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Comovement of Nominal Variables in Hyperinflation

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by

Ružica Savčić

Supervisor: Jesús Vázquez

Bilbao, Spain

INTRODUCTION

Hyperinflations are basically monetary phenomena. They start when government prints money in excess in order to finance part of its expenditures and generally end when the monetary authority manages to convince people that it will no longer resort to inflationary financing. In between prices rise, tracking the increase in base money, and exchange rate follows suit. The real sector is usually affected as well, because uncertainty about future prices results in a contracted financial market, production is cut short and real wages typically fall adding to rising unemployment. But even large changes in real variables are minor compared with the pace by which prices, money and exchange rates go up. Therefore, as pointed out in Cagan (1956), "relations between monetary factors can be studied in what almost amounts to isolation from the real sector of the economy."

Since the focus of the monetary economics is the relationship between nominal and real variables, and bearing in mind that hyperinflation is a monetary event in which changes in nominal variables bear much more weight than adjustments in real domain, this paper brings into the spotlight the correlation between three particular nominal macro-series: money supply, prices and exchange rate. Avoiding the issue of causality, the pair-wise relation is studied applying a distinct method of comovement analysis developed in den Haan (2000). The VAR models used consist of two variables, as examining comovement implies investigating correlation, which can only be present in pairs of macro-series. Thus, the first analysis performed is of comovement in money and prices, assumed to be rather high, as the quantity theory of money suggests (see, for instance, Walsh (2003)). The relationship between prices and exchange rate then follows, mostly due to remarks made in Cagan (1956) that currency depreciation, related to rapid increases in prices, is usually best assessed through variations in the exchange rate. And, while on the subject of Cagan and the hyperinflation, the model developed by Cagan is tested in terms of comovement analysed employing the aforementioned den Haan's method.

The method itself makes use of the forecast errors, obtained by comparing the original series with the VAR estimation, and the correlation between computed forecast errors produces a reliable indicative of correlation among the series themselves. As pointed out in Watson (1994), for shorter forecast periods, the forecast error can be interpreted as short-run movements in the observed variable, while for longer ones it can be regarded as long-run movements. Hence, correlation between the forecast errors for shorter (longer) forecast periods suggests correlation in short (long) run movements of the macro-series in question.

The first part of the paper explains the notion of comovement and the idea behind den Haan's procedure. The overview of Peruvian hyperinflationary episodes follows along with the data analysis. Three separate examinations are performed, as mentioned previously. The paper closes with a conclusion, summing up the findings of comovement study.

COMOVEMENT

When two variables, observed in time, exhibit synchronised fluctuations, it is said that they co-move. Comovement is usually driven by some common factors that influence the behaviour of both variables, or can be indicative of a causal relationship between the variables. The notion of comovement is rather wide and encompasses different aspects of sensitivity to common factors. In Macroeconomics, this term is often used in cross-sector or cross-country business cycle analysis. For example, the level of economic activity in different sectors of a particular country is usually similar along the business cycle. It has been observed that countries with intense trade relations tend to experience high business cycle comovement – macro variables, such as consumption and output, seem to fluctuate in a similar manner. On the other hand, in Financial Economics, comovement can refer to, say, common movement of returns of individual stocks within both national and international markets.

Consequently, there are several different ways of measuring comovement. The most frequent approach it seems is computing contemporaneous correlation coefficients of the detrended macro variables in levels, or their growth rates. Standard deviations are sometimes used, too, in order to measure relative volatility, as it is shown that higher volatility often implies lower degree of comovement[1].

Den Haan (2000) suggests a different method to analysing comovement. He argues that valuable information about the dynamics of two variables can be lost if the focus rests solely on one correlation coefficient. Furthermore, in order for the unconditional correlation to be computed, the two variables need to be rendered stationary, and the choice of the variable transformation may also affect the resulting correlation coefficients. Therefore, the author proposes the use of correlations of VAR forecast errors at different horizons. Thus dynamics of the system are well presented and easy to interpret. Moreover, the method does not require any assumptions about the order of integration of the two variables, as it can be applied to both stationary and integrated processes.

