On the Measurement of Zimbabwe's Hyperinflation

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Zimbabwe experienced the first hyperinflation of the 21st century.[1] The government terminated the reporting of official inflation statistics, however, prior to the final explosive months of Zimbabwe's hyperinflation. We demonstrate that standard economic theory can be applied to overcome this apparent insurmountable data problem. In consequence, we are able to produce the only reliable record of the second highest inflation in world history.

The Rogues' Gallery

Hyperinflations have never occurred when a commodity served as money or when paper money was convertible into a commodity. The curse of hyperinflation has only reared its ugly head when the supply of money had no natural constraints and was governed by a discretionary paper money standard.

The first hyperinflation was recorded during the French Revolution, when the monthly inflation rate peaked at 143 percent in December 1795 (Bernholz 2003: 67). More than a century elapsed before another hyperinflation occurred. Not coincidentally, the inter-

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[1]In this article, we adopt Phillip Cagan's (1956) definition of hyperinflation: a price level increase of at least 50 percent per month.

vening period represented the heyday of the gold standard. The 20th century witnessed 28 hyperinflations (Bernholz 2003: 8). Most were associated with the monetary chaos that followed the two World Wars and the collapse of communism. Zimbabwe's hyperinflation of 2007–08 represents the first episode in the 21st century and the world's 30th hyperinflation.

Most hyperinflations (17) occurred in Eastern Europe and Central Asia, with Latin America accounting for 5 and Western Europe for 4. While Southeast Asia and Africa accounted for 2 hyperinflations each, the United States has avoided hyperinflation. It came close, however, during the Revolutionary War, when the revolutionary government churned out paper continentals to pay bills. The monthly inflation rate reached a peak of 47 percent in November 1779 (Bernholz 2003: 48). A second close encounter occurred during the Civil War, when the Union government printed greenbacks to finance the war effort. Inflation peaked at a monthly rate of 40 percent in March 1864 (Bernholz 2003: 107).

Zimbabwe first breached the hyperinflation benchmark in March 2007 (Table 1). After falling below the 50 percent threshold in July, August, and September 2007, inflation soared, peaking at an astounding monthly rate of 79.6 billion percent in mid-November 2008. At that point, as one of us anticipated, people simply refused to use the Zimbabwe dollar (Hanke 2008: 9), and the hyperinflation came to an abrupt halt.

As incredible as Zimbabwe's November 2008 inflation rate was, it failed to push Zimbabwe to the top of the world's hyperinflation league table. That spot is held by Hungary (Table 2).

Zimbabwe's Data Void

Even though the Reserve Bank of Zimbabwe produced an ever-increasing torrent of money, and with it ever more inflation, it was unable, or unwilling, to report any meaningful economic data during most of 2008. Indeed, the last Reserve Bank balance sheet and money supply data produced in 2008 were for March (Reserve Bank of Zimbabwe 2008a). As for the 2008 inflation data, the last available figures were for July, and these were not released until October (Reserve Bank of Zimbabwe 2008b).

This data void hid Zimbabwe's hyperinflation experience under a shroud of secrecy. Our problem was to lift that shroud by measuring

TABLE 1
Zimbabwe's Hyperinflation

Date	Month-over-month inflation rate (%)	Year-over-year inflation rate (%)
March 2007	50.54	2,200.20
April 2007	100.70	3,713.90
May 2007	55.40	4,530.00
June 2007	86.20	7,251.10
July 2007	31.60	7,634.80
August 2007	11.80	6,592.80
September 2007	38.70	7,982.10
October 2007	135.62	14,840.65
November 2007	131.42	26,470.78
December 2007	240.06	66,212.30
January 2008	120.83	100,580.16
February 2008	125.86	164,900.29
March 2008	281.29	417,823.13
April 2008	212.54	650,599.00
May 2008	433.40	2,233,713.43
June 2008	839.30	11,268,758.90
July 2008	2,600.24	231,150,888.87
August 2008	3,190.00	9,690,000,000.00
September 2008	12,400.00	471,000,000,000.00
October 2008	690,000,000.00	3,840,000,000,000,000,000.00
14 November 2008	79,600,000,000.00	89,700,000,000,000,000,000,000.00

Notes: The Reserve Bank of Zimbabwe reported inflation rates for March 2007–July 2008. The authors calculated rates for August 2008–14 November 2008.
Sources: Reserve Bank of Zimbabwe (2008a) and authors' calculations.

inflation after July 2008, when conventional inflation measures were not available.

