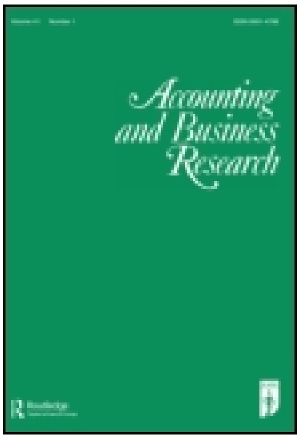

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IAS 29 and the cost of holding money under hyperinflationary conditions

Andrew Higson [a], Yoshikatsu Shinozawa [a] & Mark Tippett [a]
[a] Loughborough University
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IAS 29 and the cost of holding money under hyperinflationary conditions

Andrew Higson, Yoshikatsu Shinozawa and Mark Tippett*

Abstract—Empirical evidence is presented on the efficacy of procedures summarised in IAS 29: *Financial Reporting in Hyperinflationary Economies* for estimating the loss in purchasing power from holding monetary items during hyperinflationary periods. Our empirical analysis encompasses 32 hyperinflationary economies covering a wide variety of hyperinflationary conditions and spanning a period of more than 80 years. While the estimation procedures summarised in IAS 29 perform poorly under all the hyperinflationary conditions encompassed by our sample, they are especially poor when the rate of inflation accelerates towards the end of a relatively short hyperinflationary period. For these latter economies, our best estimate of the actual purchasing power loss is typically only a small fraction of the figure obtained under the IAS 29 procedures. For hyperinflations of longer duration, the IAS 29 procedures return estimated purchasing power losses that are typically around 10% larger than our best estimate of the actual losses. We also derive and empirically test a general class of 'two point' estimation formulae that make more efficient use of the sparse information set on which the IAS 29 estimation procedures are based. The results obtained from this procedure are encouraging and suggest it is possible to obtain reliable estimates of purchasing power losses using only sparse information sets provided realistic assumptions are made about the way monetary holdings respond to variations in the purchasing power of the currency.

Key words: Hyperinflation; IAS 29; monetary items; quadrature (estimating) formula; purchasing power loss.

1. Introduction

Seigniorage is the process whereby governments print currency and exchange it at face value for the goods and services required to implement their spending programmes. Governments generally ensure that the rate of growth in the currency is roughly comparable with the rate of growth in general economic activity. However, there are numerous instances of weak and/or insipid governments that have relied almost exclusively on seigniorage to finance their spending programmes. In these cases the rate of growth in the currency normally far exceeds the rate of growth in general economic activity and the currency ends up being debased by hyperinflation. The most notorious example of this practice is provided by the German hyperinflation during the Weimar Republic after the First World War as it struggled to meet the reparation payments required of it under the Versailles Treaty. More recent examples of these hyperinflationary seigniorage practices are provided by Angola between 1996 and 2005, Belarus between 1995 and 2003, Madagascar between 1994 and 1996, Poland between 1990 and 1995, Romania between 1994 and 2002, Russia after the break-up of the Soviet Union in 1992, Turkey until the reform of the currency in 2005 and the Ukraine between 1993 and 1997. Hence, it is not unusual to encounter organisations that have to operate under hyperinflationary conditions and the International Accounting Standards Board (IASB) has endorsed the financial reporting standard IAS 29: *Financial Reporting in Hyperinflationary Economies* (IASC, 1989) to meet the unique financial reporting problems that arise in such environments.

IAS 29 does not establish an absolute rate of inflation at which hyperinflationary conditions will be deemed to prevail but instead sets out some general characteristics that indicate the presence of hyperinflation and under which the reporting provisions summarised in the standard are to be implemented. The characteristics include the observation (para. 3) that the 'general population' prefers to maintain its wealth in non-monetary assets or in monetary assets denominated in a relatively stable foreign currency; that interest rates on debt transactions are linked to the rate of change in prices while credit sales and purchases are made at prices which compensate for the expected loss in purchasing power over the credit period; and that the cumulative rate of inflation over the previous three years is approaching or exceeds 100%. When these conditions are satisfied, para. 8 of IAS 29 mandates that published corporate financial statements 'shall be stated in terms of the measuring unit current at the reporting date'. This means that the revenue and expense items appearing on an organisation's profit and loss statement will have to be restated by multiplying them by the

*Andrew Higson and Yoshikatsu Shinozawa are lecturers and Mark Tippett is Professor of Accounting and Finance at Loughborough University. Correspondence should be addressed to Mark Tippett at the Business School, Loughborough University, Leicestershire, LE11 3TU. E-mail: M.Tippett@lboro.ac.uk

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ratio of the general price index at the end of the reporting period to the general price index at the time when the revenue was received or expense incurred. Likewise, the fixed assets appearing on an organisation's balance sheet will have to be restated by multiplying them by the ratio of the general price index at the balance sheet date to the general price index at the time when the fixed assets were acquired. However, IAS 29 also notes that organisations typically hold assets and liabilities denominated in the currency of the hyperinflationary economy (so called monetary assets and liabilities or monetary items) and these will rapidly decrease in purchasing power as the hyperinflation eats away at their nominal value. Given this, para. 9 of IAS 29 also mandates that the net gain or loss in purchasing power from holding these monetary assets and liabilities must be included in the organisation's profit or loss and separately disclosed.

Unfortunately, IAS 29 provides only limited guidance about how the gain or loss from holding these monetary items is to be estimated, suggesting instead that (para. 10) 'consistent application of these ... procedures and judgements' employed in estimating the gain or loss in purchasing power 'is more important than the precise accuracy of the resulting amounts included in the restated financial statements'. However, if shareholders and others are to make effective assessments about how well organisations have managed their monetary assets and liabilities and the purchasing power gains and losses that arise from them (both in absolute terms and in comparison with other organisations) then it is important that the gain or loss from holding monetary items reported on an organisation's profit and loss statement be as accurate as possible.

This 'consistency rather than accuracy' principle that underscores the re-statement process summarised in IAS 29 no doubt informs the 'illustrative' examples appended to the statement by those countries which have sought to make their domestic accounting standards compatible with the standards issued by the IASB. The estimation procedures demonstrated in these illustrative examples are based on the premise that an organisation's monetary position[1] changes on just a few (typically, one or two) occasions over an annual reporting period and that in between these changes its monetary position remains constant.[2] However, there is a long line of empirical work beginning with Cagan (1956) which shows that organisations rapidly adjust their holdings of monetary items as the rate of inflation gains momentum.[3] In the German hyperinflation referred to earlier, for example, Cagan (1956: 102) shows that real monetary holdings declined by over 90% in the period from July 1922 until October 1923 as a consequence of a monthly inflation rate which grew from 43% in July 1922 to over of 3,773% by October 1923.[4] In such hyperinflationary environments, it is problematic whether an organisation's monetary holdings over the reporting period can be captured by the one or two observations of that variable on which the IAS 29 estimation procedures are invariably based. This in turn means that the IAS 29 estimation procedures will form an unreliable basis for assessing the efficiency (or otherwise) with which organisations manage the purchasing power gains and losses that arise on their monetary assets and liabilities.

Given this, our purpose here is twofold. First, we use data from 32 hyperinflationary economies spanning an 80-year period to asses the relative efficiency of the procedures summarised in IAS 29 for estimating purchasing power gains and losses under a broad range of hyperinflationary environments. Our empirical analysis shows that the estimation procedures summarised in IAS 29 perform poorly, but especially so when the rate of inflation accelerates towards the end of a relatively short hyperinflationary period. For these latter economies, our best estimate of the actual purchasing power loss is typically only a small fraction of the figure obtained under the IAS 29 procedures. For hyperinflations of longer duration, the IAS 29 procedures return estimated purchasing power losses that are typically around 10% larger than our best estimate of the actual losses.

Our second contribution lies in the development of more sophisticated approaches for estimating

[1] An organisation's monetary position or equivalently its monetary items, is its monetary assets less its monetary liabilities. While an individual organisation's monetary position can be positive or negative (depending on whether its monetary assets exceed its monetary liabilities) for the economy as a whole the aggregate monetary position must be negative since someone has to hold the currency issued by the government. See Lucas (2000:247) for further discussion of this point.

[2] A good example of this practice is to be found in the numerical example appended to International Public Sector Accounting Standard *IPSAS 10: Financial Reporting in Hyperinflationary Economies* which is available from the following website:

http://www.ifac.org/Members/Source_Files/Public_Sector/IPSAS10.PDF

Other countries which have adopted IASB standards have also followed this practice. For example, until recently the Australian Accounting Standards Board appended the IPSAS 10 numerical example to *AASB 129: Financial Reporting in Hyperinflationary Economies* which is the Australian equivalent of IAS 29. AASB 129, complete with the IPSAS 10 numerical example, may be viewed at the following website:

http://www.comlaw.gov.au/ComLaw/Legislation/LegislativeInstrument1.nsf/0/BF20E8CBE34CD250CA25700300244CCA/$file/AASB129_07-04c.pdf.

[3] See Lucas (2000) for a summary of this literature.

[4] An organisation's real monetary position is the book value of its monetary items divided by the price index used to calculate the gain or loss in purchasing power arising on its monetary items. It is, in other words, equivalent to the 'purchasing power' of the firm's monetary items.

the purchasing power gains and losses that arise on monetary holdings. These more sophisticated procedures invoke the assumption that organisations rapidly adjust their monetary holdings as the rate of inflation gains momentum in contrast to the estimation procedures summarised in IAS 29, which make the unlikely assumption that organisations adjust their monetary holdings on just one or two occasions over a given hyperinflationary period. Moreover, our empirical analysis shows that the estimated purchasing power losses under these more sophisticated techniques are typically within 2.5% of our best estimate of the actual purchasing power losses. This result has the important implication that it is possible to obtain reliable estimates of purchasing power losses using only the sparse information set on which the IAS 29 estimation procedures are typically based provided realistic assumptions are made about the way organisations adjust their monetary holdings in response to variations in the purchasing power of the currency on issue.

We commence our analysis in the next section by summarising the numerical procedures we use for determining our 'best estimates' of the actual purchasing power losses that arise on the hyperinflationary economies employed in our empirical analysis. We then illustrate the practical application of these procedures by determining our best estimates of the actual losses in purchasing power on the currency on issue for the US and the UK for each year over the period from 1990 until 2005. Our calculations show that the procedures endorsed by IAS 29 return systematically biased estimates of the purchasing power losses on the currencies of both countries when compared to our best estimates of the actual purchasing power losses. Fortunately, the estimation errors are not particularly large – typically, 3–4% of our best estimate of the actual figure. However, the systematic nature of the errors suggests that were the IAS 29 procedures to be applied to the data of hyperinflationary economies then errors of a considerably larger magnitude would be incurred. Section 3 explores this latter issue in further detail by comparing the estimated purchasing power losses for our 32 hyperinflationary economies under the IAS 29 procedures with our best estimate of the actual purchasing power losses. In Section 4 we derive and then empirically evaluate a general class of 'two-point' estimation formulae that make more efficient use of the sparse information set on which the IAS 29 estimation procedures are typically based. As previously noted, while this two-point estimation procedure is based on the same information set as the IAS 29 estimation procedures, our empirical analysis shows that the two-point procedure provides much more reliable estimates of the purchasing power losses arising on the hyperinflationary economies examined in our empirical work. Our analysis concludes in Section 5 by summarising our main results and briefly examining their implications for the quality of earnings reported by firms that have to operate under hyperinflationary conditions.