When dealing with cointegrated series, the estimates on VAR coefficients are super-consistent[2], so no detrending is necessary. Therefore, the first step in computing comovement is the estimation of the following VAR model

$$X_t = \mu + Bt + Ct^2 + \sum_{l=1}^{L} A_l X_{t-l} + \varepsilon_t \ ,$$

X_t is an N-vector of variables, A_l is a N×N matrix of regression coefficients to be estimated along with μ, B and C, N-vectors of constants, t stands for trend, which basically implies that time enters the regression, both in linear and quadratic form, so as to capture a permanent increase in the level of observed variables, and finally an N-vector of white noise innovations (ε_t components are assumed stationary and serially uncorrelated, though allowed to be correlated with each other). In order to achieve stationarity of elements in ε_t, needed for consistency, the VAR model needs to be correctly specified, and enough number of lags (L) included. In particular, if X_t is integrated of order one, $X_t \sim I(1)$, the lag order should not be lower than 1. For $X_t \sim I(2)$, at least 2 lags should be included in the regression, etc.

After deriving the estimates of the model, K-period ahead forecast error is computed as a difference between the realisation of the time series and its forecast

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[1] Kose, Prasad and Terrones (2003)

[2] Mark E.Watson (1994)

$$Y^{ue}_{t+K,t} = Y_{t+K} - E_t Y_{t+K} ,$$

where Y_t is any of the random variables included in X_t and $E_t Y_{t+K}$ is a K-period ahead forecast of the variable Y_t.

Finally, the correlation between two series of forecast errors is calculated for different forecast horizons. The idea behind this approach is that in analysing the difference between the actual data and the prediction, obtained from VAR fit by OLS, the response of the studied variables to an exogenous structural shock is recovered in terms of the behaviour not predicted by the model. Since the structural shocks are assumed uncorrelated, they can cause comovement in observed variables only through particular economic interactions under scrutiny. By means of high correlation between the forecast errors, a similar reaction pattern of the variables under examination is revealed and it can serve as a strong argument in favour of comovement of the studied time series.

This particular point is maybe more evident from the relationship between the K-step ahead forecast error and the unanticipated shifts in the exogenous variables, characterized by the vector of white-noise innovations ε_t. As pointed out in Watson (1994), for a K-step ahead forecast made at time t, defined as $Y_{t+K,t} = E(Y_{t+K} \mid \{\varepsilon_s\}^{t}_{s=-\infty})$, the resulting forecast error can be written as $Y^{ue}_{t+K,t} = \sum_{k=1}^{K} C_k \varepsilon_{t+k}$. Introducing the impulse response function as an indicator of how each of the variables in the VAR model changes in response to a one unit 'impulse' in a particular element of the innovation vector, $\varepsilon_{j,t}$, it can be shown (see den Haan, 2000) that the covariance of the K-period ahead forecast errors is basically a total of products between the impulses averaged across different structural shocks. For M shocks driving the two variables in the model, the covariance can be expressed as

$$COV(K) = \sum_{k=1}^{K} \sum_{m=1}^{M} Y^{imp,m}_{1,k} Y^{imp,m}_{2,k} ,$$

where $Y_{j,k}^{imp,m}$ is a k^{th} period impulse response of variable Y_j, to a one-standard-deviation disturbance of the m^{th} shock.

In what follows, analysis of comovement between nominal variables in hyperinflation is performed applying den Haan's methodology, i.e. measuring pair-wise correlation of forecast errors constructed as differences between the realisations of the time series and their predictions at different forecast horizons.

EMPIRICAL RESULTS

A. Brief history of Peruvian hyperinflation[3]

Hyperinflation can be defined as a rapid increase in prices leading to substantial falls in purchasing power and consequently to currency depreciation. What distinguishes hyperinflation from a high inflation is the very pace by which prices augment, though no universal classification is agreed upon thus far. Monthly inflation rates of 20%, 30% or more can safely be regarded as hyperinflation.

The roots of hyperinflation, on the other hand, lie indubitably in swift expansion of money supply. Excess money printing triggers a rapid price rise, attributable to an economy's inability to respond to growing demand in such a short period. Various theories differ in their explanation of what causes hyperinflation, from irresponsible behaviour on the part of monetary authorities to crisis of confidence. However, this phenomenon is regularly associated with economic depressions, political and social crises and often wars. In such circumstances, the government usually fails to enact appropriate tax programmes and consequently turns to excessive money printing in order to finance its increasing expenditure. Raising revenues is thus achieved by imposing the so-called "inflation tax" – the note-issuing authorities benefit from the collected seignorage, while the value of money held by the citizens depreciates. Nonetheless, this type of financing is never sustainable, as soon as the price increase reaches such heights that money printing fails to follow, because the body, which issues currency, cannot print the paper money faster than the rate at which it is depreciating. Therefore, the revenue is high at the start, while people are unaware of the actions taken by the government, but tends to decline later on, when citizens lose confidence in domestic currency and substitute it for a foreign one. In need of ever depreciating money, the authority in charge issues new bills at an increasing speed, while prices skyrocket in response. This scenario is typical for all hyperinflations and the Peruvian episode was no exception.

