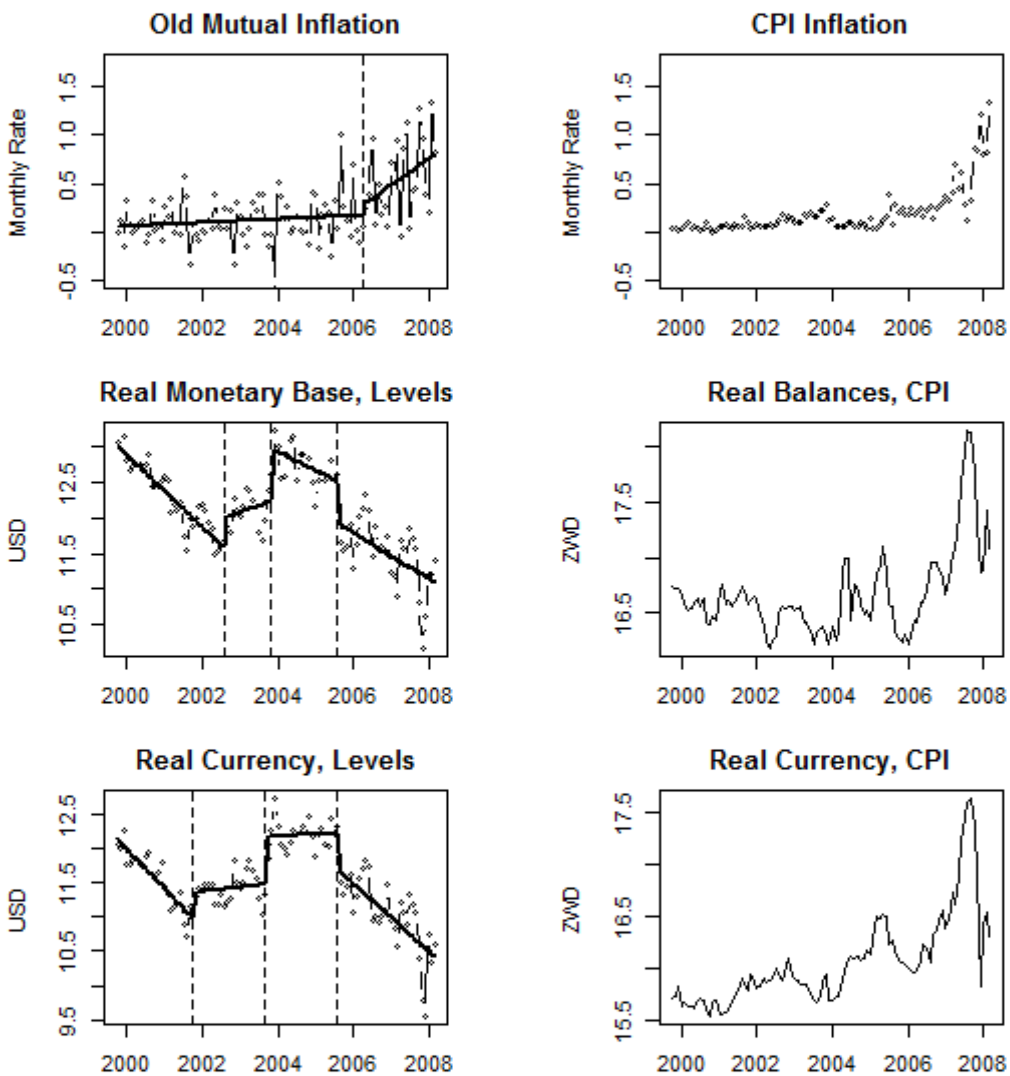
Note: The models estimated for each variable include an intercept and trend, and they allow for breakpoints in both the intercept and trend. For the estimation, the raw data monetary base and currency-in-circulation series, expressed in millions of Z$, are divided by the OM rate.

Figure 2 depicts from October 1999 through March 2008 the following: (1) the OM rate and CPI inflation in the top row, (2) the real monetary base measured relative to the OM rate (and therefore expressed in US$) and the CPI in the middle row, and (3) real currency in circulation measured relative to the OM rate (and therefore expressed in US$) and the CPI in the bottom row. The units for the nominal monetary aggregates are millions of Z$. Figures in the left column each depict the fitted values of a linear model with a trend that includes interaction terms with structural breaks determined using the Bai and Perron (1998, 2003) method. The trends reveal the decline in real balances especially after Gideon Gono became RBZ governor.

To understand the decline in real balances, the RBZ attempted to alleviate the burden of an increasingly overvalued exchange rate on exporters by providing producer subsidies and credit to the private sector that was funded by the Reserve Bank at highly concessional rates. The first of these, the Productive Sector Facility (PSF), was launched in February 2004 as an alternative to devaluing the currency. Under the PSF, companies borrowed at interest rates of 30 percent, later adjusted to 50 percent in July

2004. It was the expansion of these QFAs that spurred sharp increases in reserve money as well as broad money in 2004–2005, feeding into the acute inflationary spiral (IMF 2005). In trying to resolve the problem of crippling banknote shortages that followed the hyperinflation, the RBZ issued a monetary policy statement on July 31, 2006, in which the Z$ was revalued by removing three zeros from the nominal exchange rate. This could explain the structural break in inflation in 2006.

Figure 2. Inflation, Real Money Balances, and Real Currency Levels, October 1999–March 2008



For figures in the right column, the real monetary base and currency in circulation measured relative to CPI have a primarily flat profile that likely reflects the effects of the price controls mentioned earlier. These findings would be inconsistent with the local currency losing value, and they lend further support for the use of the OM rate of inflation.

2.2. Seignorage

To motivate the discussion of the RBZ's seignorage revenue-generating activities and how they relate to the seignorage-maximizing rate, we start by defining the real value of seignorage as the sum of the inflation tax on real balances currently held and changes in real balances:

$$\frac{M_{t+1}-M_t}{P_{t+1}} = \frac{M_t}{P_t}\frac{P_{t+1}-P_t}{P_t} + \frac{M_{t+1}}{P_{t+1}} - \frac{M_t}{P_t}, \tag{3}$$

where M_t is some measure of the money supply, such as currency in circulation, and P_t is some measure of the deflator. In the steady state, defined as a case where the public does not change its holdings of currency, the second term on the right-hand side of equation (3) equals zero, in which case real seignorage equals real inflation tax revenues. Such a situation might be expected to arise if additional real balances do not get absorbed by the public and actual inflation equals the value expected by the public.