2. Estimation procedures

Cagan (1956: 78) notes that inflationary seigniorage policies reduce the purchasing power of the currency and thereby impose a tax on all who have money or have money owed to them. One can illustrate this point by dividing a typical reporting year into n subintervals of equal length and supposing that an organisation's net monetary position (monetary assets less monetary liabilities) at the beginning of the j^{th} of these subintervals amounts to $m(\frac{j-1}{n})$ pounds. Then if $P(\cdot)$ is an index of prices, the loss (or gain) in purchasing power over this j^{th} subinterval will be approximately

$$m(\frac{j-1}{n}).\frac{P(\frac{j}{n}) - P(\frac{j-1}{n})}{P(\frac{j-1}{n})}.$$

Furthermore, one can re-state this loss (or gain) in purchasing power in terms of the price level which prevails at the end of the reporting year, in which case it follows that

$$P(1).\frac{m(\frac{j-1}{n})}{P(\frac{j}{n})}.\frac{P(\frac{j}{n}) - P(\frac{j-1}{n})}{P(\frac{j-1}{n})}$$

is the approximate loss in purchasing power over the j^{th} sub-interval in end of reporting year prices. Summing these calculations over all n subintervals and letting $n \to \infty$ shows that the loss in purchasing power will be identically equal to

$$P(1)\int_0^1 \frac{m(t)}{P(t)}\cdot\frac{P'(t)}{P(t)}dt = P(1)\int_0^1 \frac{m(t)}{P(t)}\cdot d\log[P(t)].^{5}$$

Of course the difficulty here is that over any given year the index of prices, P(t), and the real holding of monetary items, $\frac{m(t)}{P(t)}$, are observed at a small number of points only. In between these points, one has to infer somehow what the monetary position and the index of prices might have been.

Probably the most useful and best documented way of addressing numerical integration problems like this is to approximate the real monetary position, $\frac{m(t)}{P(t)}$, and the logarithm of the index of prices, P(t), by interpolating polynomials based on the

[5] See Willett (1987, 1989) and Ijiri (1976) for an account of how a firm's double-entry bookkeeping system may be represented in terms of the net inflow/outflow of its monetary items.

Table 1
Formulae for estimating purchasing power gains and losses on monetary items

First-degree interpolation formula

$$P(1)\int_0^1 \frac{m(t)}{P(t)}.d\log[P(t)] \approx \frac{P(1)}{2}\sum_{j=1}^{12}\left[\frac{m(\frac{j-1}{12})}{P(\frac{j-1}{12})}+\frac{m(\frac{j}{12})}{P(\frac{j}{12})}\right].\log\left[\frac{P(\frac{j}{12})}{P(\frac{j-1}{12})}\right]$$

Second-degree interpolation formula

$$P(1)\int_0^1 \frac{m(t)}{P(t)}.d\log[P(t)] \approx \frac{P(1)}{6}\sum_{j=1}^{6}\left\{\left[\frac{3m(\frac{2j-2}{12})}{P(\frac{2j-2}{12})}+\frac{4m(\frac{2j-1}{12})}{P(\frac{2j-1}{12})}-\frac{m(\frac{2j}{12})}{P(\frac{2j}{12})}\right].\log\left[\frac{P(\frac{2j-1}{12})}{P(\frac{2j-2}{12})}\right]+\left[-\frac{m(\frac{2j-2}{12})}{P(\frac{2j-2}{12})}+\frac{4m(\frac{2j-1}{12})}{P(\frac{2j-1}{12})}+\frac{3m(\frac{2j}{12})}{P(\frac{2j}{12})}\right].\log\left[\frac{P(\frac{2j}{12})}{P(\frac{2j-1}{12})}\right]\right\}$$

Third-degree interpolation formula

$$P(1)\int_0^1 \frac{m(t)}{P(t)}.d\log[P(t)] \approx \frac{P(1)}{80}\sum_{j=1}^{4}\left\{\left[\frac{40m(\frac{3j-3}{12})}{P(\frac{3j-3}{12})}+\frac{57m(\frac{3j-2}{12})}{P(\frac{3j-2}{12})}-\frac{24m(\frac{3j-1}{12})}{P(\frac{3j-1}{12})}+\frac{7m(\frac{3j}{12})}{P(\frac{3j}{12})}\right].\log\left[\frac{P(\frac{3j-2}{12})}{P(\frac{3j-3}{12})}\right]+\right.$$

$$\left.\left[\frac{-17m(\frac{3j-3}{12})}{P(\frac{3j-3}{12})}+\frac{57m(\frac{3j-2}{12})}{P(\frac{3j-2}{12})}+\frac{57m(\frac{3j-1}{12})}{P(\frac{3j-1}{12})}-\frac{17m(\frac{3j}{12})}{P(\frac{3j}{12})}\right].\log\left[\frac{P(\frac{3j-1}{12})}{P(\frac{3j-2}{12})}\right]+\left[\frac{7m(\frac{3j-3}{12})}{P(\frac{3j-3}{12})}-\frac{24m(\frac{3j-2}{12})}{P(\frac{3j-2}{12})}+\frac{57m(\frac{3j-1}{12})}{P(\frac{3j-1}{12})}+\frac{40m(\frac{3j}{12})}{P(\frac{3j}{12})}\right].\log\left[\frac{P(\frac{3j}{12})}{P(\frac{3j-1}{12})}\right]\right\}$$

Fourth-degree interpolation formula

$$P(1)\int_0^1 \frac{m(t)}{P(t)}.d\log[P(t)] \approx \frac{P(1)}{1890}\sum_{j=1}^{3}\left\{\left[\frac{945m(\frac{4j-4}{12})}{P(\frac{4j-4}{12})}+\frac{1472m(\frac{4j-3}{12})}{P(\frac{4j-3}{12})}-\frac{804m(\frac{4j-2}{12})}{P(\frac{4j-2}{12})}+\frac{384m(\frac{4j-1}{12})}{P(\frac{4j-1}{12})}-\frac{107m(\frac{4j}{12})}{P(\frac{4j}{12})}\right].\log\left[\frac{P(\frac{4j-3}{12})}{P(\frac{4j-4}{12})}\right]+\right.$$

$$\left[\frac{-527m(\frac{4j-4}{12})}{P(\frac{4j-4}{12})}+\frac{1472m(\frac{4j-3}{12})}{P(\frac{4j-3}{12})}+\frac{1308m(\frac{4j-2}{12})}{P(\frac{4j-2}{12})}-\frac{640m(\frac{4j-1}{12})}{P(\frac{4j-1}{12})}+\frac{277m(\frac{4j}{12})}{P(\frac{4j}{12})}\right].\log\left[\frac{P(\frac{4j-2}{12})}{P(\frac{4j-3}{12})}\right]+$$

$$\left[\frac{277m(\frac{4j-4}{12})}{P(\frac{4j-4}{12})}-\frac{640m(\frac{4j-3}{12})}{P(\frac{4j-3}{12})}+\frac{1308m(\frac{4j-2}{12})}{P(\frac{4j-2}{12})}+\frac{1472m(\frac{4j-1}{12})}{P(\frac{4j-1}{12})}-\frac{527m(\frac{4j}{12})}{P(\frac{4j}{12})}\right].\log\left[\frac{P(\frac{4j-1}{12})}{P(\frac{4j-2}{12})}\right]+$$

$$\left.\left[\frac{-107m(\frac{4j-4}{12})}{P(\frac{4j-4}{12})}+\frac{384m(\frac{4j-3}{12})}{P(\frac{4j-3}{12})}-\frac{804m(\frac{4j-2}{12})}{P(\frac{4j-2}{12})}+\frac{1472m(\frac{4j-1}{12})}{P(\frac{4j-1}{12})}+\frac{945m(\frac{4j}{12})}{P(\frac{4j}{12})}\right].\log\left[\frac{P(\frac{4j}{12})}{P(\frac{4j-1}{12})}\right]\right\}$$

This table summarises four formulae for estimating the purchasing power gains and losses that arise over an annual period on an organisation's monetary holdings. The formula in the first panel approximates the ratio of the organisation's monetary holdings to the price index, $\frac{m(t)}{P(t)}$, and the logarithm of the price index, log[P(t)], by linear (or first-degree) interpolating polynomials. The formula in the second panel approximates $\frac{m(t)}{P(t)}$ and log[P(t)] by quadratic (or second-degree) interpolating polynomials. The third panel is based on cubic (third degree) polynomial approximations while the fourth panel employs quartic (fourth-degree) polynomial approximations.

small number of points at which the exact values of these functions are known. The case for this particular approximating procedure is strong (Carnahan et al., 1969:2–3). For a start, the theory of polynomial approximations is well developed and fairly simple. Furthermore, most of the other functions that one might consider as potential candidates for approximation purposes (trigonometric, logarithmic, exponential functions, etc.) must themselves be evaluated using these polynomial approximation techniques. Finally, there are strong analytical reasons for believing that interpolating polynomials will provide 'good' approximations to the real monetary holdings and price index functions. Here, 'good' implies that the differences between the approximating polynomial and the function being approximated can be reduced to an arbitrarily small figure. The important result here is the Weierstrass Approximation Theorem, which under a minimal set of regularity conditions and in the present context, says that the real monetary holdings and price index functions can be approximated to any desired degree of accuracy by a particular interpolating polynomial (Carnahan et al., 1969:3). Moreover, this result is normally implemented by employing low order interpolating polynomial approximation formulae (Carnahan et al., 1969:77). Given this, in Table 1 we summarise some low order approximating formulae for the purchasing power gain or loss based on the assumption that both the price index and real monetary holdings are observed on a monthly basis throughout the reporting year.

The formula in the first panel of this table approximates $\frac{m(t)}{P(t)}$ and log[P(t)] by linear (or first degree) interpolating polynomials. The formula in the second panel approximates $\frac{m(t)}{P(t)}$ and log[P(t)] by quadratic (or second degree) interpolating polynomials. The third panel is based on cubic (third degree) polynomial approximations whilst the fourth panel employs quartic (fourth degree) polynomial approximations. The Appendix provides further details about how these polynomial approximating formulae are determined.

One can demonstrate the application of these formulae by using them to estimate the loss in purchasing power for the currency on issue in the US and the UK. For the US the monetary aggregate M1 (currency, traveller's checks, demand deposits and other checkable deposits) is taken to be the currency on issue whilst the inflation rate over any given period is determined from the Consumer Price Index (CPI).[6] The M1 data were downloaded from the Federal Reserve Statistical Release website, http://www.federalreserve.gov/releases/h6/hist/h6hist1.pdf, while CPI data were downloaded from the Economagic website, http://www.economagic.com/em-cgi/data.exe/blscu/CUUR0000AA0. The results from applying the approximating formulae to these data are summarised in Table 2. The first column in this Table gives the year of the estimate while the next four columns contain the estimate of the loss in purchasing power on the currency using first, second, third and fourth-degree interpolating polynomial approximation. Thus, for the year ending 31 December 2005 the first, third and fourth-degree interpolation formulae estimate the purchasing power loss on the currency at \$46.21 bn while the third-degree formula returns a marginally higher estimate of \$46.23 bn. The final column of Table 2 contains the estimated loss in purchasing power computed by applying the procedures summarised in IAS 29. This procedure is based on para. 27 of IAS 29 and applies the appropriate rate of inflation to the currency on issue at the beginning and end of each year in accordance with the following formula:

$$P(1)\int_0^1 m(t).\frac{P'(t)}{P^2(t)}dt =$$

$$P(1)[m(0)\int_0^c \frac{P'(t)}{P^2(t)}dt + m(1)\int_c^1 \frac{P'(t)}{P^2(t)}dt] =$$

$$\frac{P(1)}{P(c)}.m(0).\frac{P(c) - P(0)}{P(0)} + m(1).\frac{P(1) - P(c)}{P(c)}$$

where c is some generally unknown number that lies between zero and one.[7] This result is otherwise known as the (Weighted) Mean-Value Theorem for integrals (Apostol,1967: 219–220) and will always

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[6] M1 is the monetary aggregate which is normally employed in empirical work of the kind undertaken here. See, for example, Lucas (2000:248–252).