In July 1985 the newly elected president, Alán García, inherited Peru characterised by low per capita income, high unemployment and high inflation, with a history of stop-and-go economic policy sequences, where democratic rule was cyclically succeeded by military juntas. This economic and political instability, along with predominant poverty, gave way to a populist course adopted by the new government.

The economic advisers to the president held a view that as long as there was capacity lying idly around, stimulating consumption would inevitably lead to an economic recovery. Moreover, higher firm activity would imply lowering the unit cost, hence inducing deflation instead of inflation. They also insisted upon import restrictions, so that domestic consumption would feed on domestic production, and improvement in the balance of payments would follow. Finally, as a way of promoting exports, they favoured multiple exchange rates, believing that higher exchange rates should be put on export goods with higher supply elasticity, thus maximising the level of exports. In return for a custom made exchange rate granted by the Central Bank, the exporting firms would contract themselves to a given export target. Basically, the whole policy adopted was discretion inclined, regulating prices, wages, interest rates, import tariffs and exchange rates.

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[3] The data used in this paper, along with the view on Peruvian hyperinflation, rely heavily on Ricardo Lago's "The Illusion of Pursuing Redistribution through Macropolicy: Peru's Heterodox Experience, 1985-1990," published in 1991 in *The Macroeconomics of Populism in Latin America*, edited by Rudiger Dornbusch and Sebastian Edwards, NBER Conference Report, University of Chicago Press.

So, in August, the economic recovery programme was launched, based on demand stimulation through increased real wages, direct subsidy projects and public works, as well as reduction in taxes and freeze of public sector prices and tariffs, aimed at income redistribution between the public and the private sector. Credit programmes for microentrepreneurs, along with accordingly stimulated demand, were to boost the informal sector. The agricultural sector was hugely subsidised, with high guaranteed prices for producers, increased input subsidies and favourable credit lines. On the other hand, as a tool for fighting inflation, freezes on prices, costs, interest rates and exchange rates were introduced.

However, the only downside to this unorthodox strategy was that the finances were to be obtained through external debt default and the Central Bank. This led to investment significantly lower than planned, as foreign sources were reluctant to finance a country that resorted to default. Thus the trade-off between consumption and investment was resolved in favour of the former, shortening the life of economic expansion. Furthermore, revenues of the public sector dropped and Central Bank incurred losses caused by sustaining multiple exchange rates and favourable interest rates. Ultimately, currency appreciation prompted higher consumption of imported goods and a drop in international reserves caused by current account deficit. High inflation was at the doorstep.

In the wake of García's third year in power, distortions in the economy were getting out of hand. The Central Bank was reaching for the gold reserves, and moving its external deposits from one country to another in fear of seizure by creditors. In spite of this, real wages were still increasing, as granted by the government, and favourable credit lines were being extended to the farmers. Central Bank's financial system was too fragile for such a heavy load, so it began inflationary financing. A well-known price-cost spiral followed and by September 1988 hyperinflation reached 114% monthly rate[4]. After a set of policy measures, the price rise was put under control, only to explode once again and even more violently two years later.

Considering the fact that the anti-inflationary actions created a break in the series of nominal variables observed, just the first wave of hyperinflation is analysed below. The results are thus much clearer and more conclusive. However, the second wave is not examined, mainly due to the lack of data for the closing two months of hyperinflation.

B. Comovement of nominal variables

i) Prices and Money

The increasing pattern of the two series can be clearly detected from Figure 1, where the monthly price index, taking July 1985 for a base period, is plotted against monthly index of broad money[5], with the same base month. A logarithmic transformation is applied to the series, rendering them less volatile and consequently more easily comparable.

During the observed period prices exhibited close to exponential growth pattern, exploding in the final year. The growth in money base seems more even, with less oscillation around the trend, particularly after summer in 1985. But, it should be borne in mind that prices were managed by the government and only in the closing months went out of control.