Cagan (1956) assumed that during a hyperinflation, the real and monetary sides of the economy could be analyzed separately, and proposed a simple model of money demand that relates the natural log of real balances to expected inflation:

$$ln(m_t) = \gamma - \alpha\pi_t^e, \tag{4}$$

where $m_t = M_t/P_t$ measures real balances and $\pi_t^e = (P_{t+1}^e - P_t)/P_t$ measures expected inflation. Assuming expected inflation equals actual inflation, then given the inflation tax function, $\pi_t m_t$, substituting in the money demand function and taking natural logs yields

$$ln(\pi_t m_t) = ln(\pi_t) + \gamma - \alpha\pi_t. \tag{5}$$

This, after maximizing with respect to π_t yields the seignorage-maximizing rate $-1/\alpha$. For inflation rates below the seignorage-maximizing rate, the central bank would be operating on the correct side of the inflation tax Laffer curve.

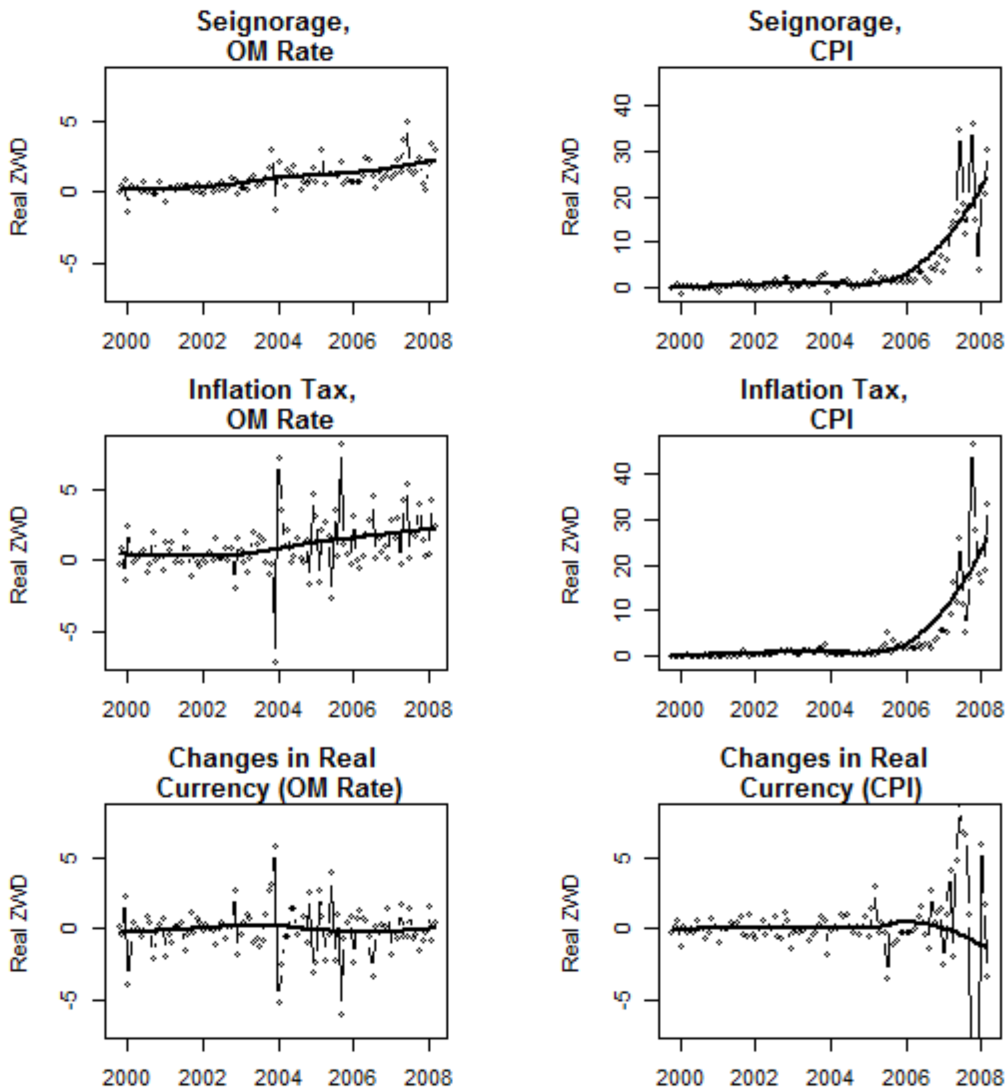
To understand why the regime in Zimbabwe may have turned to seignorage, Cukierman, Edwards, and Tabellini (1992) find that countries with more polarized and unstable political systems rely more on seignorage because of the inefficiency of the tax system. Heymann and Leijonhufvud (1995) note that hyperinflations lead to missing markets; any missing markets could further hamper the regime’s ability to collect other taxes. Selgin and White (1999) suggest that seignorage-enhancing institutions emerge sooner in countries with fiscal crisis. Deck, McCabe, and Porter (2006) find experimental evidence suggesting that hyperinflations lead to a collapse of trade, which could also hamper the regime’s ability to collect other taxes. Moreover, Aisen and Veiga (2008), using panel data, identify social polarization and political instability within an authoritarian regime, high debt, lack of central bank independence, and lack of freedom or lack of access to international trade and finance as conditions ripe for a central bank to increase its seignorage-generating activities. Broadly speaking, the conditions identified in these studies describe the situation in Zimbabwe.

In particular, the RBZ increasingly relied on the parallel market to raise foreign currency to pay for essential exports such as fuel and electricity. At the same time, the Z$ was being printed at an unprecedented rate to finance its QFAs and to appease the state patronage systems that included the army and the national youth service program (see IMF 2005 and Mawowa and Matongo 2010). Moreover, McIndoe-Calder (2018) shows that tax revenues had been declining leading up to the hyperinflation.

Figure 3 depicts (1) real OM rate, (2) CPI seignorage and inflation tax revenues, and (3) the difference between the two series, measuring changes in real currency in circulation, which lends further support for using the OM rate as a measure of inflation. The figure illustrates the breakdown in January 2000 values of real seignorage coming from the inflation tax and changes in real currency holdings for both the OM rate and the CPI from October 1999 through March 2008. The top row depicts seignorage. The middle row depicts the inflation tax. The last row depicts the changes in real currency in circulation. Each panel also depicts a quadratic Loess fit of the series against a constant and trend.[8] The effects of the price controls mentioned earlier on the CPI likely explain the extent to which the CPI-based seignorage and inflation tax revenues greatly exceed the OM rate estimates. Finally, changes in currency in circulation may be close to a steady-state condition as the series exhibits stationarity. Given doubts about the quality of CPI inflation data, in our remaining analysis we focus exclusively on results based on the OM rate.

[8] We use the quadratic Loess fit to emphasize the differences between the two inflation series, although differences also exist with the linear Loess fit, which generates nearly identical values as a Hodrick-Prescott filter with the smoothing parameter set to 129,600, given the monthly frequency of the data.