[7] Simple algebraic manipulation shows that this formula may be re-stated as

$$m(0).\frac{P(1) - P(0)}{P(0)} + (m(1) - m(0)).\frac{P(1) - P(c)}{P(c)}.$$

This shows that the loss in purchasing power is comprised of the rate of inflation over the entire year multiplied by the currency on issue at the beginning of the year plus the rate of inflation over the period from time c until the end of the year multiplied by the change in the currency on issue during the year. Moreover, one can take the derivative through this expression with respect to P(c) and thereby show:

$$\frac{d\{\int_0^1 \frac{m(t)}{P(t)}.\frac{P'(t)}{P(t)}dt\}}{dP(c)} = -\frac{m(1) - m(0)}{P^2(c)}.$$

Now, in hyperinflationary economies the currency on issue at the end of any period [m(1)] invariably exceeds the currency on issue at the beginning of the period [m(0)] by a considerable margin in which case the above derivative is negative. Minimal regularity conditions will then imply that the loss (or gain) in purchasing power on an organisation's monetary items will decline as $c \rightarrow 1$.

Table 2
Estimated loss in purchasing power on the monetary aggregate M1 for the US economy (bn of 31 December 2005 dollars)

Year	Degree of interpolation				
	First $bn	*Second* $bn	*Third* $bn	*Fourth* $bn	*IAS 29* $bn
1991	36.73	36.76	36.73	36.76	37.75
1992	38.85	38.87	38.86	38.90	39.77
1993	39.06	39.05	39.05	39.06	39.97
1994	39.75	39.76	39.77	39.80	40.57
1995	37.66	37.68	37.66	37.67	38.40
1996	45.35	45.32	45.33	45.33	46.25
1997	22.54	22.54	22.54	22.55	23.20
1998	20.82	20.81	20.81	20.82	21.42
1999	33.57	34.66	33.89	33.97	35.35
2000	42.06	42.07	42.12	42.17	43.42
2001	18.68	18.70	18.71	18.71	18.42
2002	31.03	30.99	31.02	31.00	31.76
2003	24.79	24.82	24.81	24.84	25.30
2004	44.56	44.58	44.58	44.64	45.14
2005	46.21	46.23	46.21	46.21	47.39

This table summarises annual estimates of the loss in purchasing power on the US currency using the polynomial formulae details of which are to be found in Table 1. The column headed 'first' estimates the purchasing power loss using the first-degree (linear) interpolation formula; the column headed 'second' estimates the purchasing power loss using the second-degree (quadratic) interpolation formula; the column headed 'third' estimates the purchasing power loss using the cubic interpolation formula; the column headed 'fourth' estimates the purchasing power loss using quartic interpolation. The column headed 'IAS 29' estimates the purchasing power loss using the procedures endorsed by IAS 29: *Financial Reporting in Hyperinflationary Economies*. Data for the monetary aggregate, M1, were downloaded from the Federal Reserve Statistical Release website, http://www.federalreserve.gov/releases/h6/hist/h6hist1.pdf, while Consumer Price Index data were downloaded from the Economagic website, http://www.economagic.com/em-cgi/data.exe/blscu/CUUR0000AA0.

give the exact figure for the loss (or gain) in purchasing power on an organisation's monetary holdings provided one is able to specify the "correct" value of the parameter c. Unfortunately, there is no obvious way of either knowing or determining c in any specific inflationary environment and given this, a convention has arisen which lets $c = \frac{1}{2}$.[8] Note that under this convention Table 2 shows that the IAS 29 procedures return an estimated purchasing power loss for the year ending 31 December 2005, which is over $1bn higher than the estimated purchasing power losses under the polynomial formulae. Against this, the four polynomial approximation methods return almost identical estimates of the loss in purchasing power in any given year. Moreover, the IAS 29 procedures return estimates of the loss in purchasing power which, in all but one year (2001) are larger than those obtained from the four polynomial interpolation methods.

Table 3 summarises similar information relating to the loss in purchasing power on the U.K. currency. Again, the monetary aggregate M1 is taken to be the currency on issue and data for this variable were downloaded from the Bank of England website. Data for the UK Consumer Price index were downloaded from the UK National Statistics Office website. The results from applying the approximating formulae to the UK data are summarised in Table 3. The format of this table is the

[8] See the 'illustrative example' appended to *IPSAS 10: Financial Reporting in Hyperinflationary Economies* and *AASB 129: Financial Reporting in Hyperinflationary Economies* referred to earlier. Earlier examples of this convention are provided by para. 232 of the now withdrawn US Financial Accounting Standards Board Statement #33: *Financial Reporting of Changing Prices* and the illustrative example provided in the Guidance Notes which accompany the (also withdrawn) U.K. Accounting Standards Committee's SSAP #16: *Current Cost Accounting*. However, it is not hard to contemplate situations in which this convention will lead to extremely poor estimates of purchasing power gains and losses. If an organisation operates under seasonal conditions – an ice-cream vendor, for example – then its monetary position at the height of the season ($m(\frac{1}{2})$)may bear little resemblance to its monetary position at the beginning ($m(0)$) and end of the season ($m(1)$). If, for example, the ice-cream vendor carries no monetary items out of season so that $m(0)=m(1)=0$ then the above formula estimates the purchasing power gain on his monetary items at nothing. However, since at the height of summer the ice-cream vendor has borrowed heavily to finance his trading activities, the purchasing power gain on his debt will be significant.

Table 3
Estimated loss in purchasing power on the monetary aggregate M1 for the UK economy (£bn of 31 December 2005 dollars)

	Degree of interpolation				
Year	*First* $bn	*Second* $bn	*Third* $bn	*Fourth* $bn	*IAS 29* $bn
1991	16.68	16.58	16.68	16.64	16.64
1992	5.94	5.92	5.95	5.94	5.85
1993	5.98	5.96	5.98	5.96	5.87
1994	5.40	5.36	5.39	5.37	5.22
1995	8.13	8.07	8.10	8.07	7.78
1996	6.82	6.78	6.83	6.82	6.67
1997	5.85	5.86	5.90	5.88	5.59
1998	5.95	5.90	5.99	5.98	5.76
1999	4.98	4.98	5.00	4.99	4.77
2000	3.70	3.70	3.74	3.73	3.45
2001	5.58	5.51	5.61	5.60	5.03
2002	9.23	9.20	9.24	9.23	9.25
2003	7.43	7.39	7.45	7.43	7.55
2004	10.91	10.90	10.95	10.92	10.72
2005	13.74	13.67	13.75	13.72	13.69

This table summarises annual estimates of the loss in purchasing power on the UK currency using the polynomial formulae, details of which are to be found in Table 1. The column headed 'first' estimates the purchasing power loss using the first-degree (linear) interpolation formula; the column headed 'second' estimates the purchasing power loss using the second-degree (quadratic) interpolation formula; the column headed 'third' estimates the purchasing power loss using the cubic interpolation formula; the column headed 'fourth' estimates the purchasing power loss using quartic interpolation. The column headed 'IAS 29' estimates the purchasing power loss using the procedures endorsed by IAS 29: *Financial Reporting in Hyperinflationary Economies*. Data for the monetary aggregate, M1, were downloaded from the Bank of England website while Consumer Price Index data were downloaded from the UK National Statistics Office website.

same as that for Table 2. Note how this table again shows that the four polynomial interpolation methods return almost identical estimates of the loss in purchasing power on the currency. However, when the IAS 29 procedures are applied to the UK data they return a lower estimate of the loss in purchasing power on the currency than is the case with the polynomial approximation methods in all but two years (2002 and 2003). This is in direct contrast to the US results, where the IAS 29 procedures consistently return higher estimates of the loss in purchasing power on the currency.

One might argue that the systematic differences observed in these two tables are of little consequence since the deviations between the annual estimates obtained under the IAS 29 procedures and the polynomial approximation techniques are relatively small. For the US data, estimates obtained using the polynomial approximation formulae vary by no more than 4% from estimates obtained under the IAS 29 procedures. For the UK data, there are two years (2000 and 2001) where differences in the estimates are in excess of 8%. In other years, however, the differences are generally much less than 5%. Here, one must remember however that these differences have arisen in what can only be described as modest inflationary environments. The average annual rate of inflation over the 15-year period ending 31 December 2005 was 2.6% for the US and a mere 2.1% for the UK. However, in the hyperinflationary environments envisaged by IAS 29 the cumulative rate of inflation over the previous three years will typically be of the order of 100% or more. It is questionable whether results obtained for the relatively low inflationary environments experienced in the US and UK can be replicated in the hyperinflationary environments envisaged by IAS 29. Given this, in the next section we use the data pertaining to 32 hyperinflationary economies and which between them encompass a wide variety of hyperinflationary environments covering a period of over eighty years, to make assessments about the relative efficiency of the procedures summarised in IAS 29 for estimating purchasing power gains and losses during hyperinflationary periods.

3. Data and empirical analysis

Our empirical analysis is based on the seven hyperinflations analysed by Cagan (1956) as well as a further 25 hyperinflationary economies for

Table 4
Summary statistics for hyperinflationary economies examined by Cagan (1956)

Country	*Purchasing power loss on the currency for year ended:*	*Average rate of inflation (per month)*	*First*	*Second*	*Third*	*Fourth*
Austria	August, 1922	0.50	0.7499	0.7427	0.7497	0.7412
Germany	November, 1923	38.04	0.0000	0.0000	0.0000	0.0000
Greece	October, 1944	10.16	0.0003	0.0003	0.0003	0.0003
Hungary (1)	February, 1924	0.40	1.1028	1.0933	1.0891	1.0906
Hungary (2)	July, 1946	3.49×10^{13}	0.0000	0.0000	0.0000	0.0000
Poland	January, 1924	0.77	0.0766	0.0745	0.0764	0.0742
Russia (1)	February, 1924	0.78	0.2011	0.2028	0.1998	0.2030
Russia (2)	February, 1923	0.28	0.5854	0.5819	0.5829	0.5834

The first and second columns in this table give the country and period over which the hyperinflation occurred. The third column summarises the average monthly rate of inflation over the duration of the given hyperinflation. Thus, the average rate of inflation for the Austrian economy in the year to August 1922 amounts to 50% (per month). Likewise, the average rate of inflation for the Polish economy in the year to January 1924 amounts to 77% (per month). The column headed 'first' gives the ratio of the estimated purchasing power loss based on the linear interpolation formula summarised in Table 1 to the estimate obtained using the IAS 29 procedures; the column headed 'second' gives the ratio of the estimated purchasing power loss based on the quadratic interpolation formula summarised in Table 1 to the estimate obtained using the IAS 29 procedures; the column headed 'third' gives the ratio of the estimated purchasing power loss based on cubic interpolation to the estimate obtained using the IAS 29 procedures; the column headed 'fourth' gives the ratio of the estimated purchasing power loss based on quartic interpolation to the estimate obtained using the IAS 29 procedures. The data on which this table is based are taken from Cagan (1956).

which data are available from the International Monetary Fund's website. Summary details of the hyperinflationary economies analysed by Cagan (1956) are contained in Table 4. Cagan (1956:26) shows that the first of these hyperinflations – namely, the Austrian hyperinflation – lasted for about a year and petered out towards the end of August 1922. The average rate of inflation over the year ending on this date was 50% (per month). The final four columns give the ratio of the estimated loss in purchasing power on the Austrian currency for the year ending August 1922 from applying the polynomial approximating formulae, to the estimated loss in purchasing power from applying the IAS 29 procedures. These ratios are all in the vicinity of 0.75, which implies that the estimates of the purchasing power loss using the polynomial approximating formulae are approximately 25% lower than the estimates obtained from using the IAS 29 procedures. Against this, Table 4 shows that the estimates of the loss in purchasing power on the Hungarian currency for the year ending February 1924 using the polynomial approximating formulae are about 9% larger than the estimated loss in purchasing power obtained from the IAS 29 procedures. With the exception of Russia, the other statistics summarised in Table 4 are to be interpreted in the same way as those for the Austrian and Hungarian hyperinflations. The Russian hyperinflation began in December 1921 and concluded approximately 26 months later in February 1924.[9] Given this, one can estimate the loss in purchasing power from holding the Russian currency for two annual periods. The first of these is for the year ending February 1923 for which the estimated losses in purchasing power under the polynomial approximating formulae are about 40% lower than the estimated purchasing power losses computed under the IAS 29 procedures. For the second of these periods – the year ending February 1924 – the estimated losses in purchasing power under the polynomial approximating formulae are about 80% lower than the estimated losses obtained from the IAS 29 procedures.