PPP to the Rescue

Does economic theory provide any insights that might assist in solving our problem? The principle of purchasing power parity (PPP) should be able to come to our rescue. PPP states that the ratio of the price levels between two countries is equal to the exchange rate between their currencies. Changes in the exchange rate and the ratio of the price levels move in lock step with one another, with the linkage between the exchange rate and price level maintained by price arbitrage.

TABLE 2
Highest Monthly Inflation Rates in History

Country	Month with highest inflation rate	Highest monthly inflation rate	Equivalent daily inflation rate	Time required for prices to double
Hungary	July 1946	$4.19 \times 10^{16}\%$	207%	15.0 hours
Zimbabwe	Mid-November 2008	79,600,000,000%	98.0%	24.7 hours
Yugoslavia	January 1994	313,000,000%	64.6%	1.4 days
Germany	October 1923	29,500%	20.9%	3.7 days
Greece	October 1944	13,800%	17.9%	4.3 days
China	May 1949	2,178%	11.0%	6.7 days

Notes: The authors calculated "equivalent daily inflation rate" and "time required for prices to double."
Sources: Hungary (Nogaro 1948); Zimbabwe (authors' calculations); Yugoslavia (Petrović , Bogetić , and Vujošević 1999); Germany (Sargent 1986); Greece (Makinen 1986); China (Chou 1963).

To determine the PPP for Zimbabwe relative to the United States, let

P_{ZIM} = the Zimbabwe price level in Zimbabwe dollars (ZWD),
P_{US} = the United States price level in U.S. dollars (USD), and
$E_{ZWD/USD}$ = the exchange rate (ZWD per unit of USD).

Then PPP, in a static sense, states that:

$$(1)\quad \frac{P_{ZIM}}{P_{US}} = E_{ZWD/USD}$$

PPP can be interpreted in a dynamic sense by looking at the changes in price levels and values of currencies over time. This relative form of PPP states that:

$$(2)\quad \frac{1+\frac{\Delta P_{ZIM}}{P_{ZIM}}}{1+\frac{\Delta P_{US}}{P_{US}}} = 1 + \frac{\Delta E_{ZWD/USD}}{E_{ZWD/USD}}$$

Given the state of hyperinflation in Zimbabwe, the change in the price level in the United States relative to that in Zimbabwe is insignificant. In consequence, ΔP_{US} can be assumed to be zero. As a result, (2) becomes

$$(3)\quad \frac{\Delta P_{ZIM}}{P_{ZIM}} = \frac{\Delta E_{ZWD/USD}}{E_{ZWD/USD}}$$

Accordingly, the percentage change in the price level in Zimbabwe equals the percentage change in the exchange rate (ZWD per unit of USD). Therefore, if PPP holds and we know the percentage change in the Zimbabwe dollar/U.S. dollar exchange rate, we can estimate the percentage change in the Zimbabwean price level and our problem is solved.

But does PPP hold during periods of hyperinflation? If not, we cannot use changes in the Zimbabwe dollar/U.S. dollar exchange rate to estimate Zimbabwe's inflation rate. There is a consensus among economists that, over relatively short periods of time and at relatively low inflation rates, the link between exchange rates and price levels is loose. But as inflation rates increase, the link becomes tighter. In a study of the German hyperinflation of 1921–23, Jacob Frenkel

(1976) found that correlations between various German price indices and the German mark/U.S. dollar exchange rate were all close to one. Every 1 percent increase in the exchange rate was associated with a 1 percent increase in the price level. Frenkel's empirical work strongly suggests that PPP holds when a country is hyperinflating. Additional evidence supporting the PPP principle during periods of very high or hyperinflation has been reported for a wide range of countries (see McNown and Wallace 1989, Phylastis 1992, Mahdave and Zhou 1994, Zhou 1997, and Bleaney 1998).