Figure 3. Real Seignorage, Inflation Tax Revenues, and Changes in Real Currency, October 1999 through March 2008



To understand how RBZ staff used those seignorage revenues, table 2 reports the yearly median relative to the monetary base of the following: (1) currency in circulation, (2) domestic credit to the central government, (3) domestic credit to the private sector, (4) domestic credit to depository banks from 1999 through 2008, (5) net foreign assets, and (6) "other items net."

Table 2. Currency in Circulation and RBZ Assets as a Fraction of the Monetary Base, 1999–2008

	1999, Q4	2000	2001	2002	2003	2004	2005	2006	2007	2008, Q1
Currency in circulation	0.37	0.41	0.42	0.61	0.56	0.55	0.73	0.64	0.64	0.46
Domestic credit (to government)	3.25	4.07	0.96	0.78	1.15	1.02	0.90	0.40	0.05	0.30
Domestic credit (to private sector)	0.07	0.09	0.06	0.04	0.01	0.01	0.04	0.22	0.52	0.44
Domestic credit (to depository institutions)	0.11	0.11	0.27	0.39	0.25	0.87	0.58	0.12	0.01	0.03
Net foreign assets	−0.61	−0.52	−0.31	−0.26	−0.64	−0.75	−0.79	−0.39	−0.06	−0.01
"Other items net"/nonearning assets	0.48	0.22	0.09	0.12	0.19	0.16	0.34	0.74	0.54	0.15

The table shows that currency, which was used to fund the patronage system at work in Zimbabwe, made up more than half of the monetary base in the period 2002–2007.[9] Also, until 2007, the bulk of domestic credit went to the central government, but a substantial amount was allocated to the private sector from 2006 to 2008. In addition, the shares of domestic credit extended to the banking system were nontrivial from 2001 to 2006, especially in 2004 and 2005, which likely reflects the bank insolvency crisis that occurred. Among the measures undertaken, the RBZ in December 2003 created the Troubled Bank Fund with loans extended for periods up to three months. The fund was supposed to be terminated by March 31, 2004, but was extended beyond that date since

[9] See *Los Angeles Times* (2008), which highlights the payments to soldiers who supported the regime. Mawowa and Matongo (2010) corroborate this by highlighting that printed notes went to support the regime's patronage system, even as officials claimed to be using the currency to purchase fuel and electricity.

banks were unable to pay down their debts.[10] Finally, table 2 shows that net foreign assets were negative throughout the sample.

Concerning "other items net," Munoz (2007) refers to this category as "nonearning assets" and indicates that they largely reflect QFAs. By 2006, Munoz (2007) estimates that losses from QFAs equaled about 75 percent of GDP, and as table 2 suggests, those losses made up a significant portion of the monetary base in 2006 and 2007.

3. Estimating the Seignorage-Maximizing Rate in Zimbabwe

Mladenovic and Petrovic (2010) use co-integration methods to estimate the Cagan-type money demand function based on the MMER. In appendix A2, we report our tests for co-integration between the inflation and real monetary base or currency in circulation, assuming seven lags, as suggested by the Akaike Information Criterion, which is recommended for monthly data. Given the lack of co-integration between our measure of inflation and either the real monetary base or currency in circulation, we estimate the semielasticity for each measure of real balances with respect to OM rate inflation using a just identified, bivariate, short-run SVAR:

$$\begin{pmatrix} 1 & 0 \\ -\alpha & 1 \end{pmatrix} \begin{pmatrix} \pi_t \\ ln(m_t) \end{pmatrix} = \begin{pmatrix} \beta_{1,0} \\ \beta_{2,0} \end{pmatrix} + \begin{pmatrix} \beta_{1,1} & \beta_{1,2} \\ \beta_{2,1} & \beta_{2,2} \end{pmatrix} \begin{pmatrix} \pi_{t-1} \\ ln(m_{t-1}) \end{pmatrix} + \cdots$$

$$+ \begin{pmatrix} \beta_{1,2p-1} & \beta_{1,2p} \\ \beta_{2,2p-1} & \beta_{2,2p} \end{pmatrix} \begin{pmatrix} \pi_{t-p} \\ ln(m_{t-p}) \end{pmatrix} + \begin{pmatrix} \varepsilon_{\pi,t} \\ \varepsilon_{m,t} \end{pmatrix}, \tag{6}$$

where m_t equals either the real monetary base or currency in circulation, deflated by the end-of-month OM rate; π_t is the OM rate of inflation; α is the semielasticity of the

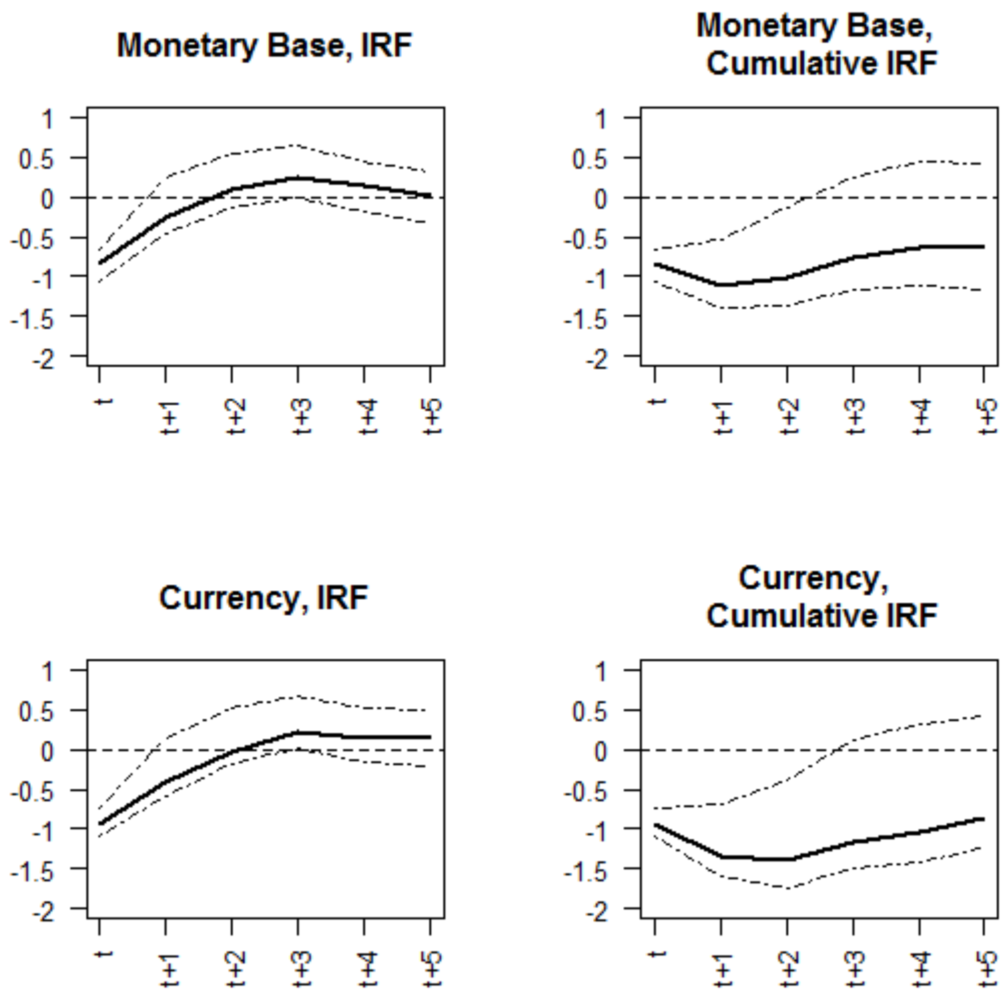
[10] See Munoz (2007, 8).

