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When and why hyperinflating monetary authorities abandon a currency

Stephen Matteo Miller *

Mercatus Center, George Mason University, 3434 Washington Blvd., 4th Floor, Arlington, VA 22201, United States

HIGHLIGHTS

- Hyperinflating monetary authorities occasionally abandon the currency with delay.
- Model the monetary authority as an exhaustible seignorage extracting monopolist.
- Remaining seignorage resembles an annuity, comprised of a long and short position.
- Delay rises with higher remaining seignorage or lower seignorage extraction rates.

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ABSTRACT

Hyperinflating monetary authorities occasionally abandon the currency with delay to extract remaining seignorage. Modeling the monetary authority as an exhaustible resource extracting monopolist shows the delay increases with higher remaining seignorage or real interest rates or lower seignorage maximizing rates.

1. Introduction

The government in Zimbabwe outlived the Zimbabwe dollar following the recent hyperinflation, as the government declared an official dollarization, leading to a complete currency substitution, and Thiers's law (good money drives out bad money).[1] The South African *rand*, the *euro*, the *US dollar*, *pound* sterling, *metical* and *kwacha* have served as good money replacing the Zimbabwe dollar. The end of the hyperinflation differs from most previous experiences.

Writing before Zimbabwe's hyperinflation, Bernholz (2003) observes that currencies tend to outlive governments in power during hyperinflations, but Thiers's law can mean the government outlives the currency. While Bernholz (2003) identifies several prior cases of Thiers's law, among them, only the Revolutionary French experience ended with a hyperinflation.

Moreover, White (1995) observes that the *assignat* hyperinflation ended with a delay of nearly two months after the monetary authorities publicly destroyed the note printing plates. The monetary authorities attempted one last currency reform with the *mandat*, which also experienced a rapid decline in value, and when the currency ended, specie served as the good money replacing Revolutionary French currency. Similarly, the Zimbabwean monetary authorities received their last shipments of note paper not long after the German government pressured the Reserve Bank of Zimbabwe's (RBZ) note supplier to stop its dealings with the RBZ; the official dollarization happened almost seven months

* Tel.: +1 703 993 8998; fax: +1 703 993 493.
E-mail address: smiller@mercatus.gmu.edu.

[1] For an announcement of the official beginning of the multi-currency dollarization, see "Zimbabwe Abandons its Currency" on January 29, 2009, which is available from http://news.bbc.co.uk/2/hi/7859033.stm.

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later.[2] The French experience occurred under a bimetallic standard, while Zimbabwe's experience stands as the only case of a hyperinflation under a fiat standard to experience a complete currency substitution and official dollarization.

I examine the problem of a monetary authority that ends a currency with a delay under a fiat standard. To do this, I draw an analogy between a monetary Leviathan (see Brennan and Buchanan, 1981) and an exhaustible resource profit maximizing monopolist that extracts seignorage at a rate that equates marginal and average profits as in Hotelling (1931). I solve a particular model for the optimal stopping time assuming a Cagan (1956) type money demand function, given that Miller and Ndhlela (2015) find a stable Cagan-type demand for money exists in Zimbabwe before the RBZ stopped reporting monetary statistics. The optimal stopping time extends with a higher initial stock of remaining seignorage or real interest rate, or a lower seignorage maximizing inflation rate.

2. Theory: the delayed end of a hyperinflating currency

I model the delayed end to a hyperinflation using Brennan and Buchanan's (1981) notion of a monetary Leviathan. Here the monetary authority's objective is to maximize revenue rather than social welfare, which may well explain RBZ staff objectives, as findings in Miller and Ndhlela (2015) suggest RBZ staff appear to have operated on the correct side of the inflation tax Laffer curve prior to the hyperinflation's end.

Consider that monopoly note issue provides the most important mechanism for generating seignorage (see Selgin and White, 1999). Brennan and Buchanan (1981) claim a monetary Leviathan would confiscate the present discounted value of seignorage as the terminal date of the government's power approaches. In their example the terminal date occurs because of a change in power. However, in Zimbabwe, the problem of choosing the terminal date arose from the RBZ's inability to procure new note paper, although the printing presses also experienced decay.[3]

The problem of maximizing revenue given a fixed stock of note paper resembles a Hotelling (1931) type problem for a monopolist that chooses the optimal stopping time to extract an exhaustible resource (see Ferguson and Lim, 1998 and Pemberton and Rau, 2011). The model implies that the monetary authority with a finite amount of paper may apply a rule equating marginal and average profits, until it extracts all remaining seignorage, which could explain the hyperinflation's delayed end.

To show this, start by assuming the money market is in continuous equilibrium, such that real balances (m_t) equal real quantity demanded ($L(\pi_t)$). Define the present value of seignorage as the sum of initial equilibrium real balances demanded, plus the stream of discounted future equilibrium inflation tax revenues

$$S = \int_0^T \exp(-rt)\,\pi_t L(\pi_t)\,dt + L(\pi_0)\,. \tag{1}$$

At time t, changing the lower limit gives remaining equilibrium seignorage as

$$R = \int_t^T \exp(-rs)\,\pi_s L(\pi_s)\,ds. \tag{2}$$

[2] See http://www.gi-de.com/en/about_g_d/press/press_releases/Giesecke-%26-Devrient-halts-deliveries-to-the-Reserve-Bank-of-Zimbabwe-g10756.jsp. In addition, for a description of the deteriorating note printing infrastructure see "A Crisis it Can't Paper Over", LA Times July 14, 2008, available from http://articles.latimes.com/2008/jul/14/world/fg-money14.