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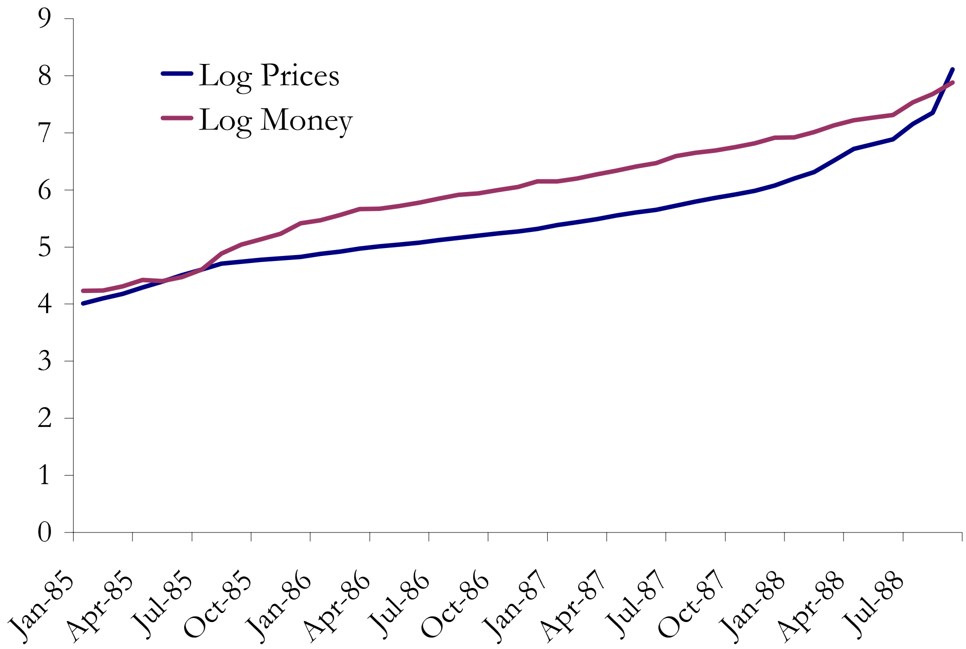
[4] Percentage increase over previous month.

[5] Deposits denominated in dollars are excluded from this quantity.

Figure 1. The monthly indices of prices and money



Using den Haan's methodology we can now compute comovement between these two variables. So, starting from the initial model,

$$X_t = \mu + Bt + Ct^2 + \sum_{l=1}^{L} A_l X_{t-l} + \varepsilon_t \ ,$$

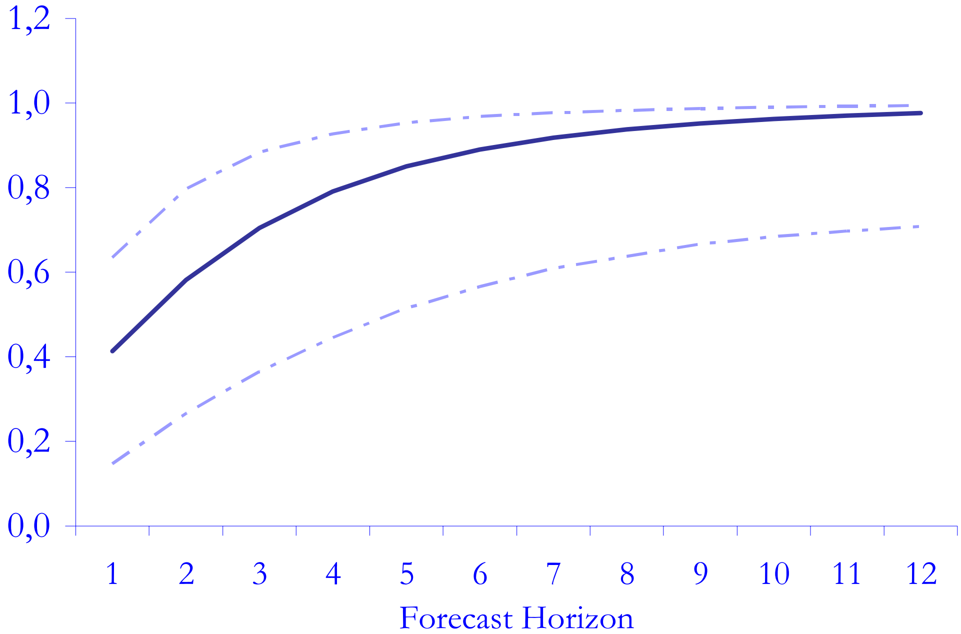
our X_t now includes the two observed time series. Since both prices and money are integrated of order 2, the model specification suggests using the first differences and then including at least one lag in the model. Imposing a unit root condition reduces the series by one observation. Finally, 1 lag and a linear trend are included in the VAR estimation, since the Akaike information criterion does not decrease much when the second lag is included, so for the sake of parsimony the model is kept as simple as possible,

$$\Delta X_t = \mu + Bt + A_1 \Delta X_{t-1} + \varepsilon_t \, .$$

A bootstrapping technique developed in Runkle (1987) is used to calculate the confidence bands for the correlation coefficients between the forecast errors and the results are presented in Figure 2.