real monetary base or currency in circulation with respect to the OM rate of inflation; and $\varepsilon_{\pi,t}$ and $\varepsilon_{m,t}$ are the errors for the OM rate of inflation and the monetary base or currency, respectively. In appendix A3 we report the results of misspecification tests as well as the roots of the characteristic polynomial, which all lie below one, suggesting that the models are stable, which supports the general validity of our approach.

Table A4 reports the SVAR model coefficient estimates. The contemporaneous semielasticity of the monetary base with respect to the OM rate of inflation equals −0.85, the negative inverse of which implies a monthly seignorage-maximizing rate of 118 percent based on Cagan's (1956) suggested measure. Similarly, the contemporaneous semielasticity of real currency with respect to the OM rate of inflation equals −0.93, the negative inverse of which implies a monthly seignorage-maximizing rate of 108 percent.

We focus on estimates of the contemporaneous semielasticity of the real monetary base or currency in circulation relative to inflation, given that we find that the effects on real balances of unanticipated inflation shocks generated through impulse response functions die out quickly. To show this, figure 4 depicts the semielasticities over time based on OIRFs and cumulative OIRFs, as well as the 99 percent confidence interval generated from 1,000-run bootstrapped standard errors. The figure shows that for the monetary base and currency in circulation, the effects beyond the contemporaneous effects of the unanticipated inflation shocks die out quickly.

Figure 4. Orthogonalized Impulse Response Functions and Cumulative Orthogonalized Impulse Response Functions



Note: For the estimation, the raw data monetary base and currency-in-circulation series, expressed in millions of Z$, are divided by the OM rate.

The short-lived effects of unanticipated inflation shocks seem to support the MMER's prediction of the transmission of monetary shocks to the exchange rate before prices. They also seem to be consistent with the transmission described by Mawowa and

Matongo (2010, 329), who write the following concerning alleged RBZ activities in the parallel market:

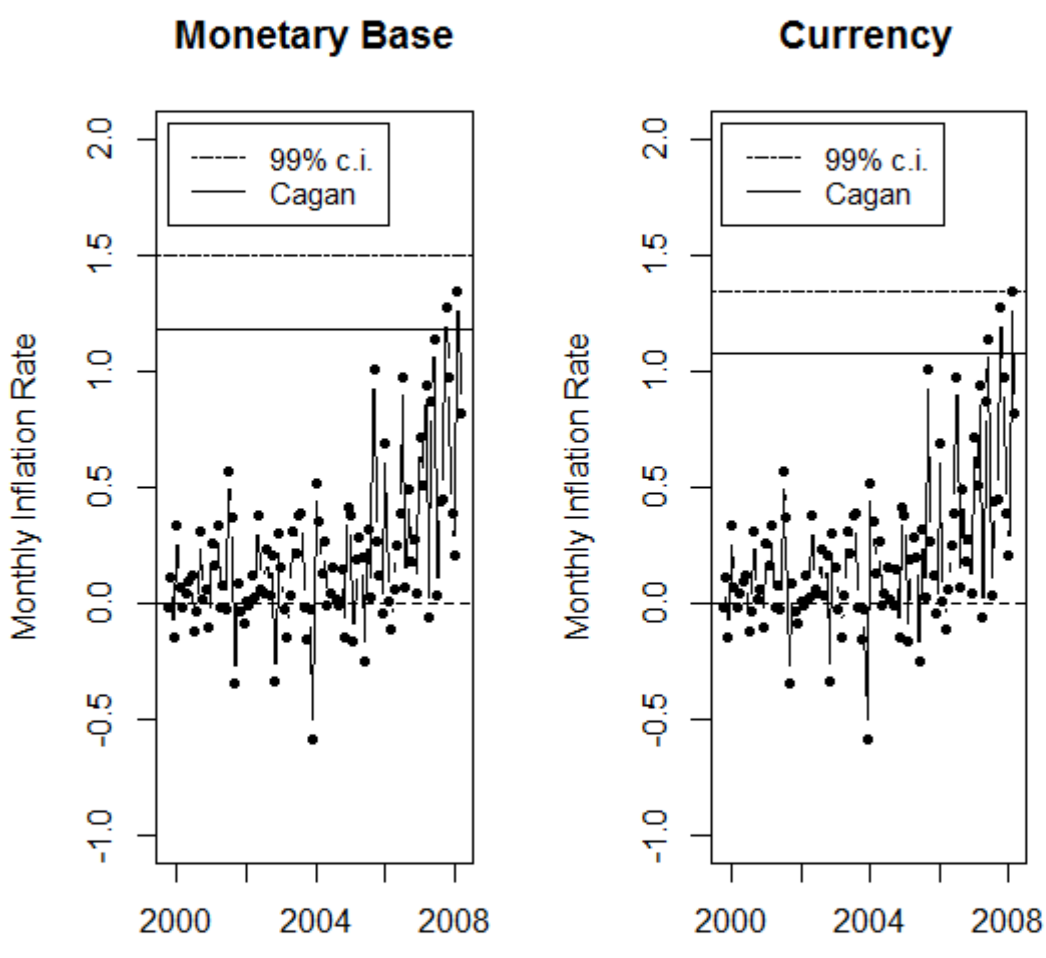
> Informants narrated a story about a team of three occasional dealers who would arrive at the busy Chicken Inn outlet on the corner of Fort Street and 11th Avenue in Bulawayo, each driving a posh sedan car (usually a Mercedes Benz, a Toyota Camry or a BMW). The boot of one of these cars, usually the Mercedes Benz, would be filled with brand new banknotes in sealed plastic packets of the Reserve Bank of Zimbabwe (RBZ). Brisk trading in a targeted currency would begin, with an instant and dramatic fall in the exchange rate of the local currency against the targeted currency on the "World Bank". At one time, it is alleged, the rate tumbled by over 200 per cent within minutes of the arrival of this trio. . . .
>
> Such behaviour by the occasional dealers raised strong suspicion in the "World Bank" and other such markets that they were proxies of the RBZ. This suspicion was heightened by the observation that the occasional dealer never sold foreign currency but only ever bought it. Signs of the RBZ's involvement are not without resonance elsewhere. In 2008, a commission set up by a regional court in the east of Zimbabwe to investigate smuggling of diamonds in the area was shocked to find a vehicle loaded with sealed brand new Zimbabwe dollars, amounting to trillions. According to one member of the commission, the consistent serial numbers on the bank notes, and the large volume at a time when banks were restricted from issuing large amounts of cash, suggested a link to the Reserve Bank of Zimbabwe.