Overall, Table 4 shows that the IAS 29 procedures tend to return significantly larger estimates of the loss in purchasing power when compared with the polynomial approximating formulae. In six of the seven hyperinflations examined by Cagan (1956), Table 4 shows that the estimated loss in purchasing power on the currency is significantly lower under the polynomial approximating formulae than is the case with IAS 29 procedures. Indeed, for the German hyperinflation the polynomial estimate of the purchasing power loss on the currency is on average barely 0.000016% of the

[9] The other six hyperinflations summarised in Table 4 all lasted for around a year or less.

estimate obtained from the IAS 29 procedures whilst for the Hungarian hyperinflation which concluded in July 1946, the polynomial estimate is on average just $4.33 \times 10^{-20}\%$ of the estimate obtained from the IAS 29 procedures. The root cause of these gigantic differences appears to lie in the fact that with the exception of the Greek hyperinflation, the inflation rate for each country accelerates towards the end of the hyperinflationary period and the real currency on issue declines instantaneously and dramatically in response to it. In other words, organisations adjust their monetary holdings in response to changes in the inflation rate much more frequently than the once or twice a year scenario envisaged by the IAS 29 procedures. One can see this more clearly from Table 5, which summarises an index of the real currency on issue during each month as well as the monthly rate of inflation and the price index for the Hungarian hyperinflation, which endured over the year to July, 1946 (Cagan, 1956: 110–111). Note how this table shows that by October 1945, the real value of the currency on issue was just a fourth of what it had been in July 1945 and that by January 1946, it was an eighth of what it had been just six months' earlier. In other words, when the inflation rate is rapidly increasing organisations adjust their monetary holdings much more frequently than the one or two occasions envisaged by the IAS 29 procedures and so, they will more than likely return unreliable estimates of purchasing power losses as a consequence. The polynomial interpolating techniques, however, are based on the assumption that the real value of the currency on issue changes instantaneously in response to variations in the rate of inflation and therefore, they are unlikely to suffer from this problem. Given this, one should not be too surprised to see the large differences in the estimated purchasing power losses that are summarised in Table 4.[10]

Table 6 provides summary information relating to the 25 more recent hyperinflationary economies for which data are available from the International Monetary Fund's (IMF) website, http://www.imfstatistics.org/imf/. As with our estimates of the purchasing power losses for the UK and US, we take M1 to be the currency on issue (Lucas, 2000: 248–252) while the inflation rate over any given period is determined from the Consumer Price Index (CPI) for the particular country. The first two columns in Table 6 give the country and the period over which the hyperinflation was deemed

[10] Using the polynomial formulae summarised in Table 1 shows that our best estimate of the loss in purchasing power on the Hungarian currency for the year to July 1946 amounts to

$$\int_0^1 \frac{m(t)}{P(t)} \cdot d\log[P(t)] = 185.45$$

where the loss in purchasing power is stated in units of July 1946 purchasing power. Now, the weighted mean value theorem given earlier shows that the purchasing power loss has the following representation over this period:

$$\int_0^1 \frac{m(t)}{P(t)} \cdot d\log[P(t)] = \frac{m(0)}{P(0)} \cdot \frac{P(c) - P(0)}{P(c)} + \frac{m(1)}{P(1)} \cdot \frac{P(1) - P(c)}{P(c)}$$

where c is some generally unknown parameter that lies between zero and unity. This means that if one follows the usual convention of letting $c = \frac{1}{2}$ one obtains the following estimate of the purchasing power loss for the Hungarian hyperinflation under the IAS 29 procedures:

$$\int_0^1 \frac{m(t)}{P(t)} \cdot d\log[P(t)] = \frac{m(0)}{P(0)} \cdot \frac{P(\frac{1}{2}) - P(0)}{P(\frac{1}{2})} + \frac{m(1)}{P(1)} \cdot \frac{P(1) - P(\frac{1}{2})}{P(\frac{1}{2})} =$$

$$24.81 \times \frac{688.49 - 1}{688.49} + 0.08 \times \frac{3.81 \times 10^{27} - 688.49}{688.49}$$

or $24.77 + 4.29 \times 10^{23} = 4.29 \times 10^{23}$ in units of July 1946 purchasing power. From this it follows that the ratio of our best estimate of the purchasing power loss to the estimate of the purchasing power loss under the IAS 29 procedures is

$$\frac{185.45}{4.29 \times 10^{23}} = 4.33 \times 10^{-20}\%.$$

as stated in the text. Here, however, Table 5 shows that the average monthly rate of inflation for the six months ending in July, 1946 is 6.98×10^{13}, a figure that far exceeds the rates of inflation for the months of February, March, April, May and June, 1946. This shows that the distribution of the monthly rates of inflation is highly skewed and so a simple average of these rates of inflation provides a poor summary measure of the inflation rate over this period. Likewise, the inflation rate used to estimate purchasing power losses under IAS 29 over the six months ending in July, 1946 – namely,

$$\frac{P(\frac{1}{2}) - P(0)}{P(\frac{1}{2})} = \frac{3.81 \times 10^{27} - 688.49}{688.49} = 4.29 \times 10^{23}$$

– will also be a poor reflection of the rate of inflation over this period and will lead to the enormous errors documented for the Hungarian hyperinflation summarised in Table 4. We have previously shown, however, that one can address this problem by letting the unknown parameter $c \to 1$. Given this one can base the estimate of the loss in purchasing power in the Hungarian currency on the price index at the beginning of August 1945 (time zero), the price index at the end of June, 1946 (thereby setting $c = \frac{11}{12}$) and the price index at the end of July 1946 (time one). Using the data summarised in Table 5 we then have the following estimate of the purchasing power loss for the Hungarian hyperinflation:

$$\frac{m(0)}{P(0)} \cdot \frac{P(\frac{11}{12}) - P(0)}{P(\frac{11}{12})} + \frac{m(1)}{P(1)} \cdot \frac{P(1) - P(\frac{11}{12})}{P(\frac{11}{12})} =$$

$$24.81 \times \frac{9.08 \times 10^{12} - 1}{9.08 \times 10^{12}} + 0.08 \times \frac{3.81 \times 10^{27} - 9.08 \times 10^{12}}{9.08 \times 10^{12}}$$

or $24.81 + 3.25 \times 10^{13} = 3.25 \times 10^{13}$ in units of July, 1946 purchasing power. While this estimate is about half the figure obtained under the IAS 29 procedures (where, it will be recalled $c = \frac{1}{2}$), it is still substantially larger than our best estimate of the purchasing power loss (185.45) given earlier. This reflects the fact that the rate of inflation for July 1946 is gigantic when compared to the rates of inflation for the other months in the year ending in July 1946. This in turn means that the parameter c will have to be very close to but not quite equal to unity if the weighted mean value formula is to give a reliable estimate of the purchasing power loss for the Hungarian hyperinflation.

Table 5
Monthly inflation rates and index of real currency on issue for Hungarian hyperinflation ending in July 1946

Month	*Rate of inflation (per month)*	*Price index* $[P(t)]$	*Real currency* $[\frac{m(t)}{P(t)}]$
July, 1945	0.37	1.00	24.81
August	0.63	1.63	21.94
September	1.22	3.61	16.37
October	5.41	23.14	6.17
November	4.35	123.79	3.82
December	2.19	395.18	2.58
January, 1946	0.74	688.49	3.20
February	5.03	4,152.41	1.88
March	3.29	17,807.38	3.17
April	18.15	340,957.30	2.83
May	314.65	1.08×10^8	2.01
June	84,410.19	9.08×10^{12}	3.15
July	4.19×10^{14}	3.81×10^{27}	0.08

The first column in the table gives the month and year of the Hungarian hyperinflation, which concluded in July 1946. The second column gives the rate of inflation during the given month. Thus, the rate of inflation for the month of July, 1945 was 37% and the rate of inflation for the month of April 1946 was 1,815%. The third column summarises the price index constructed from the inflation rates given in the second column. Thus, the price index for the end of August 1945 is one plus the inflation rate during August 1945 or 1.63. The price index for September 1945 is one plus the inflation rate for September, 1945 multiplied by the price index for August, 1945 or $2.22 \times 1.63 = 3.61$. Likewise, the price index for October 1945 is one plus the inflation rate for October 1945 multiplied by the price index for September 1945 or $6.41 \times 3.61 = 23.14$. Finally, the last column is an index of the real currency on issue during the given month.

to have occurred. In conformity with para. 3 of IAS 29, a hyperinflationary period was deemed to commence at the beginning of any three-year period for which the accumulated rate of inflation exceeded 100%. The hyperinflationary period was deemed to have concluded at the end of any three-year period for which the accumulated rate of inflation had fallen below 100%. Thus, under these criteria the Argentinean hyperinflation was deemed to have commenced at the beginning of 1971 and continued for 23 years before petering out at the end of 1993. The next four columns give the average annual rate of inflation, the standard deviation of the annual rate of inflation and the minimum and maximum annual rates of inflation over this 23-year hyperinflationary period. This shows that the average rate of inflation during the Argentinean hyperinflation was 447.68% (per annum); that the standard deviation of the annual rate of inflation rate was 996.22%; that the maximum rate of inflation during this period was 4,923.32% (per annum) whilst the minimum rate of inflation was 7.36% (per annum). The other statistics summarised in Table 6 are to be interpreted in the same way as those for the Argentinean hyperinflation. Here we also need to emphasise that the data for some countries are incomplete (e.g. Democratic Republic of Congo, Russia and Zimbabwe among others) and that this placed limits on the extent to which the relevant hyperinflations could be analysed.

Table 7 summarises the relative loss in purchasing power on the currency on issue for each of the 25 hyperinflationary economies for which data are available from the IMF website under the four polynomial approximating techniques as compared to those obtained from the simple IAS 29 estimation procedures. The first two columns in this table identify the country and duration of the hyperinflation. The third column summarises the number of years over which our analysis is based. Hence, for Argentina our analysis covers the 23-year period from 1971 to 1993. The next two columns give the median of the ratio of the loss in purchasing power from using the polynomial approximating techniques to the loss in purchasing power as calculated from the IAS 29 procedures. Thus, for the Argentinean hyperinflation the 23 ratios are ordered from smallest to largest for each of the four polynomial approximating techniques. The twelfth ordered ratio is the median and it is this statistic which is reported in Table 7 for each polynomial technique. Thus, these results show that for the Argentinean hyperinflation the median estimate of the purchasing power loss for the polynomial approximating techniques is about 10%

Table 6
Summary statistics for hyperinflationary economies with data available on the International Monetary Fund (IMF) website: http://www.imfstatistics.org/imf/

Country	*Period of hyperinflation*	*Average rate of inflation (per annum)*	*Standard deviation of rate of inflation*	*Maximum rate of inflation*	*Minimum rate of inflation*
Angola	1996–2005	2.7065	4.6465	16.5011	0.1853
Argentina	1971–1993	4.4768	9.9622	49.2332	0.0736
Belarus	1995–2003	1.1034	0.8637	2.5120	0.2540
Bolivia	1979–1988	11.1654	24.3383	81.7052	0.1066
Brazil	1980–1996	6.4424	7.3473	24.7714	0.0956
Chile	1968–1976	1.9008	1.8264	5.5862	0.1940
Congo, De R.	1976–1995	11.5316	24.2986	97.9689	0.1433
Dominican Re	1989–1991	0.4081	0.2973	0.7992	0.0790
Ecuador	1984–2002	0.4054	0.2143	0.9100	0.0936
Estonia	1993–1995	0.3537	0.0643	0.4165	0.2653
Israel	1974–1987	1.1032	1.1300	4.4488	0.1610
Jamaica	1991–1994	0.4433	0.2129	0.8019	0.2679
Madagascar	1994–1996	0.3560	0.2164	0.6122	0.0828
Mexico	1986–1990	0.7324	0.5225	1.5916	0.1970
Nicaragua	1988–1993	66.8353	90.8414	240.3105	0.0352
Peru	1976–1994	7.0490	17.7508	76.4975	0.1538
Poland	1990–1995	0.6995	0.7076	2.2587	0.2195
Romania	1994–2002	4.1650	0.3723	1.5142	0.1784
Russia	1998–2000	0.4704	0.2724	0.8438	0.2018
Suriname	1992–2002	1.0634	1.6377	5.8648	0.0122
Turkey	1977–2003	0.5912	0.2346	1.2025	0.1613
Ukraine	1993–1997	21.5756	40.0113	101.5503	0.1012
Uruguay	1976–1996	0.5866	0.2486	1.2895	0.2053
Venezuela	1987–1998	0.5002	0.2241	1.0324	0.2991
Zimbabwe	1998–2001	0.6771	0.2591	1.1207	0.4663