Since short run tends quickly toward a long run scenario in hyperinflation, the changes being so swift and substantial, not more than 12 periods ahead are considered for the forecast horizon. And seeing that the forecast horizon increases, the uncertainly grows and the part of the variable behaviour not explained by the model becomes sizeable. The correlation between the short-run movements in prices and money is lower than expected, 0.4, whereas the correlation between the long-run movements is much higher. Thus, an increase in the correlation coefficient can be observed, reaching 0.8 by the 4 months-ahead forecast horizon.

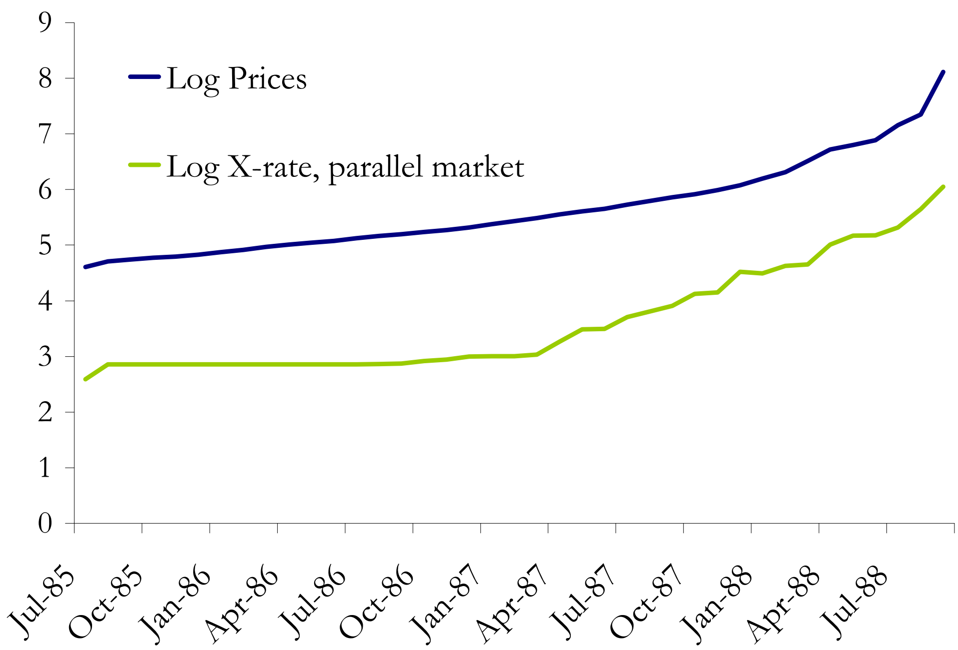
Figure 2. The comovement between prices and money



This result bears witness to the monetary theory dating way back to the period between the two world wars, which stated that in hyperinflation money and prices exhibit a highly synchronised movement. However, this synchronicity is not instantaneous. It is obvious that it takes some time for the prices to catch up.