4. Discussion of Empirical Results

4.1. Inflation and the Seignorage-Maximizing Rate

Given that figure 3 showed that seignorage and the inflation tax were rising toward the end of the sample, with our estimates of the seignorage-maximizing rate we can compare measured inflation with the seignorage-maximizing rate. Figure 5 depicts the OM rate of inflation against the seignorage-maximizing rates for the real monetary base in the panel on the left, and currency in circulation in the panel on the right. The figure also depicts the upper bound of the 99 percent confidence interval for the Cagan money demand estimates generated from the bootstrapped standard errors for time period t depicted in figure 4. For real balances, the seignorage-maximizing rate equals 118 percent, while the estimate implied by the upper bound of the 99 percent confidence interval equals 150 percent. For real currency in circulation, the seignorage-maximizing rate equals 108 percent, while the estimate implied by the upper bound of the 99 percent confidence interval equals 134 percent. Toward the end of the sample, the OM rate of inflation exceeds the seignorage-maximizing rate for the monetary base two times and never exceeds the upper bound of the 99 percent confidence interval.

Figure 5. Monthly Inflation Depicted against the Seignorage-Maximizing Rates for the Monetary Base and Currency in Circulation, October 1999–March 2008



For currency in circulation, the OM rate of inflation exceeds the seignorage-maximizing rate three times and exceeds the upper bound of the 99 percent confidence interval one time.

4.2. Comparing with Other Estimates of the Seignorage-Maximizing Rate

Like Mladenovic and Petrovic (2010), our estimates of the Cagan money demand seignorage-maximizing rates for real balances relative to parallel market exchange rates exceed the results reported by Cagan (1956) based on real balances relative to price index inflation. Cagan estimates the seignorage-maximizing rates for seven classic European hyperinflations ranging from 11.5 to 43.5 percent per month and finds that price index inflation far exceeds those rates. Barro (1972), also using monthly price index inflation data, builds on Cagan's framework and relates seignorage maximization to currency substitutes. While the framework generates higher seignorage-maximizing rates than Cagan's estimates for five countries, ranging from 84 to 154 percent, he still finds that in Germany and Hungary after World War II, inflation far exceeded the seignorage-maximizing rate. The literature since then generally confirms Cagan's Paradox.[11]

Our estimates also exceed all values reported in Mladenovic and Petrovic's (2010) table 7. The values they report based on price data for Austria, Germany, Hungary, and Poland after World War I come from Taylor (1991), while those for Greece

[11] That applies to studies taking a rational expectations approach (e.g., Sargent and Wallace 1973; Sargent 1977; Salemi and Sargent 1979; and Salemi 1979). That also applies to the more recent studies that apply co-integration methods since Taylor (1991), who finds that real balances and inflation are each integrated of order one, or I(1), while a linear combination of real balances and inflation should be integrated of order zero, or I(0), suggesting co-integration (see Granger 1981; Engle and Granger 1987). This recent literature includes Engsted (1994, 1996), Petrovic and Vujosevic (1996), and Petrovic and Mladenovic (2000).

and Russia come from Engsted (1994). The values based on monthly black-market exchange rate imputed inflation rates for Serbia come from Petrovic and Mladenovic (2000), while those for monthly official exchange-market imputed inflation rates in Germany come from Engsted (1996).

However, even our monthly seignorage-maximizing rates lie well below Mladenovic and Petrovic's (2010) estimate of 559 percent per month for Serbia during the extreme portion of the hyperinflation. To put these differences in perspective, aside from the differences in the ways that the hyperinflations in Zimbabwe and Yugoslavia ended, recall that our sample excludes the last 10 months before the end of the Zimbabwe dollar, while their sample includes the last seven months of the Yugoslav hyperinflation. Overall, as in Mladenovic and Petrovic (2010), these findings suggest that the Zimbabwean experience may not be consistent with Cagan's Paradox, while at the same time being consistent with the fiscal dominance of monetary policy, given the RBZ's aim of supporting the regime.

Finally, McIndoe-Calder (2018) also applies an autoregressive distributed lag (ARDL) approach to estimate long-run money demand for Zimbabwe from 1980 to 2008 and finds evidence of Cagan's Paradox too.[12] While our conclusions may differ, our findings could be complementary in that McIndoe-Calder (2018) examines the long-run conditions that lead to the increased use of seignorage and the hyperinflation, while our study focuses more on the period leading up to the end of the hyperinflation

[12] As an inflation series, McIndoe-Calder (2018) splices together three series: the black or parallel market rates from the World Currency Yearbook from 1980 to 1993, a farm compensation series from 1993 to 1999, and the Techfin series from 1999 to 2009. The estimates are based on single-equation models applied to data from January 1980 through January 2008. The baseline ARDL estimates of the monthly seigniorage-maximizing rate equal 27 percent, and inflation was below the seigniorage-maximizing rate for most of the sample, until the period after the devaluation in August 2006 through the end of the sample.

and the currency. Given that the evidence here suggests that the RBZ could have operated on the correct side of the inflation tax Laffer curve, it is worth revisiting how the hyperinflation ended.

4.3. The End of the Zimbabwean Hyperinflation

Hyperinflations typically end when the regime in power loses power, and subsequent currency reform follows (see Paldam 1994; Bernholz 2003). However, consistent with Thiers's law, which arises when the "good" drives out the "bad" money (see Bernholz 2003), in Zimbabwe the regime remained in power long after the hyperinflation.

The end of the seignorage machine arose partly from the German government's pressure on Giesecke & Devrient, the German paper supplier, to cease operations in Zimbabwe on July 1, 2008, three months after the end of our sample, in response to public outcry in Germany once dealings became widely known (Nordland 2008). The decay of the printing presses and the inability of Fidelity Printers & Refiners to continue printing currency for the RBZ also played a role. The hyperinflation lasted nearly seven more months until Zimbabwe's minister of finance legalized the use of foreign currency as the medium of exchange on January 29, 2009.

While the delay might seem puzzling, the RBZ likely had a remaining stock of paper (Berger and Thornycroft 2008). Miller (2016) shows how a monetary authority that has a fixed stock of remaining paper might end the currency with delay rather than immediately. Such behavior would be consistent with that of a seignorage-maximizing monopoly monetary authority, which extracts all seignorage using a Hotelling (1931) type of optimal stopping rule that equates average and marginal profits. In such a scenario, the delay rises when the remaining seignorage is greater or the rate of seignorage extraction is slower.