[3] Although note paper was more likely the binding constraint, Sebastien Berger and Peta Thornycroft address the delay between the announcement and the actual end of the note supply on July 30 2008 The Telegraph http://www.telegraph.co.uk/news/worldnews/africaandindianocean/zimbabwe/2475081/Zimbabwe-to-cut-ten-zeros-from-banknotes-in-fight-against-inflation.html.

I obtain the state equation by differentiating (2) with respect to time

$$\dot{R} = -\exp(-rt)\,\pi_t L(\pi_t)\,. \tag{3}$$

Subject to this constraint, the monopoly monetary authority maximizes profits generated by the equilibrium inflation tax defined as revenue ($\pi_t L(\pi_t)$) net of cost ($c(\pi_t)$) over an endogenous horizon (T)

$$\max_{\pi,T} \int_{t_0}^T \exp(-rt)\left[\pi_t L(\pi_t) - c(\pi_t)\right] dt \tag{4}$$

s.t. $\dot{R} = -\exp(-rt)\,\pi_t L(\pi_t)$, $R(t_0) = R(0)$, $R(T) \geq 0$, T is free.
The Hamiltonian for this problem is

$$H = \exp(-rt)\left[\pi_t L(\pi_t) - c(\pi_t)\right] - \lambda_t \exp(-rt)\,\pi_t L(\pi_t)\,. \tag{5}$$

The first order necessary conditions with respect to the control, state- and co-state variables, and terminal date include

$$\begin{aligned} H_\pi &= L(\pi_t) + \pi_t \frac{\partial L(\pi_t)}{\partial \pi_t} - \frac{\partial c(\pi_t)}{\partial \pi_t} \\ &\quad - \lambda_t \left[L(\pi_t) + \pi_t \frac{\partial L(\pi_t)}{\partial \pi_t} \right] = 0 \end{aligned} \tag{6}$$

$$H_R = -\dot{\lambda} = 0 \tag{7}$$

$$H_\lambda = -\pi_t L(\pi_t)\exp(-rt) = \dot{R} \tag{8}$$

$$H_T = \pi_T L(\pi_T) - c(\pi_T) - \lambda_T \pi_T L(\pi_T) = 0. \tag{9}$$

To understand the delayed end of the Zimbabwe dollar, rearranging (6) implies the shadow price at the optimal stopping time (T) should equal

$$\begin{aligned} \lambda_T &= \frac{L(\pi_T) + \pi_T \frac{\partial L(\pi_T)}{\partial \pi_T} - \frac{\partial c(\pi_T)}{\partial \pi_T}}{L(\pi_T) + \pi_T \frac{\partial L(\pi_T)}{\partial \pi_T}} \\ &= 1 - \frac{\frac{\partial c(\pi_T)}{\partial \pi_T}}{L(\pi_T) + \pi_T \frac{\partial L(\pi_T)}{\partial \pi_T}}. \end{aligned} \tag{10}$$

Also, (9) implies that the Hamiltonian at the optimal stopping time (T) must equal zero, which implies

$$\lambda_T = \frac{\pi_T L(\pi_T) - c(\pi_T)}{\pi_T L(\pi_T)} = 1 - \frac{c(\pi_T)}{\pi_T L(\pi_T)}. \tag{11}$$

Equating (10) and (11) implies that the optimal stopping time occurs when the ratio of marginal cost to marginal revenue equals the ratio of average cost to average revenue

$$\frac{\frac{\partial c(\pi_T)}{\partial \pi_T}}{L(\pi_T) + \pi_T \frac{\partial L(\pi_T)}{\partial \pi_T}} = \frac{c(\pi_T)}{\pi_T L(\pi_T)}. \tag{12}$$

3. Results and discussion: determinants of the terminal date

To analyze properties of the terminal date, I start with a simplified Cagan (1956) type money demand function, $L(\pi_t) = \exp(-\alpha\pi_t)$, and quadratic cost function, $c(\pi_t) = 0.5(\pi_t)^2$, and solve for the terminal inflation rate (π_T). The first derivatives of the money demand and cost functions at the terminal date (T) equal $dL(\pi_T)/d\pi_T = -\alpha\exp(-\alpha\pi_T)$ and $dc(\pi_T)/d\pi_T = \pi_T$, respectively. Substituting these expressions into Eq. (12) yields

$$\frac{\pi_T}{\exp(-\alpha\pi_T) - \alpha\pi\exp(-\alpha\pi_T)} = \frac{0.5(\pi_T)^2}{\pi_T\exp(-\alpha\pi_T)} \tag{13}$$

which after simplifying means that at the terminal date (T), the inflation rate should equal the seignorage maximizing rate

$$\pi_T = -1/\alpha. \tag{14}$$