i) Prices and Exchange Rate

Figure 3. The monthly price index and the parallel market exchange rate



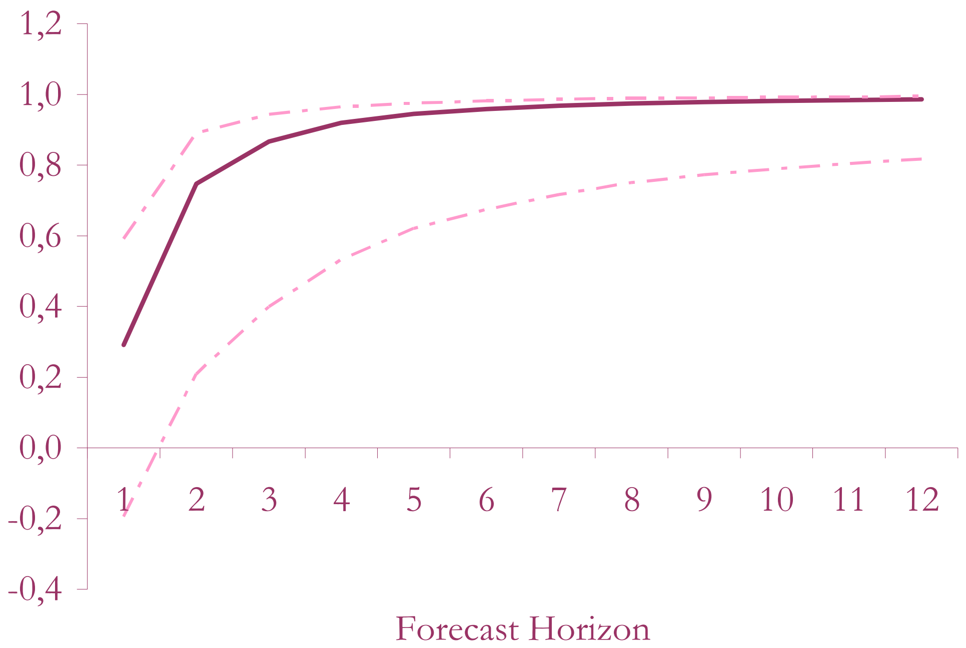
As previously mentioned, the government of Peru had set different exchange rates for different producers during their 6-year rule. Being highly controlled, these rates were not very indicative of the true value of Peruvian currency at the time. This is why in analysing the relationship between price level and the value of the currency, the exchange rate on the black-market is considered. The behaviour of these two variables is graphed in Figure 3.

According to the Purchasing Power Parity theory, there is a strong relationship between the country's inflation rate and the change in its exchange rate. Basically, the theory postulates that the relative prices in different countries should remain constant, implying that if in a particular country the prices go up, the exchange rate should follow. Since the market exchange rate appears more volatile than prices, the theory suggests that their relationship is the most intense in the long-run equilibrium. Plotting the correlation coefficients between the forecast errors of the VAR model of the two variables in first differences, when a trend and one lag are included[6],

$$\Delta X_t = \mu + Bt + A_1 \Delta X_{t-1} + \varepsilon_t ,$$

proves this point, as shown in Figure 4.

Figure 4. The comovement between prices and exchange rate



Once more, the correlation between the short-run movements is not substantially high, just slightly over 0.2, but it rapidly increases to reach almost perfect correlation by the 10-period ahead forecast horizon.

An interesting thing happens in analysing comovement between prices and money as well as prices and exchange rates – confidence bands for the correlation coefficients between the forecast errors decrease with the forecast horizon. Counterintuitive as it may seem, this occurrence has a proper explanation behind it. It has to do with the manner in which the bands are computed, in addition to the property of the series themselves.

The bootstrapping technique applied (see Runkle (1987) or Hamilton (1994)) creates an estimate of the small-sample distribution of $\hat{A}$ without presuming that white noise

[6] Again, the difference in AIC is negligible. When only the first lag is included, the model contains a linear trend, and the AIC value is -9.4308. Adding a second lag removes the trend from the model, and results in AIC value of -9.56.

innovations ε_t are normally distributed. An artificial sample of X_t is generated using out-of-sample values of X_t (in this case lags included in the model) and a simulated random variable, assumed to follow a uniform distribution, taking on values of fitted residuals from the estimated VAR with probability 1/T. Hence, a new, simulated X_1 is created as

$$\Delta X_1^{(1)s} = \hat{\mu} + \hat{B}_t + \hat{A}\Delta X_0 + \varepsilon_1^{(1)s},$$

where s in the superscript stands for simulated, ΔX_0 is the actual value of observed differenced series and $\hat{\mu}$, $\hat{B}$ and $\hat{A}$ are OLS estimates of the original VAR. Obviously, the observed series start at t=1, but 0 in the subscript ΔX_0 is there to distinguish it from ΔX_1 and 1 in subscript here is for the benefit of clarity. Taking the next draw with replacement from the uniform distribution, another synthetic observation is added to the artificial sample,

$$\Delta X_2^{(1)s} = \hat{\mu} + \hat{B}_t + \hat{A}\Delta X_1^{(1)s} + \varepsilon_2^{(1)s},$$

and so on until a whole sample of T observations is generated. Thus constructed synthetic VAR is next estimated by ordinary least squares to produce estimates for $\hat{\mu}^{(1)}$, $\hat{B}^{(1)}$ and $\hat{A}^{(1)}$. Consequently, new forecast errors, along with new correlation coefficients are calculated. The simulation is then repeated 2500 times to create a 95% confidence interval for the originally computed correlation coefficients.