4.4. Comparing Zimbabwean and Revolutionary French Experiences

While the Zimbabwean experience differs from the typical hyperinflation, it has features similar to the Revolutionary French experience. For instance, both regimes originated from popular movements. Mugabe's regime, the Zimbabwe African National Union Patriotic Front (ZANU PF), began as a popular independence movement from British colonial rule in 1963. Likewise, the Estates General benefited from popular support to address long-standing problems in French public finance that ultimately resulted in the revolution to eradicate the monarchy in France (see White 1995). Between September 1792 and September 1793, the abolition of the French monarchy led to the creation of the French Republic through the Convention Nationale.

Once established, new regimes, as in Zimbabwe and Revolutionary France, typically create a new currency, and as Selgin and White (1999) suggest, seignorage-enhancing institutions emerge sooner in countries with fiscal crisis. The viability of the new currency may be in question since the new regime may have limited alternative resources from which to extract taxes, which puts the currency on a weak foundation.

The Zimbabwe dollar was created as an unbacked fiat currency to replace the Rhodesian dollar in the post–Bretton Woods era. The *assignat* in Revolutionary France was born out of the Estates General's failed attempt to establish an asset-backed currency, as was common in the 18th century (see White 1995). The plan to resolve long-standing problems in public finance involved expropriating clergy-owned lands and using the future proceeds of the land sales to back the *assignat* as a way to establish credibility.

De facto, though, the *assignat* was largely unbacked and eventually led to the creation of the short-lived replacement currency, the *mandat*, which was unbacked (see Sargent and Velde 1995; White 1995; and Bernholz 2003).

The currencies in Zimbabwe and Revolutionary France bore the seeds of their own destruction, as the regimes increasingly relied on them to finance their expenditures after other revenue sources diminished. Just as the Zimbabwean regime's use of the unbacked Zimbabwe dollar for public finance explains the hyperinflation, this seems true in Revolutionary France. The *assignat* failed to resolve French public finances, as land sales did not provide sufficient revenues to retire the debt, which began rising again with the French war against Austria in April 1792.

The Convention Nationale attempted to impose price controls through Robespierre's Terror in a militaristic fashion, as we observed in Zimbabwe, yet prices continued to rise (see Sargent and Velde 1995; White 1995). As in Zimbabwe, price controls resulted in food shortages and were repealed by 1794 (see White 1995). Even though Robespierre's Reign of Terror came to an end, the French Revolution continued, and with that came the hyperinflation in France.

Sargent and Velde (1995) observe that to manage the unrest, an early response to the hyperinflation in France was for officials to blame financial markets for the hyperinflation. Accordingly, they briefly shut down the markets to trade *assignats*, although the government did later reopen the market to learn about the *assignats*' value. Likewise, in Zimbabwe, Gideon Gono frequently criticized speculators for creating the hyperinflation, and he attempted to shut down the Zimbabwe Stock Exchange to restrict attempts by people to uncover the inflation rate by applying the law of one price to Old Mutual prices.[13]

White (1995) notes that the end of the *assignat* came about with the Convention Nationale's announcement on December 23–24, 1795, that it would limit the number of *assignat* at 40 billion to control inflation. Yet as in Zimbabwe, we see a delay in the currency's end as the regime extracted the remaining seignorage through February 19, 1796. The *mandat* was introduced to replace the *assignat* soon after, but specie ultimately returned to circulation on February 4, 1797 (see Sargent and Velde 1995; Bernholz 2003). The decision to abandon the currency coincided with a search for new revenue sources.

Following post-hyperinflation tax reforms in Zimbabwe, the Zimbabwe Revenue Authority reported that its revenue collection exceeded its targets.[14] Kramarenko et al. (2010) report in appendix table IV-1 that reforms included tax harmonization measures, value-added-tax reforms, and reductions in tax and tariff rates. These efforts resemble what happened in Revolutionary France: White (1995) observes that after the hyperinflation, the regime found new revenues in gold collected from newly acquired territories in Italy and Switzerland and subsequently introduced new taxes. Thus, the Convention Nationale and the Zimbabwean regime both extracted all seignorage revenue, abandoned their currency, and then looked to extract revenue elsewhere. While these experiences may differ in how they ended vis-à-vis the classic

[13] While Gideon Gono's statement on November 20, 2008, subsequently appeared on the RBZ website, the statements are no longer publicly available.
[14] See the 2010 Zimbabwe Revenue Authority's Revenue Performance Report, available at https://www.zimra.co.zw/index.php?option=com_content&view=article&id=1245&Itemid=209 (accessed on January 13, 2019).

hyperinflations covered by Sargent (1982), as we discuss next, the similarities lie with the fiscal dominance of monetary policy.

4.5. Classic Hyperinflations

Sargent (1982) summarizes the successful ends of the four classic European hyperinflations after World War I, observing that governments were taking action to ease social tension at war's end and that the losers of the war were being forced to pay reparations. With economies across the continent destroyed, unemployment was high and many turned to the government for relief, which paved the way for the fiscal dominance of monetary policy.

For instance, with the end of the Austro-Hungarian Empire after World War I, new nation-states emerged, and many people were displaced as they sought to return to their regions of ethnic origin. This was particularly true in Austria, where the government extended food relief and unemployment benefits to alleviate the problem of the mass return of ethnic Austrians from across the former Austro-Hungarian Empire. State-owned monopolies, like the railroads, operated by deficit. The payments were extended just as the victors' Reparation Commission was expecting repayment for war reparations. As in Zimbabwe more recently, the Austrian authorities also sought to fight currency substitution and imposed exchange controls through the Devisenzentrale (see Sargent 1982, 49).

As the inflation rate approached an average of 10,000 percent annually, the League of Nations intervened to control the country's finances in August 1922, and the inflation stopped and the exchange rate stabilized (see Sargent 1982, 52). Interestingly, Sargent (1982) shows that monetary liabilities continued to rise after price stabilization.

After creating the Austrian National Bank from the remnants of the Austro-Hungarian Bank, the government took measures to cut state employment–related expenditures and increase revenues through new taxes.

Not surprisingly, the Hungarian experience was similar to Austria's, in that the government even instituted the Hungarian Devisenzentrale to stop currency substitution. One notable exception is that the Hungarian State Note Institute extended a significant amount of personal loans at low interest rates. The call for reform by members of the League of Nations initiated the end of inflation as the government reined in public expenditures, although the exchange rate stabilization occurred in March 1924. As with Austria, monetary liabilities in Hungary continued to rise after prices stabilized.