The first and second columns in the table give the country and period over which the hyperinflation occurred. The third and fourth columns summarise the average annual rate of inflation and the standard deviation of the annual rate of inflation over the duration of the given hyperinflation. Thus, the average annual rate of inflation for the Mexican economy was 73.24% with a standard deviation of 52.25%. The fifth and sixth columns give the maximum and minimum annual rates of inflation over the period of the hyperinflation.

lower than the purchasing power loss computed under the IAS 29 procedures. Furthermore, one can average the four polynomial estimates of the purchasing power loss and then divide this average by the estimate of the purchasing power loss obtained from the IAS 29 procedures. The final two columns give the number of these (average) ratios that are less than one and the number that exceed unity. Hence, for the 23 years on which our analysis of the Argentinean hyperinflation is based, there are 20 years in which this (average) ratio is less than one and only three years in which the (average) ratio exceeds one. The other statistics summarised in Table 7 are to be interpreted in the same way as those for the Argentinean hyperinflation.

Probably the most striking characteristic displayed by Table 7 is that for all but one country (namely, Belarus), the median ratios are less than unity. Indeed, of the 272 country-years on which Table 7 is based, there are 229 occasions on which the ratio of the estimated purchasing power loss from the polynomial approximating formulae to the estimated loss under the IAS 29 procedures is less than unity, and only 43 occasions where the ratio exceeds unity. Moreover, a simple sign test rejects the null hypothesis that the median ratio for the 'population' of hyperinflationary economies is equal to unity at any reasonable level of significance [Conover (1971:121–126)]. This, of course, is compatible with the hypothesis that the polynomial-based formulae will tend to return lower estimates of purchasing power losses than will be the case with the IAS 29 procedures.

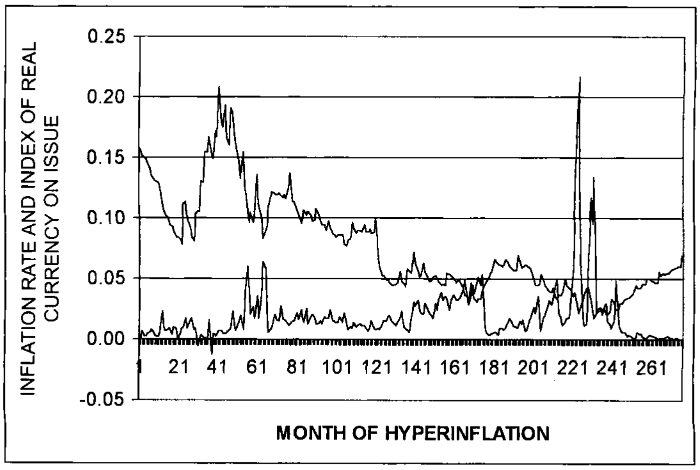
Here it is important to note, however, that for the more recent hyperinflationary economies extracted from the IMF website, the differences between the polynomial-based approximations of the purchasing power loss and those based on the IAS 29

Table 7
Median ratio of the average of four polynomial estimates to the IAS 29 estimate of the annual purchasing power loss for hyperinflationary economies with data available on the International Monetary Fund (IMF) website: http://www.imfstatistics.org/imf/

Country	*Period of hyperinflation*	*# Observations*	*First*	*Second*	*Third*	*Fourth*	*Ratios < 1*	*Ratios > 1*
Angola	1996–2005	10	0.8210	0.8161	0.8135	0.8147	9	1
Argentina	1971–1993	23	0.8909	0.9021	0.8975	0.9035	20	3
Belarus	1995–2003	9	1.0239	1.0221	1.0217	1.0225	3	6
Bolivia	1979–1988	10	0.8647	0.8652	0.8647	0.8667	9	1
Brazil	1980–1996	17	0.8183	0.8139	0.8077	0.8122	15	2
Chile	1968–1976	9	0.9770	0.9834	0.9752	0.9853	6	3
Congo, De R.	1976–1995	20	0.9430	0.9445	0.9403	0.9428	13	7
Dominican Re	1989–1991	3	0.8807	0.8788	0.8790	0.8781	3	0
Ecuador	1984–2002	19	0.9190	0.9133	0.9155	0.9117	16	3
Estonia	1993–1995	3	0.9556	0.9555	0.9553	0.9567	3	0
Israel	1974–1987	14	0.9719	0.9740	0.9655	0.9755	9	5
Jamaica	1991–1994	4	0.9531	0.9487	0.9486	0.9468	3	1
Madagascar	1994–1996	3	0.9719	0.9743	0.9724	0.9769	3	0
Mexico	1986–1990	5	0.8494	0.8461	0.8477	0.8455	5	0
Nicaragua	1988–1993	6	0.9730	0.9661	0.9677	0.9602	4	2
Peru	1976–1994	19	0.9174	0.9175	0.9177	0.9181	19	0
Poland	1990–1995	6	0.9489	0.9467	0.9485	0.9466	4	2
Romania	1994–2002	9	0.8427	0.8392	0.8397	0.8394	9	0
Russia	1998–2000	3	0.9383	0.9365	0.9364	0.9369	3	0
Suriname	1992–2002	11	0.9797	0.9754	0.9808	0.9759	8	3
Turkey	1977–2003	27	0.8050	0.7984	0.8028	0.7958	27	0
Ukraine	1993–1997	5	0.9478	0.9441	0.9428	0.9428	4	1
Uruguay	1976–1996	21	0.8833	0.8773	0.8814	0.8779	21	0
Venezuela	1987–1998	12	0.9028	0.9014	0.8977	0.9012	11	1
Zimbabwe	1998–2001	4	0.9865	0.9855	0.9859	0.9843	2	2
TOTALS		272					229	43

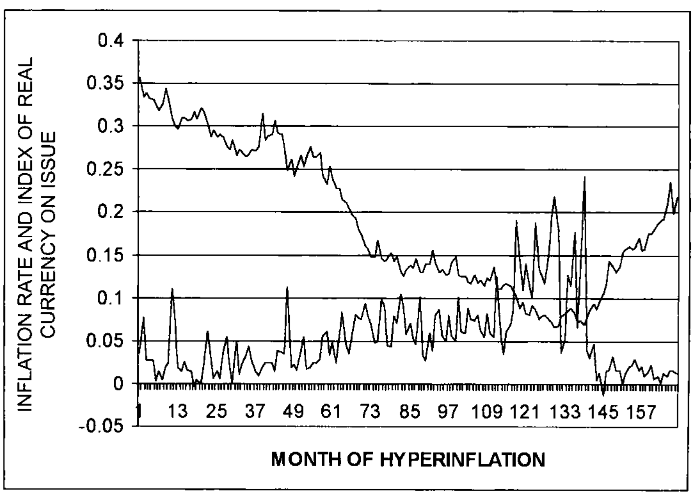
The first, second and third columns in the table give the country, the period and the number of years over which the hyperinflation occurred. The column headed 'first' gives the median ratio of the estimated purchasing power loss based on the linear interpolation formula summarised in Table 1 to the estimate obtained using the IAS 29 procedures; the column headed 'second' gives the median ratio of the estimated purchasing power loss based on the quadratic interpolation formula summarised in Table 1 to the estimate obtained using the IAS 29 procedures; the column headed 'third' gives the median ratio of the estimated purchasing power loss based on cubic interpolation to the estimate obtained using the IAS 29 procedures; the column headed 'fourth' gives the median ratio of the estimated purchasing power loss based on cubic interpolation to the estimate obtained using the IAS 29 procedures. The penultimate column gives the number of observations for which the simple average of the first, second, third and fourth interpolating ratios for each year is less than unity. The final column gives the number of observations for which the simple average of the first, second, third and fourth interpolating ratios for each year exceeds unity.

Figure 1
Index of real currency on issue and monthly rate of inflation for Argentinean economy from January 1971 (month 1) until December 1993 (month 276)



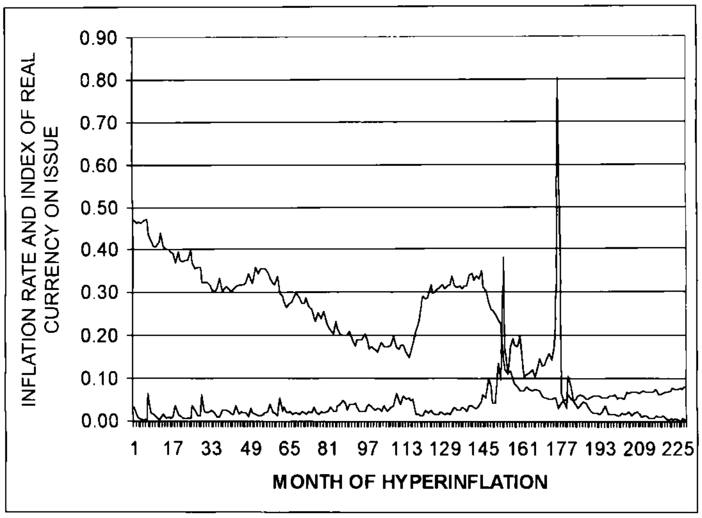
The data series that starts at just above 0.15 at month zero and then gradually declines is an index of the real currency on issue. The data series that begins at just above the origin at time zero and then gradually increases is the continuously compounded monthly rate of inflation divided by 5. The currency on issue series was extracted from line 34 of the International Monetary Fund's database, http://www.imfstatistics.org/imf/. The Consumer Price Index series was extracted from line 64 of the IMF's database.

Figure 2
Index of real currency on issue and monthly rate of inflation for Israeli economy from January 1974 (month 1) until December 1987 (month 168)



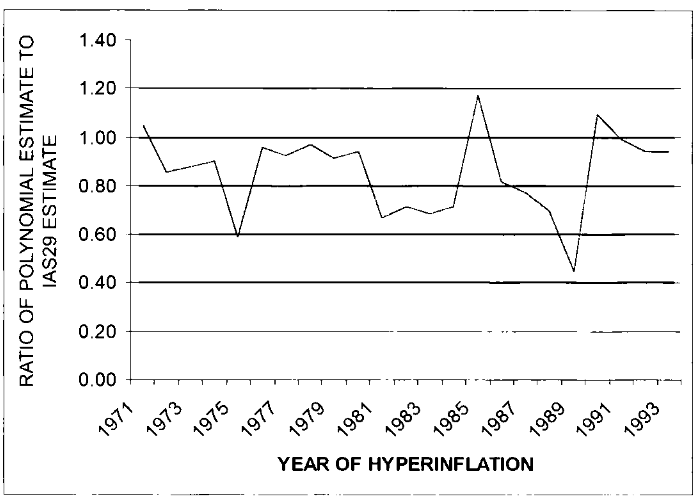
The data series that starts at just above 0.35 at month zero and then gradually declines is an index of the real currency on issue. The data series that begins at just below 0.05 at time zero and then gradually increases is the continuously compounded monthly rate of inflation. The currency on issue series was extracted from line 34 of the International Monetary Fund's database, http://www.imfstatistics.org/imf/. The Consumer Price Index series was extracted from line 64 of the IMF's database.