Since all three series are integrated of order one, and additionally pairwise cointegrated, the estimators of VAR coefficients are superconsistent, converging to their true value at rate T, as shown in Stock (1994). Therefore, the further in the future the forecast, the lower the variance of the estimator. Consequently, the span of the forecast errors in the simulation narrows, producing smaller variation of the correlation coefficients. Thus the contraction of the confidence interval makes full sense due to superconsistency.

iii) Real Money Balances and Inflation

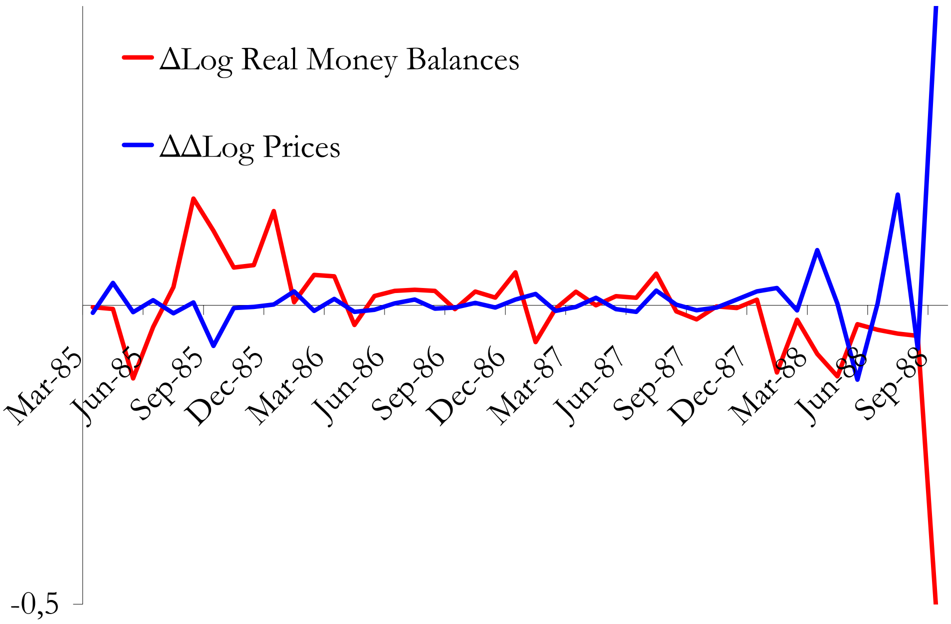
When prices go up, people usually tend to increase the real amount of cash they are holding. However, in hyperinflations, due to amplified uncertainty and speedy depreciation of national money, individuals generally prefer to hold their wealth in other forms, mostly foreign currency. Thus, during hyperinflations the real cash balances, defined as an index of the real value of the quantity of money, have a tendency to fall. The relationship between inflation and real money balances has been under study ever since Cagan's seminal work (1956) in which he tested hypothesis that observed variations in real cash balances are for the most part rooted in variations in the expected rate of change in prices. Furthermore, he found negative correlation between observed variables, just as theory suggests, postulating the following model:

$$\mathrm{Log}\frac{M_t}{P_t} = -\alpha \cdot E_t \pi_{t+1} - \gamma .$$

So, on the left-hand side there is a logarithmic transformation of real cash balances and on the right a one-step-ahead expectation of inflation rate at time t, plus a constant.

It can be seen from Figure 5. how demand for real money balances depends inversely on changes in prices. The original series are presented in first differences to make the relationship more evident.