That PPP holds under conditions of very high inflation or hyperinflation should not be surprising. After all, under these conditions, the temporal dimension of price arbitrage is compressed and the long run effectively becomes the short run. For example, in July 2008, Zimbabwe's inflation was 2,600 percent a month—equivalent to a 12 percent daily rate. That is per day—not per month, or per year. In these circumstances, arbitrage benefits per unit of time are relatively large and transaction costs can be overcome quickly. Accordingly, price arbitrage works to ensure that PPP holds.[2]

During hyperinflations, the spatial dimension of price arbitrage also becomes compressed. This, too, tends to ensure that PPP holds. With floating exchange rates, Thiers' Law prevails: "good money" drives "bad money" out of circulation (Bernholz 1995). In Zimbabwe, foreign currencies obtained on the black market floated against the Zimbabwe dollar and they rapidly replaced it. Indeed, the U.S. dollar, South African rand, Botswana pula, Zambian kwacha, and Mozambican metical all became increasingly popular in Zimbabwe during 2008 (*IRINnews* 2009). With foreign currencies widely circulating within Zimbabwe, price arbitrage could be conducted with ease because the associated transaction costs were relatively low. In the extreme, goods were offered in Zimbabwe dollars and U.S. dollars in the same store. Accordingly, price arbitrage could be carried out over a very small space at virtually no transaction costs.

In addition to the theoretical arguments and empirical evidence supporting PPP during hyperinflation, consider also the behavior of people in Zimbabwe during 2008. Those who accepted Zimbabwe

[2]For a general model that incorporates transaction costs into the determination of PPP, see Sercu, Uppal, and Van Hulle (1995).

dollars in exchange for goods and services revised their prices upward based on hourly (or shorter) updates of the black-market exchange rate with the U.S. dollar (Brulliard 2008). In consequence, price increases for goods and services sold in Zimbabwe dollars mirrored the depreciation of the Zimbabwe dollar against the U.S. dollar and other foreign currencies. Similar observations were documented in Argentina during its 1989–90 bout of hyperinflation. Indeed, Heymann and Leijonhufvud (1995: 181) found that "on a day-to-day basis, in fact, the state of the exchanges becomes more important than the state of the market for the good itself in determining its price."

PPP to the Rescue, Again

Armed with PPP, we set out to obtain market-determined exchange rates for the Zimbabwe dollar against the U.S. dollar. Yet, given the plethora of exchange controls that existed in Zimbabwe (International Monetary Fund 2008: 1588–1601), we immediately faced yet another data availability problem. The Zimbabwe dollar was not freely traded on an organized exchange that reported exchange rates. Moreover, there were multiple black-market exchange rates for cash, as well as non-cash Zimbabwe dollars (credit and debit cards, checks and bank transfers).[3] The resulting exchange rates were not reported on a reliable, systematic basis.

With no organized market for the Zimbabwe dollar, it appeared that we faced an insurmountable data hurdle. But the organized stock market in Harare did provide prices that allowed us to calculate Zimbabwe dollar exchange rates. One stock—that of the insurance and investment company Old Mutual—was listed on both the London Stock Exchange and the Zimbabwe Stock Exchange. Each share of Old Mutual commands the same claim on the company's earnings and assets, irrespective of the market it is traded on. The

[3]Cash was in relative short supply and traded at a premium to non-cash Zimbabwe dollars because of government-mandated cash withdrawal limits and the government's unwillingness (or inability) to supply paper money (Biriwasha 2008). Cash was used only for relatively small transactions. Large transactions, such as the purchase of imports or equities on the Zimbabwe Stock Exchange, required non-cash Zimbabwe dollars. Accordingly, the non-cash form of the Zimbabwe dollar was more important than cash. This can be verified by, among other things, observing the ratio of M2 to notes and coins in circulation. That ratio was four in March 2008 (Reserve Bank of Zimbabwe 2008a).

only difference between Old Mutual shares traded on different exchanges is that the shares traded in London are denominated in British pounds sterling, whereas those traded in Harare are denominated in Zimbabwe dollars.