Figure 3
Index of real currency on issue and monthly rate of inflation for Peruvian economy from January 1976 (month 1) until December 1994 (month 228)



The data series that starts at just below 0.50 at month zero and then gradually declines is an index of the real currency on issue. The data series that begins just above the origin at time zero and then gradually increases is the continuously compounded monthly rate of inflation divided by two. The currency on issue series was extracted from line 34 of the International Monetary Fund's database, http://www.imfstatistics.org/imf/. The Consumer Price Index series was extracted from line 64 of the IMF's database.

Figure 4
Ratio of the average of four polynomial estimates to the IAS 29 estimate of the annual purchasing power loss on the Argentinean currency from 1971 to 1993



This graph depicts the ratio of two data series. The first is based on the four estimates of the purchasing power loss on the Argentinean currency using the polynomial formulae summarised in Table 1. For each year, the four estimates obtained from these formulae are averaged to give the first data series. The second data series estimates the purchasing power loss using the IAS 29 procedures. The graph summarises the ratio of the average polynomial estimate to the IAS 29 estimate of the purchasing power loss for each year of the Argentinean hyperinflation.

procedures are much smaller than is the case for the earlier hyper-inflations examined by Cagan (1956).[11] We have previously noted that the principal reason for this is that the hyperinflations examined by Cagan (1956) were characterised by rapidly increasing rates of inflation that reached a crescendo over a short period of time (typically one to two years or less) and then quickly petered out. Moreover, during this period of rapidly increasing inflation there is a precipitous decline in the real value of the currency on issue. The more recent IMF hyperinflations in contrast have tended to be of much longer duration (typically five to 20 years) and the real value of the currency on issue has tended to decline much more slowly for the IMF hyperinflations than is the case with the Cagan (1956) hyperinflations. This is illustrated by Figures 1, 2 and 3, which graph the time series of an index of the real currency on issue and the monthly rate of inflation for the Argentinean, Israeli and Peruvian hyperinflations, respectively. These graphs, which are typical of the 25 hyperinflations for which data are available from the IMF web site show that the rate of decline in the index of real currency on issue is quite modest when compared to the 'equivalent' data for the Hungarian hyperinflation of 1945 and 1946 examined by Cagan (1956), details of which are summarised in Table 5. This means that for the IMF hyperinflations the beginning of the year and end of year figures for the real value currency on issue (and their associated inflation rates) are much more likely to be 'representative' of their values over the entire year than will be the will be the case for the Cagan (1956) hyperinflations. Hence, it is more likely that the IAS 29 procedures, which are based on just these two observations of the real value of the currency on issue (and their associated inflation rates), will provide more reliable estimates of the purchasing power losses from inflation than is the case when it is applied to the 'short, sharp' hyperinflations examined by Cagan (1956). Against this, it must be emphasised that even for the IMF hyperinflations summarised in Table 7 the IAS 29 procedures appear to return estimated purchasing power losses that typically, are 10% higher than those obtained from using the four polynomial approximation formulae summarised in Table 1.

However, even for the IMF hyperinflations there is a great deal of variation in the data. For the Argentinean hyperinflation, the ratio of the average of the four polynomial estimates of the purchasing power loss to the purchasing power loss obtained from the IAS 29 procedures varies from 0.4469 in 1989 to 1.1744 in 1985. The complete time series of this ratio for the Argentinean hyperinflation is displayed in Figure 4. Likewise, for the Israeli hyperinflation this ratio varies from 0.7954 in 1984 to 1.0754 in 1986. Again, the complete time series of this ratio for the Israeli economy is displayed in Figure 5. Finally, for the Peruvian hyperinflation, the ratio of the average of the four polynomial estimates of the purchasing power loss to the purchasing power loss obtained from the IAS 29 procedures varies from 0.2592 in 1990 to 0.9962 in 1994. The complete time series of this ratio for the Peruvian economy is displayed in Figure 6. Hence, while the IAS 29 procedures return median estimates of the purchasing power loss that is approximately 10% higher than those obtained from the polynomial approximating formulae, the variation in the difference between the estimates is generally large. In other words, while there might be little difference in the estimates obtained from the polynomial approximating formulae and the IAS 29 procedures in any given year, in a contiguous year the polynomial based estimates can be less than half the estimate obtained from the IAS 29 procedures.

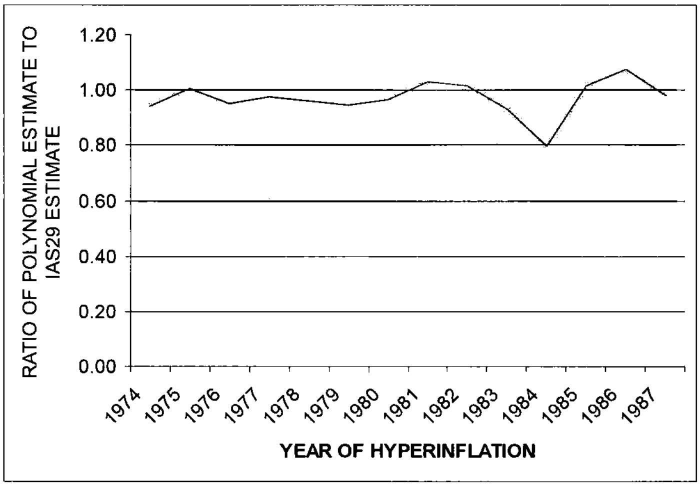
4. A general 'two-point' formula

The most obvious way of addressing this issue of the unreliability of simple estimation procedures (as summarised in IAS 29) is to employ more robust (sophisticated) estimating formulae. There are two possibilities here. First, one can sample an organisation's monetary position and the inflation rate more frequently than just the one or two observations needed to implement the IAS 29 procedures. For example, if an organisation had monthly observations of both its monetary position and the rate of inflation, then its purchasing power gains and losses could be more reliably estimated using the low order polynomial formulae summarised in Table 1. The principal difficulty here, however, is that organisations would have to prepare detailed financial statements more frequently than is normally the case and this will be a costly exercise that most organisations will want to avoid. Fortunately, there is a second alternative.

This second alternative makes more realistic assumptions about the way an organisation's monetary holdings vary over time. Here Cagan (1956:31) notes that 'the only cost of holding cash balances that seems to fluctuate widely enough to account for the drastic changes in real cash balances during hyperinflations is the rate of depreciation in the value of money ...' Given this, it is probably reasonable to assume that for the hyper-

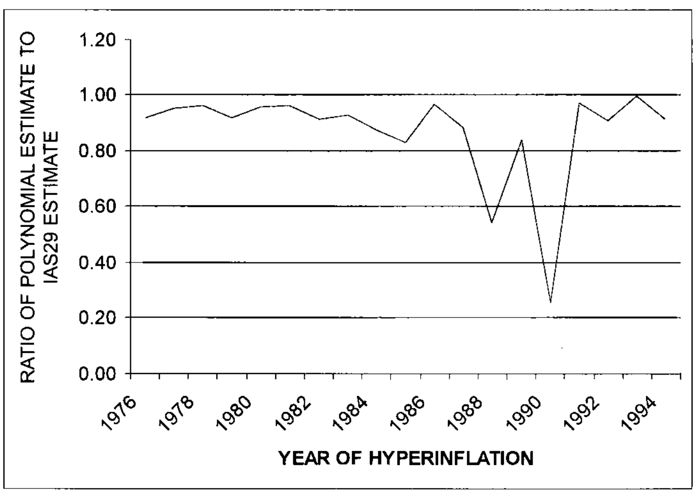
[11] Except for the Hungarian hyperinflation, which petered out in February 1924, Table 4 shows that the median ratios for the polynomial approximations to the estimates obtained from the IAS 29 procedures are all less than 0.75. While Table 7 shows that with one exception (Belarus) the equivalent ratios for the post-war hyperinflations are all less than unity, they are nonetheless much higher than the 0.75 recorded for the 'highest' median ratio for the Cagan (1956) hyperinflations.

Figure 5
Ratio of the average of four polynomial estimates to the IAS 29 estimate of the annual purchasing power loss on the Israeli currency from 1974 to 1987



This graph depicts the ratio of two data series. The first is based on the four estimates of the purchasing power loss on the Israeli currency using the polynomial formulae summarised in Table 1. For each year, the four estimates obtained from these formulae are averaged to give the first data series. The second data series estimates the purchasing power loss using the IAS 29 procedures. The graph summarises the ratio of the average polynomial estimate to the IAS 29 estimate of the purchasing power loss for each year of the Israeli hyperinflation.

Figure 6
Ratio of the average of four polynomial estimates to the IAS 29 estimate of the annual purchasing power loss on the Peruvian currency from 1976 to 1994



This graph depicts the ratio of two data series. The first is based on the four estimates of the purchasing power loss on the Peruvian currency using the polynomial formulae summarised in Table 1. For each year, the four estimates obtained from these formulae are averaged to give the first data series. The second data series estimates the purchasing power loss using the IAS 29 procedures. The graph summarises the ratio of the average polynomial estimate to the IAS 29 estimate of the purchasing power loss for each year of the Peruvian hyperinflation.

inflationary economies examined in our empirical work the single most important determinant of an organisation's investment in monetary items will be the persistent eating away of the purchasing power of the currency due to inflation. Now, as P(t) is the price level at time t, it follows that $x(t) = \frac{1}{P(t)}$ represents the 'purchasing power' of the currency at this time. Moreover, one can define the variable, $z(t) = -\log[G(x(t))]$, as the logarithm of an arbitrary function, G(x(t)), of the purchasing power of the currency. Differentiating through z(t) shows:

$$\frac{dz(t)}{dt} = -\frac{dz}{dG}\cdot\frac{dG}{dx}\cdot\frac{dx}{dP}\cdot\frac{dP}{dt} = \frac{G'(x)}{G(x)}\cdot\frac{P'(t)}{P^2(t)}$$

or equivalently:

$$P(1)\int_0^1 \frac{G'(x)}{G(x)}\cdot\frac{P'(t)}{P^2(t)}dt = -P(1).\log[G(x(t))]_0^1 =$$

$$P(1).\log\left\{\frac{G(\frac{1}{P(0)})}{G(\frac{1}{P(1)})}\right\}$$

This result shows that if the nominal value of an organisation's investment in monetary items amounts to $m(x) = \frac{G'(x)}{G(x)}$ at time t, then the loss in purchasing power over the unit time period can be stated in terms of the logarithm of the function, G(x). In principle, this means that one only requires the organisation's beginning and end of period investment in monetary items as well as the price index at these two points in order to determine the purchasing power losses which arise in any given period.