In Germany, the hyperinflation erupted in response to the reparations, especially after the French occupation of the Ruhr Valley in 1923. Another common problem is that taxpayers realized that by delaying payments, they could reduce their liabilities, and did so, which likely contributed to the decline in revenues and exacerbated the growing deficit problem. During this period there was significant currency substitution as well. The currency stabilized after the implementation of public finance reforms, largely from a reduction in the number of public employees, after which real balances grew.

Emerging after World War I from a collection of regions in Germany, Russia, and the former Austro-Hungarian Empire, Poland accordingly had multiple currencies in circulation. Upon its creation the government ran up deficits that were financed by the Polish State Loan Bank. After the hyperinflation, the government sought to balance the budget and create an independent central bank that would reestablish convertibility.

Comparing Zimbabwe's history with these earlier episodes, we see the following in terms of similarities: (1) large, persistent budget deficits, financed by (2) unbacked fiat currency because governments were not collecting taxes, and (3) ultimately, price stability, which in the case of Zimbabwe arose once the currency was abandoned. Previous hyperinflations also brought a change in government.

Mugabe's regime was arguably weakened by the hyperinflation, in that a power-sharing arrangement was introduced after the hyperinflation's end, which did not last long. Two notable distinctions with previous hyperinflationary experiences include the dollarization, rather than currency reform. As a result, instead of a rapid rise of high-powered money after the inflation in Europe, in Zimbabwe the dollarization resulted in the currency's elimination.

5. Conclusion

Larochelle, Alwang, and Taruvinga (2014) and Stoeffler et al. (2015) provide empirical evidence of the tragic welfare effects that Zimbabwe's hyperinflation had on people there. Dire fiscal conditions led to Zimbabwe's recent hyperinflation. Using the OM rate to measure inflation, we find that the RBZ, even during Governor Gono's tenure, seems to have operated on the correct side of the inflation tax Laffer curve, contrary to Cagan's Paradox. One explanation for this finding is that the RBZ may have acted as both an issuer of the Zimbabwe dollar and a buyer of foreign currency in the parallel market. Our findings also corroborate Mladenovic and Petrovic's (2010) findings, albeit using lower-frequency data, and could suggest that the quality of price data may also play a role in understanding the dynamics of hyperinflation, as Engsted (1996) and Mladenovic and Petrovic (2010). The experience could also be consistent with what

White (1995) observed in Revolutionary France, whereby the regime tried to extract all remaining seignorage after destroying the note-printing plates. The delay seems consistent with a Leviathan monetary authority that extracts all remaining seignorage before abandoning the currency, as suggested by Miller (2016).

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Appendix A1. Dynamics of Real Balances and Parallel Market Rates

Before estimating money demand and the seignorage-maximizing rate of inflation, we examine the stationarity properties of the series used. Table A1 reports the results of our Augmented Dickey Fuller (ADF) Unit Root tests for nonstationarity and the results of the KPSS test for stationarity (Kwiatkowski et al. 1992) for OM rate inflation, the real monetary base, and currency. The ADF test specifications include a trend for tests of the variables in levels and no drift for tests of first differences of the variables. The KPSS test specifications include a trend for tests of the variables in levels and a drift term for tests of first differences of the variables. Because we use monthly data, we use the Akaike Information Criteria (AIC) to determine the optimal number of lagged changes to include in each specification for the ADF tests.

Table A1. Unit Root Tests: Inflation, Real Monetary Base, and Currency in Circulation

		ADF test null [alternative] hypothesis I(0) [I(1)]	KPSS test null [alternative] hypothesis I(1) [I(0)]
Levels			
Inflation	test stat	–0.65 (8 lags)	0.20
	critical value	–3.99	0.12
Real monetary base	test stat	–2.90 (1 lag)	0.13
	critical value	–3.99	0.12
Real currency in circulation	test stat	–1.45 (3 lags)	0.16
	critical value	–3.99	0.12
First differences			
Inflation	test stat	–7.34 (7 lags)	0.11
	critical value	–2.58	0.35

(continued on next page)

		ADF test null [alternative] hypothesis I(0) [I(1)]	KPSS test null [alternative] hypothesis I(1) [I(0)]
Real monetary base	test stat	–5.78 (6 lags)	0.10
	critical value	–2.58	0.35
Real currency in circulation	test stat	–6.25 (4 lags)	0.13
	critical value	–2.58	0.35

Note: For the estimation, the raw data monetary base and currency-in-circulation series, expressed in millions of Z$, are divided by the OM rate. For the ADF, we use the 1 percent critical value listed below each reported test statistic and assume a trend for the levels tests for each variable and no drift for the first difference tests for each variable. We use the AIC to determine the optimal number of lagged changes to include in each ADF specification, which are reported to the right of each test statistic. For the KPSS test, we use the 10 percent critical value and assume a trend in tests of the variables in levels and a drift in tests of the variables in first differences.

For each variable in levels, the ADF test statistics are not smaller than the 1 percent critical value, suggesting that we cannot reject nonstationarity, while the KPSS test statistics exceed the 10 percent critical value, suggesting that we may reject stationarity. These results are likely owing to the presence of the structural breaks observed in figure 2 for each series. On the other hand, for each variable in first differences, the ADF test statistics are smaller than the 1 percent critical value, suggesting that we can reject nonstationarity, while the KPSS test statistics lie below the 10 percent critical value, suggesting that we cannot reject stationarity.

Appendix A2. Tests of Co-Integration between Real Balances and the OM Rate of Inflation

Table A2 shows the results of Johansen and Juselius tests of co-integration. The results suggest that the OM rate of inflation is not co-integrated with either the real monetary base or currency in circulation.

Table A2. Co-Integration Tests: Inflation and the Real Monetary Base and Currency in Circulation

		Eigenvalue test	Trace test
Monetary base			
r = 0	test stat	9.28	10.88
	10% critical value	16.85	22.76
r ≤ 1	test stat	1.60	1.60
	10% critical value	10.49	10.49
Currency in circulation			
r = 0	test stat	13.62	15.76
	10% critical value	16.85	22.76
r ≤ 1	test stat	2.14	2.14
	10% critical value	10.49	10.49

Note: For the estimation, the raw data monetary base and currency-in-circulation series, expressed in millions of Z$, are divided by the OM rate. We include a trend in the co-integrating equation, and while we do not report the results, we get similar results if we include only a constant.