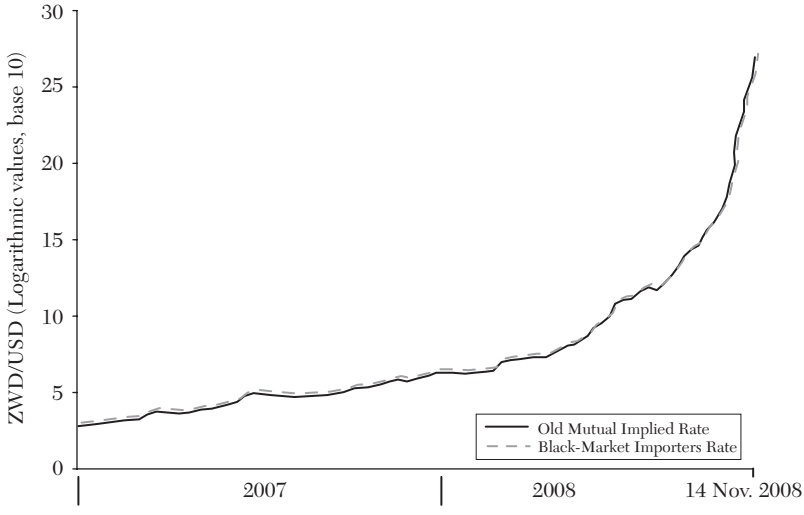
If price arbitrage works and PPP holds, the ratio of the Old Mutual share price in Harare to that in London equals the Zimbabwe dollar/sterling exchange rate. To convert the resulting Zimbabwe dollar/sterling exchange rate to a Zimbabwe dollar/U.S. dollar rate, or what we term the Old Mutual Implied Rate (OMIR), we multiplied the Zimbabwe dollar/sterling exchange rate by the sterling/U.S. dollar rate. We used the U.S. dollar rather than the pound sterling as the basis for our calculations because the U.S. dollar circulated widely and was the currency of choice in Zimbabwe during the hyperinflation. Once the OMIR was obtained, it was used to estimate the inflation rate in Zimbabwe (see equation 3).

To determine whether price arbitrage for Old Mutual shares in London and Harare was working well, we crosschecked the OMIR with data for the black-market Zimbabwe dollar/U.S. dollar exchange rate used by Zimbabwean importers to obtain foreign exchange. The unadjusted OMIR together with the importers' exchange rate data are plotted in Figure 1. A visual inspection confirms that price arbitrage for the Old Mutual shares worked well and that the OMIR could be used as a proxy for the black-market Zimbabwe dollar/U.S. dollar exchange rate. This is important because the OMIR was derived from market prices reported on an organized exchange, while the black-market data were not verifiable and were unavailable to the public. To satisfy the replication criterion, publicly available price data, such as those used to calculate the OMIR, are necessary.

While the black-market Zimbabwe dollar/U.S. dollar exchange rate increased monotonically with respect to time, a closer examination of the raw OMIR data presented in Figure 1 showed that it was more volatile than the black-market rate. To render the OMIR a more faithful, less noisy proxy for the black-market rate, we smoothed the raw OMIR data. To do so, we first took the logarithm of the raw, daily OMIR data. That stabilized the variance of the data. Then, we smoothed the data by fitting a cubic spline to them.[4] After

[4]The smoothing algorithm we employed was adopted from the Matlab® Spline Toolbox (www.mathworks.com).

FIGURE 1
Old Mutual Implied ZWD/USD Rate vs.
Black-Market Importers ZWD/USD Rate



Sources: (Old Mutual Implied Rate) Imara Asset Management Zimbabwe, Harare, Z.W.; (Black-market Importers Rate) John Robertson, Harare, Z.W.

smoothing the OMIR data, they were used to estimate the Zimbabwe inflation rate after July 2008—the last month for which the Reserve Bank published inflation rates. The results of these operations are presented in Table 1.

Conclusion

The use of PPP allowed us to overcome a series of data problems and fill Zimbabwe's inflation data void for the August 2008–November 2008 period. In consequence, we produce the only reliable record of Zimbabwe's hyperinflation. And what a record it is—the second highest inflation in world history.

Like any other positive feedback system, Zimbabwe's hyperinflation came to an abrupt halt. The trigger was an intervention by the Reserve Bank of Zimbabwe. On November 20, 2008, the Reserve Bank's governor, Dr. Gideon Gono, stated that the entire economy was "being priced via the Old Mutual rate whose share price movements had no relationship with economic fundamentals, let alone

actual corporate performance of Old Mutual itself" (Gono 2008: 7–8). In consequence, the Reserve Bank issued regulations that forced the Zimbabwe Stock Exchange to shut down. This event rapidly cascaded into a termination of all forms of non-cash foreign exchange trading and an accelerated death spiral for Zimbabwe dollar. Within weeks the entire economy spontaneously "dollarized" and prices stabilized. Indeed, since the reporting of official inflation statistics was reinstated, the monthly inflation rates for January, February, March, April, and May 2009 were –2.3, –3.1, –3.0, –1.1, and –1.0 percent, respectively (Central Statistical Office 2009, Zulu 2009).

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