One can illustrate the application of this result by following the IAS 29 procedure for estimating purchasing power gains and losses which, it will be recalled, is based on the premise that an organisation's monetary position changes on just a few (typically, one or two) occasions over an annual reporting period. In between these changes, the organisation's monetary position is assumed to remain constant. Given this, suppose an organisation maintains a nominal £1 investment in monetary items over an entire reporting period. This in turn implies that $m(x) = \frac{G'(x)}{G(x)} = 1$ or that $\log[G(x)] = x$. It then follows from the above result that the loss in purchasing power must be:

$$P(1)\int_0^1 \frac{G'(x)}{G(x)}\cdot\frac{P'(t)}{P^2(t)}dt = -P(1)[x]_0^1 = \frac{P(1) - P(0)}{P(0)}$$

In other words, the loss in purchasing power from investing one pound in monetary items over the entire reporting period will, as one might have expected, be given by the rate of inflation over this period.[12]

We have previously noted, however, that during hyperinflationary periods it is most unlikely that organisations will adjust their monetary holdings on just the few occasions on which the IAS 29 procedures for estimating purchasing power losses are based. Rather, as the hyperinflation gains in intensity organisations will become ever more vigilant in pruning their monetary holdings to the minimum compatible with maintaining their ongoing activities. Given this, we now assume that an organisation responds to the deteriorating hyperinflationary environment in which it has to operate by gradually reducing the real value of its monetary holdings. Thus, suppose that the real value of an organisation's investment in monetary items evolves in terms of the hyperbolic relationship $\frac{m(t)}{P(t)} = \frac{a}{P(t)} + b$ where a and b are parameters. Note that as the hyperinflation gains in intensity and the price level, P(t), rises, this assumption implies that the real value of the organisation's investment in monetary items asymptotically declines towards the minimum, b, compatible with maintaining its ongoing activities. This also means that $\frac{G'(x)}{G(x)} = a + \frac{b}{x}$ or $\log[G(x)] = ax + b\log(x)$ and so, the loss in purchasing power on the organisation's monetary holdings will be:

$$P(1)\int_0^1 \frac{G'(x)}{G(x)}\cdot\frac{P'(t)}{P^2(t)}dt = -P(1)[ax + b\log(x)]_0^1 =$$

$$a.\frac{P(1) - P(0)}{P(0)} + b.P(1).\log[\frac{P(1)}{P(0)}]$$

[12] One could also implement this procedure by taking the alternative approach of assuming that real monetary holdings are inversely related to the instantaneous rate of inflation (Cagan, 1956: 33–35, Lucas, 2000: 250–251). It is not hard to show, however, that this alternative procedure is compatible with the approach taken in the text. Recall that under the interpretation of the "two-point" formula taken in the text real monetary holdings are assumed to be of the form

$$\frac{m(t)}{P(t)} = \frac{1}{P(t)},$$

that is, m(t) is normalised to unity for illustrative purposes. This means that if one follows Cagan (1956:33–35) in assuming that the *logarithm of real monetary holdings must also be* inversely proportional to the rate of inflation or,

$$\log[\frac{1}{P(t)}] = -\alpha.\frac{1}{P(t)}\cdot\frac{dP(t)}{dt}$$

where $\alpha > 0$ is the constant of proportionality, that the index of prices will have to satisfy the differential equation

$$\log[P(t)] = \alpha.\frac{1}{P(t)}\cdot\frac{dP(t)}{dt}.$$

Solving this differential equation shows that the two approaches are compatible when the price index evolves in accordance with the equation $P(t) = P(0)\exp[e^{\alpha^{-1}t}]$.

This 'hyperbolic' formula requires as inputs the opening and closing values of the price index, P(t), and the parameters a and b that describe the way in which the organisation's real monetary holdings change in response to the declining purchasing power of the currency. Hence, provided the parameters a and b are known (or can be reliably estimated), then all that is required to implement this formula is the opening and closing values of the price index, P(t).[13]

One can illustrate the application of this hyperbolic formula by applying it to the data of the 25 hyperinflationary economies for which data are available from the IMF website. For each year of the hyperinflation in a given country the parameters a and b were estimated using the OLS regression procedure. Thus, for the Argentinean hyperinflation a and b were estimated in the first instance by using the 12 monthly observations of m(t) and P(t) for the year ending 31 December 1971. These estimates of a and b were then used in conjunction with the (opening) price index on 31 December 1970 and (closing) price index on 31 December 1971 to estimate the purchasing power loss on the currency using the hyperbolic formula. This procedure was also replicated for each of the 23 years for which the Argentinean hyperinflation lasted. For each year of the hyperinflation, we then computed the ratio of the estimated purchasing power loss under the hyperbolic formula to the average of the four estimates obtained from using the polynomial-based formulae summarised in Table 1.[14] The results of this exercise, summarised in Table 8a, show that the median ratio across the 23 observations available for the Argentinean hyperinflation is 1.0075. Moreover, the maximum of these 23 ratios is 1.0696 and occurs in 1990 while the minimum ratio of 0.7914 occurs in 1988. The summary information reported in Tables 8a and 8b for the other 24 hyperinflationary economies for which data are available from the IMF website are to be interpreted in the same way as those for the Argentinean hyperinflation.

The results summarised in Table 8a and Table 8b show that for most countries in our sample the hyperbolic formula returns estimated purchasing power losses that are very close to those obtained from the polynomial formulae. With the exception of Turkey, the median estimates of the purchasing power losses under the hyperbolic formula are all within 2.5% of the median estimates obtained from the polynomial-based formulae. Furthermore, there is substantial consistency across the estimates with most of the ratios summarised in Table 8 closely packed around unity. Thus, these results show that if realistic assumptions can be made about the way monetary items vary in response to changes in the purchasing power of the currency, then over any given period it is possible to make reliable estimates of the purchasing power losses that arise on the currency with as few as two observations.

The importance of making realistic assumptions about the way monetary holdings respond to variations in the purchasing power of the currency is highlighted by the Turkish hyperinflation. For Turkey, the median ratio of the estimated loss under the hyperbolic formula to the average of the estimated losses under the polynomial formulae is 1.0906. This means that the hyperbolic formula returns estimated purchasing power losses that typically, are around 9% larger than the estimates obtained from the polynomial-based formulae. In other words, for Turkey the assumption of hyperbolic variations in the real currency on issue returns significantly different estimates of purchasing power losses when compared to those obtained under the polynomial formulae and as such, do not represent a realistic model of how monetary holdings adjust in response to variations in the purchasing power of the currency on issue.[15]

[13] Again, one could implement the interpretation of the 'two-point' formula taken here by assuming that real monetary holdings are inversely related to the instantaneous rate of inflation. To provide a second example of the procedures involved, however, we now follow Lucas (2000:250–251) in assuming that real monetary holdings are inversely proportional to the square root of the rate of inflation or,

$$\frac{P(t)}{m(t)} = \alpha\sqrt{\frac{1}{P(t)}\cdot\frac{dP(t)}{dt}}$$

where $\alpha > 0$ is the constant of proportionality. Now, since the hyperbolic interpretation of the "two-point" formula given in the text assumes that real monetary holdings evolve in accordance with the formula

$$\frac{m(t)}{P(t)} = \frac{a}{P(t)} + b$$

it follows that the price index will have to satisfy the differential equation

$$\alpha\sqrt{\frac{1}{P(t)}\cdot\frac{dP(t)}{dt}} = \frac{P(t)}{a + bP(t)}.$$

Solving this differential equation shows that the two approaches are compatible when the price index evolves in accordance with the equation

$$\frac{P(t)}{P(0)}\cdot\frac{\exp[\frac{1}{2}\{\frac{a + 2bP(0)}{bP(0)}\}^2]}{\exp[\frac{1}{2}\{\frac{a + 2bP(t)}{bP(t)}\}^2]} = \exp(\frac{t}{b^2\alpha^2}).$$

[14] Since we have previously argued that purchasing power losses computed from the polynomial-based formulae are more reliable than those obtained under the procedures endorsed in IAS 29, it follows that estimates obtained from the polynomial formulae are the appropriate benchmark to use here.

[15] Turkey is unique in that we were unable to find an intertemporally consistent functional relationship between the real value of the currency on issue and the purchasing power of the Turkish lira. While there are functional forms that provide a satisfactory fit between these two variables over various subperiods, it appears that no one functional form provides a satisfactory fit over the entire period on which our analysis is based. This has the important implication that a simple 'two-point' formula for estimating the purchasing power losses on the currency may not exist for Turkey.

Table 8a
Ratio of the estimated loss on the currency under the 'hyperbolic' formula to the average estimated loss from the four polynomial-based formulae, by country and period of hyperinflation for hyperinflationary economies with data available on the international monetary fund (IMF) website: http://www.imfstatistics.org/imf/

Country/year	*ANGOL*	*ARGEN*	*BELAR*	*BOLIV*	*BRAZI*	*CHILE*	*CONG*	*DOMIN*	*ECUA*	*ESTON*	*ISRAE*	*JAMAI*	*MADA*
1968						1.0116							
1969						1.0100							
1970						1.0093							
1971		0.9922				1.0048							
1972		0.9770				1.0493							
1973		1.0252				1.0017							
1974		0.9749				0.9982					1.0026		
1975		1.0237				0.9908					0.9997		
1976		1.0447				0.9958	1.0000				1.0036		
1977		1.0031					0.9985				0.9970		
1978		1.0081					0.9942				1.0055		
1979		1.0028		0.9963			1.0160				1.0005		
1980		1.0063		1.0032	1.0105		1.0056				0.9982		
1981		1.0478		0.9842	1.0152		0.9962				0.9925		
1982		0.9820		1.0028	1.0081		0.9815				0.9961		
1983		1.0069		1.0064	1.0058		0.9307				0.9935		
1984		1.0019		0.9558	1.0091		0.5242		1.0049		1.0081		
1985		1.0356		0.5433	1.0067		0.9946		0.9961		1.0239		
1986		1.0130		0.9873	1.0683		1.0086		1.0297		0.9726		
1987		1.0256		1.0038	1.0188		1.0149		1.0141		0.9985		
1988		1.0270		1.0217	0.9878		1.0005		1.0126				
1989		0.7914			0.9856		0.9858	1.0079	1.0038				
1990		0.8526			1.3373		0.9809	0.9994	1.0095				
1991		1.0696			1.0397		1.0373	1.0218	1.0144			1.0069	
1992		1.0075			0.9715		1.0251		1.0239	1.0033		1.0128	
1993		1.0216			0.9409		1.0296		1.0113	0.9978		0.9982	
1994					0.8862		1.2761		1.0199	1.0041		1.0143	0.9750
1995			0.9972		1.0347		0.9953		1.0049				1.0015
1996	0.9145		1.0037		1.0174				1.0134				0.9749
1997	0.8997		0.9986						1.0041				
1998	1.0498		0.9646						1.0275				
1999	1.0255		1.0126						1.0724				
2000	1.0014		0.9971						1.0090				

Table 8a
Ratio of the estimated loss on the currency under the 'hyperbolic' formula to the average estimated loss from the four polynomial-based formulae, by country and period of hyperinflation for hyperinflationary economies with data available on the international monetary fund (IMF) website: http://www.imfstatistics.org/imf/ *(continued)*

Country/year	*ANGOL*	*ARGEN*	*BELAR*	*BOLIV*	*BRAZI*	*CHILE*	*CONG*	*DOMIN*	*ECUA*	*ESTON*	*ISRAE*	*JAMAI*	*MADA*
2001	0.9782		1.0187						0.9987				
2002	1.0134		1.0079						1.0003				
2003	1.0295		1.0047										
2004	1.0246												
2005	1.0116												
MEDIAN	1.0125	1.0075	1.0037	0.9995	1.0091	1.0048	0.9993	1.0079	1.0113	1.0033	0.9991	1.0099	0.9750
MAXIMUM	1.0498	1.0696	1.0187	1.0217	1.3373	1.0493	1.2761	1.0218	1.0724	1.0041	1.0239	1.0143	1.0015
MINIMUM	0.8997	0.7914	0.9646	0.5433	0.8862	0.9908	0.5242	0.9994	0.9961	0.9978	0.9726	0.9982	0.9749

Each entry in the table is the ratio of two estimates of the purchasing power loss on the currency for the given year. The first estimate is obtained by averaging the estimates obtained from the four polynomial formulae summarised in Table 1. The second estimate is obtained by using the two-point hyperbolic formula with parameters, a and b. The table summarises the ratio of the hyperbolic estimate to the average polynomial estimate of the purchasing power loss for each year of the hyperinflation for the given country.