Appendix A3. Misspecification Tests

Table A3 reports ADF and KPSS tests of nonstationarity and stationarity, respectively, for the SVAR model residuals. It also reports the results of the Portmanteau tests of serial correlation, the Multivariate Autoregressive Conditional Heteroskedasticity Lagrange Multiplier (ARCH LM) tests, tests of normality as well as the roots of the characteristic polynomial. The ADF and KPSS tests suggest the residuals are likely stationary, given that we reject the null of nonstationarity for the ADF test and do not reject the null of stationarity for the KPSS test; this was not the case when we omitted the structural breaks in the SVAR models. Portmanteau tests for serial correlation, adjusted for the smallness of the sample, indicate that we do reject the null hypothesis for no serial correlation across all specifications. The ARCH LM tests of heteroskedasticity also indicate that we cannot reject the null hypothesis of no heteroskedasticity. Jarque-Bera tests, tests of skewness, and tests of kurtosis of the residuals indicate that for the levels specification for the real monetary base, we do not reject the hypotheses of normality at the 1 percent significance level, but we do reject it at the 5 percent significance level. For the levels specification for real currency in circulation, we do not reject the hypotheses of normality. Finally, the roots of the characteristic all lie below 1, suggesting that the models are stable, which supports the general validity of our approach.

Table A3. SVAR Diagnostic Tests

		Monetary base trend but no structural breaks	Currency-in-circulation trend and structural breaks
ADF test Null [Alternative] Hypothesis I(0) [I(1)]: inflation	test stat critical value	–6.59 –2.60	–6.66 –2.60
KPSS test Null [Alternative] Hypothesis I(1) [I(0)]: inflation	test stat critical value	0.05 0.12	0.05 0.12
ADF test Null [Alternative] Hypothesis I(0) [I(1)]: real balances	test stat critical value	–6.70 –2.60	–6.35 –2.60
KPSS test Null [Alternative] Hypothesis I(1) [I(0)]: real balances	test stat critical value	0.05 0.12	0.05 0.12
Portmanteau Serial Correlation test statistic (p-value)		17.03 (0.15)	18.81 (0.09)
ARCH LM Heteroskedasticity: inflation test statistic (p-value)		12.18 (0.73)	6.18 (0.99)
ARCH LM Heteroskedasticity: real balances test statistic (p-value)		14.04 (0.60)	13.37 (0.65)
Heteroskedasticity: Multivariate test statistic (p-value)		64.36 (0.43)	70.78 (0.23)
Normality: Jarque-Bera test statistic (p-value)		12.03 (0.02)	4.64 (0.33)
Normality: Skewness test statistic (p-value)		5.98 (0.05)	1.19 (0.55)
Normality: Kurtosis test statistic (p-value)		6.05 (0.05)	3.45 (0.18)
Roots of the characteristic polynomial		0.94 0.94 0.90 0.90 0.88 0.88 0.85 0.84 0.84 0.83 0.83 0.76 0.76 0.47	0.98 0.98 0.88 0.88 0.87 0.87 0.85 0.82 0.82 0.78 0.78 0.67 0.67 0.57

Note: For the estimation, the raw data monetary base and currency-in-circulation series, expressed in millions of Z$, are divided by the OM rate. For the Portmanteau test, the suggested number of lags is equal to 10. For the ARCH LM test, we assume 7 lags as suggested by the AIC for the SVAR models.

Appendix A4. SVAR Estimates

Table A4 reports the coefficient estimates and standard errors of the bivariate SVAR reported in equation (6).

Table A4. Structural VAR Estimates

	Inflation	Monetary base	Inflation	Currency
Inflation (t)	-	–0.85*** (0.10)	-	–0.93*** (0.10)
Inflation (t–1)	–0.41* (0.21)	0.32 (0.21)	–0.45 (0.28)	0.25 (0.29)
Real balances (t–1)	0.07 (0.22)	0.68*** (0.22)	0.01 (0.29)	0.72** (0.30)
Inflation (t–2)	–0.25 (0.21)	0.22 (0.21)	–0.37 (0.24)	0.23 (0.24)
Real balances (t–2)	0.25 (0.27)	–0.24 (0.27)	0.15 (0.36)	–0.16 (0.37)
Inflation (t–3)	–0.69*** (0.21)	0.49** (0.21)	–0.48* (0.28)	0.43 (0.29)
Real balances (t–3)	–0.38 (0.27)	0.20 (0.27)	–0.08 (0.40)	0.08 (0.41)
Inflation (t–4)	–0.21 (0.22)	0.05 (0.22)	–0.14 (0.32)	–0.07 (0.33)
Real balances (t–4)	0.33 (0.28)	–0.40 (0.27)	0.22 (0.50)	–0.42 (0.51)
Inflation (t–5)	–0.28 (0.23)	0.02 (0.23)	–0.36 (0.31)	–0.09 (0.32)
Real balances (t–5)	–0.04 (0.28)	–0.01 (0.28)	–0.20 (0.50)	–0.14 (0.51)
Inflation (t–6)	–0.38 (0.23)	–0.19 (0.23)	–0.32 (0.32)	–0.23 (0.33)
Real balances (t–6)	–0.10 (0.29)	–0.18 (0.29)	0.03 (0.47)	0.02 (0.48)
Inflation (t–7)	–0.30** (0.14)	0.22 (0.14)	–0.36** (0.15)	0.17 (0.15)
Real balances (t–7)	0.17 (0.22)	0.08 (0.21)	0.08 (0.32)	0.10 (0.32)
Trend	0.01 (0.01)	–0.04*** (0.01)	0.01 (0.01)	–0.02 (0.01)
Inflation breakpoint*trend	0.06 (0.05)	–0.01 (0.05)	0.07 (0.05)	–0.01 (0.05)
Real balances breakpoint1*trend	–0.01 (0.03)	0.06** (0.03)	0.00 (0.02)	0.03 (0.02)

(continued on next page)

	Inflation	Monetary base	Inflation	Currency
Real balances breakpoint2*trend	–0.01 (0.02)	0.03 (0.02)	0.00 (0.02)	0.02 (0.02)
Real balances breakpoint3*trend	0.03 (0.05)	–0.04 (0.05)	0.02 (0.05)	–0.03 (0.05)
Const	0.46** (0.20)	–0.70*** (0.20)	0.67 (0.49)	–1.60*** (0.50)
Inflation breakpoint*const	–5.29 (3.69)	0.81 (3.67)	–6.02 (3.70)	0.52 (3.78)
Real balances breakpoint1*const	0.42 (1.00)	–1.89* (0.99)	–0.04 (0.85)	–1.07 (0.87)
Real balances breakpoint2*const	–0.17 (0.79)	–0.02 (0.78)	–0.40 (0.84)	–0.06 (0.86)
Real balances breakpoint3*const	–1.46 (3.88)	2.57 (3.86)	–1.00 (3.71)	3.21 (3.78)
Adjusted R-squared	0.47	0.81	0.45	0.78
N	95		95	

Note: * indicates 90 percent (two-sided) significance level, ** indicates 95 percent (two-sided) significance level, and *** indicates 99 percent (two-sided) significance level. For the estimation, the raw data monetary base and currency-in-circulation series, expressed in millions of Z$, are divided by the OM rate. We report standard errors in parentheses below the estimated coefficients.