Table 8b
Ratio of the estimated loss on the currency under the 'hyperbolic' formula to the average estimated loss from the four polynomial-based formulae, by country and period of hyperinflation for hyperinflationary economies with data available on the International Monetary Fund (IMF) website: http://www.imfstatistics.org/imf/

Country/year	*MEXIC*	*NICAR*	*PERU*	*POLA*	*ROMA*	*RUSSI*	*SURI*	*TURK*	*UKRAI*	*URUG*	*VENEZ*	*ZIMBA*
1968												
1969												
1970												
1971												
1972												
1973												
1974												
1975												
1976			0.9998							0.9963		
1977			1.0074					1.0393		1.0052		
1978			1.0067					1.0055		1.0055		
1979			1.0082					1.1045		0.9990		
1980			1.0029					1.0829		1.0180		
1981			1.0001					1.0655		1.0095		
1982			1.0063					1.1653		0.9667		
1983			1.0094					1.1838		1.0010		
1984			1.0045					1.1171		1.0165		
1985			1.0365					1.0875		1.0122		
1986			1.0011					1.1172		1.0099		
1987			1.0030					1.3663		1.0167	0.9929	
1988	1.0096	1.6907	0.9814					1.1228		1.0103	1.0004	
1989	1.0027	0.9049	0.9826					1.0678		1.0104	1.0066	
1990	1.0046	0.8443	0.7674	0.9048				1.0812		1.0210	1.0097	
1991	0.9967	1.0993	1.0064	0.9987				1.1237		1.0210	1.0092	
1992	0.9946	1.0143	1.0103	1.0000			0.9980	1.0870		1.0092	1.0030	
1993		1.0103	1.0019	1.0015			1.0014	1.0866	1.5072	1.0091	1.0154	
1994			1.0167	1.0063	1.0271		1.0122	1.1235	0.9673	1.0156	1.0095	
1995				1.0066	1.0042		1.4509	1.0810	1.0317	1.0121	1.0027	
1996					1.0038		1.1816	1.0721	1.0146	1.0173	1.0217	
1997					1.0288		0.9744	1.1095	1.0091		1.0109	
1998					1.0217	1.0459	0.9958	1.0906			1.0094	0.9824
1999					1.0268	1.0051	1.0178	1.1654				1.0184
2000					1.0140	1.0033	0.9447	1.1029				1.0106

Table 8b
Ratio of the estimated loss on the currency under the 'hyperbolic' formula to the average estimated loss from the four polynomial-based formulae, by country and period of hyperinflation for hyperinflationary economies with data available on the International Monetary Fund (IMF) website: http://www.imfstatistics.org/imf/ *(continued)*

Country/year	*MEXIC*	*NICAR*	*PERU*	*POLA*	*ROMA*	*RUSSI*	*SURI*	*TURK*	*UKRAI*	*URUG*	*VENEZ*	*ZIMBA*
2001					1.0187		1.0770	1.0947				0.9970
2002					1.0181		0.9898	1.0790				
2003								1.0440				
2004												
2005												
MEDIAN	1.0027	1.0123	1.0045	1.0008	1.0187	1.0051	1.0014	1.0906	1.0146	1.0103	1.0093	1.0038
MAXIMUM	1.0096	1.6907	1.0365	1.0066	1.0288	1.0459	1.4509	1.3663	1.5072	1.0210	1.0217	1.0184
MINIMUM	0.9946	0.8443	0.7674	0.9048	1.0038	1.0033	0.9447	1.0055	0.9673	0.9667	0.9929	0.9824

Each entry in the table is the ratio of two estimates of the purchasing power loss on the currency for the given year. The first estimate is obtained by averaging the estimates obtained from the four polynomial formulae summarised in Table 1. The second estimate is obtained by using the two-point hyperbolic formula with parameters, a and b. This table summarises the ratio of the hyperbolic estimate to the average polynomial estimate of the purchasing power loss for each year of the hyperinflation for the given country.

It must also be emphasised that there are important implementation issues with respect to the two-point estimation formulae derived and illustrated in this section. Foremost among these is that the two-point estimation formulae normally include parameters that must either be known or can be estimated with minimal error. The hyperbolic formula, for example, hinges on two parameters, a and b, that capture the way in which an organisation's real monetary holdings respond to variations in the purchasing power of the currency. In our empirical analysis, we estimated these parameters over successive annual periods using monthly observations and the OLS regression procedure. In the "real world", however, an efficient organisation's monetary assets and liabilities will be constantly managed in order to minimise the purchasing power losses that arise from them and so one would expect that these parameters (a and b) will either be readily available or can be determined with little difficulty.[16]

5. Summary and conclusions

The International Accounting Standards Board (IASB) has endorsed financial reporting standard IAS 29: *Financial Reporting in Hyperinflationary Economies* to address the unique financial reporting problems that arise in hyperinflationary environments. Para. 9 of IAS 29 requires that the net gain or loss in purchasing power from holding monetary assets and liabilities must be disclosed on an organisation's profit and loss statement. IAS 29 endorses an estimation procedure based on the simple assumption that an organisation's monetary position changes on just a few (typically, one or two) occasions over an annual reporting period and that in between these changes its monetary position remains constant. In contrast, we treat the problem of estimating purchasing power gains and losses that arise on an organisation's monetary holdings as an exercise in numerical analysis. Under this regime, purchasing power gains and losses are estimated by fitting interpolating polynomials to an organisation's monetary holdings and the price index from which the inflation rate is computed. We develop four estimation formulae based on this methodology and then use them to estimate the purchasing power losses that have arisen on the national currencies of 32 hyperinflationary economies covering an exhaustive set of hyperinflationary environments and spanning a period in excess of 80 years. Our analysis shows that the estimation procedures summarised in IAS 29 perform poorly in comparison to the more reliable polynomial estimation formulae, especially when the inflation rate accelerates towards the end of a relatively short hyperinflationary period.

There are, however, some distinct advantages with the estimation procedures summarised in the IAS 29 standard. The most obvious of these is that the IAS 29 estimation procedures can be implemented with just a few (typically, one or two) observations of an organisation's monetary holdings and the price index from which the rate of inflation is computed. Against this, the polynomial estimation formulae require monthly observations of the monetary holdings and price index data in order to estimate the purchasing power gains and losses that arise over an annual time period. We show, however, that if one makes 'realistic' assumptions about the way an organisation's monetary holdings respond to variations in the purchasing power of the currency, then one can derive a general class of two-point estimation formulae that use only the sparse information set on which the IAS 29 estimation procedures are based. Moreover, our empirical analysis shows that these two-point formulae return estimated purchasing power gains and losses that are similar to those obtained from the more informationally demanding polynomial interpolation techniques.

Our analysis also has important implications for the 'quality' of reported earnings during hyperinflationary periods. An organisation's earnings are regarded as having higher quality when larger sales and/or lower costs make a more significant contribution towards earnings increases than 'artificially' created profits such as those arising from inflation (Hodge, 2003: 41–43, Schipper and Vincent, 2003: 99–106). In particular, the uncertainty created by the measurement problems that arise during periods of hyperinflation mean that the quality of reported earnings is lower during hyperinflationary periods than will be the case during periods of stable prices. By providing a mechanism through which one of the more difficult measurement problems that arise in hyperinflationary environments can be resolved, our analysis makes an important contribution towards improving the quality of the earnings reported by organisations that have to operate in a hyperinflationary environment.

[16] Lucas (2000: 247) notes that 'it is in everyone's private interest to try to get someone else to hold non-interest-bearing cash and reserves. But someone has to hold it all .... All of us spend several hours per year in this effort, and we employ thousands of talented and highly trained people to help us. These person-hours are simply thrown away, wasted on a task that should not have to be performed at all.'

Appendix
Derivation of quadrature formulae

Let $f(t) = \frac{m(t)}{P(t)}$ be the real monetary holding and $g(t) = \log[P(t)]$ be the logarithm of the price index, both at time t. Now, suppose one approximates f(t) and g(t) as second degree (quadratic) interpolating polynomials. One can then follow the procedures laid down in Carnahan, Luther and Wilks (1969: 72–73) to show that the loss in purchasing power over the unit time period will then be approximated as:

$$\int_0^1 f(t)dg(t) \approx \int_0^2 [f(0) + \alpha\Delta f(0) + \frac{\alpha(\alpha - 1)}{2!}\Delta^2 f(0)][\Delta g(0) + \frac{2\alpha - 1}{2!}\Delta^2 g(0)]d\alpha$$

where $\Delta f(0) = f(\frac{1}{2}) - f(0)$ and $\Delta^2 f(0) = f(1) - 2f(\frac{1}{2}) + f(0)$ are the first and second differences in the real monetary holdings and $\Delta g(0) = g(\frac{1}{2}) - g(0)$ and $\Delta^2 g(0) = g(1) - 2g(\frac{1}{2}) + g(0)$ are the first and second differences in the logarithm of the price index. Evaluating the above integral shows:

$$\int_0^1 f(t)dg(t) \approx 2f(0)\Delta g(0) + 2\Delta f(0)\Delta g(0) + f(0)\Delta^2 g(0) + \frac{5}{3}\Delta f(0)\Delta^2 g(0) + \frac{1}{3}\Delta g(0)\Delta^2 f(0) + \frac{1}{2}\Delta^2 f(0)\Delta^2 g(0)$$

Simplifying the above expression by substituting the first and second differences for $f(\cdot)$ and $g(\cdot)$ shows:

$$\int_0^1 f(t)dg(t) \approx [\frac{1}{2}\cdot\frac{m(0)}{P(0)} + \frac{2}{3}\cdot\frac{m(\frac{1}{2})}{P(\frac{1}{2})} - \frac{1}{6}\cdot\frac{m(1)}{P(1)}]\log[\frac{P(\frac{1}{2})}{P(0)}] + [\frac{1}{2}\cdot\frac{m(1)}{P(1)} + \frac{2}{3}\cdot\frac{m(\frac{1}{2})}{P(\frac{1}{2})} - \frac{1}{6}\cdot\frac{m(0)}{P(0)}].\log[\frac{P(1)}{P(\frac{1}{2})}]$$

Now, suppose one applies this formula on a bi-monthly basis over the fiscal year, beginning with the months January and February. It then follows that $\frac{m(0)}{P(0)}$ will be the real monetary position on 1 January, $\frac{m(\frac{1}{2})}{P(\frac{1}{2})}$ will be the real monetary position on 31 January and $\frac{m(1)}{P(1)}$ will be the real monetary position on 28 February. Likewise, log[P(0)] will be the logarithm of the price index on 1 January, $\log[P(\frac{1}{2})]$ will be the logarithm of the price index on 31 January and log[P(1)] will be the logarithm of the price index on 28 February. Moreover, this means that the second degree interpolation formula for

$$\int_0^1 f(t)dg(t)$$

given above, will be the estimated purchasing power loss for the months of January and February. One can apply this formula again to determine the estimated purchasing power loss for the months of March and April and then again to determine the estimated purchasing power loss for the months of May and June and so on for each bi-monthly period over the entire year. When one adds the six bi-monthly estimates of the purchasing power losses together then one will have the purchasing power loss for the entire year as determined by the following formula:

$$P(1)\sum_{j=1}^{6}\int_{\frac{j-1}{6}}^{\frac{j}{6}}\frac{m(t)}{P(t)}.d\log[P(t)] \approx \frac{P(1)}{6}\sum_{j=1}^{6}\{[\frac{3m(\frac{2j-2}{12})}{P(\frac{2j-2}{12})} + \frac{4m(\frac{2j-1}{12})}{P(\frac{2j-1}{12})} - \frac{m(\frac{2j}{12})}{P(\frac{2j}{12})}].\log[\frac{P(\frac{2j-1}{12})}{P(\frac{2j-2}{12})}] +$$

$$[-\frac{m(\frac{2j-2}{12})}{P(\frac{2j-2}{12})} + \frac{4m(\frac{2j-1}{12})}{P(\frac{2j-1}{12})} + \frac{3m(\frac{2j}{12})}{P(\frac{2j}{12})}].\log[\frac{P(\frac{2j}{12})}{P(\frac{2j-1}{12})}]\}$$

Here we have multiplied the expression

$$\int_0^1 \frac{m(t)}{P(t)}.d\log[P(t)] = \sum_{j=1}^{6}\int_{\frac{j-1}{6}}^{\frac{j}{6}}\frac{m(t)}{P(t)}.d\log[P(t)]$$

by P(1), the value of the price index on 31 December, in order to state the purchasing power loss at the price level prevailing at the end of the relevant year. The estimation formulae for first, third and fourth-degree interpolation are derived in similar fashion to the formula given here for second-degree interpolation.

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