Figure 5. First differences of real money balances and inflation

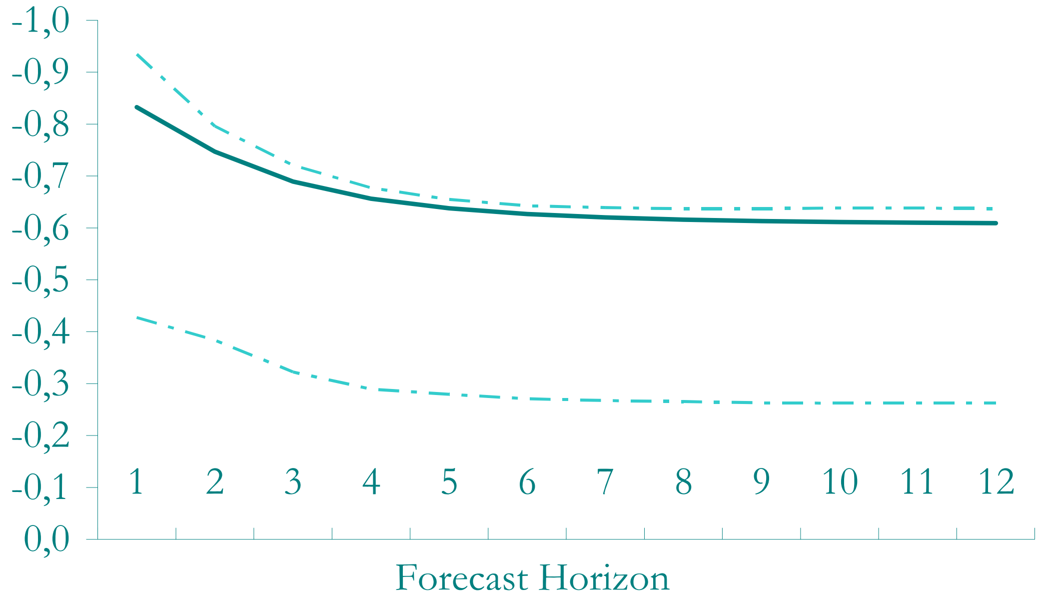


Conditions for correct estimation of the coefficient α in Cagan's model has been under great debate for decades, but suffice it to say that Sargent and Wallace (1973) showed how implications of the model hold both under adaptive and under rational expectations. Therefore, approximating the expected inflation at time t+1 by the quantity observed at time t, we can define the following VAR model

$$X_t = \mu + Bt + A_1 X_{t-1} + \varepsilon_t .$$

The two variables on which the model is built are the difference in logarithmic transformations of money and prices (Log Money_t – Log Prices_t), the real cash balances, and the first difference of logarithmic transformation of price index (Log Prices_t – Log Prices_{t-1}), the continuously compounded approximation of inflation rate.

Figure 6a. The comovement between real cash balances and inflation

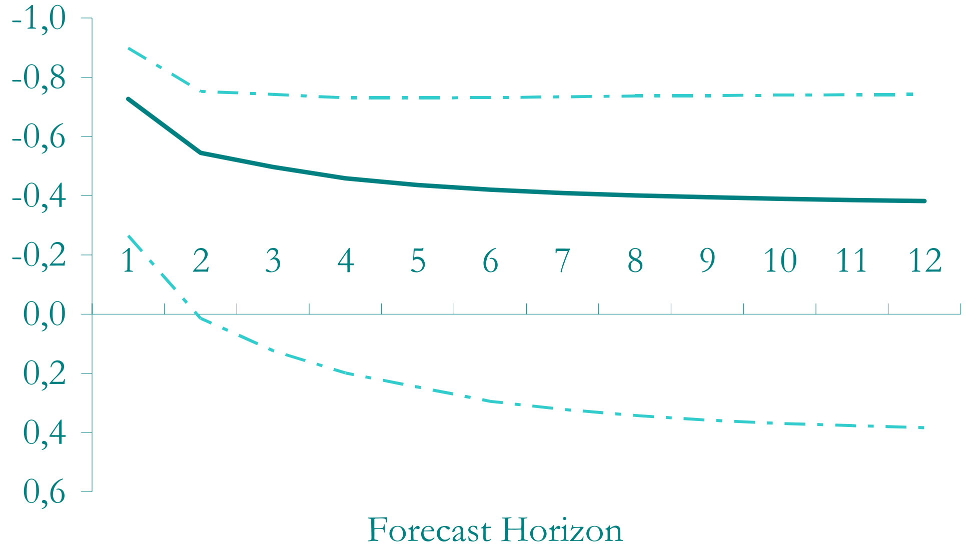


As expected, negative correlation of the forecast errors brings yet another proof of the theory. The greatest contribution of Cagan's paper is that it demonstrated how, in a frenzied situation of raging price increase, a stable money demand schedule could be detected through this inverse relationship between real balances and expected inflation rate. Furthermore, as pointed out in María-Dolores and Vázquez (2007), in equilibrium, a negative correlation between two variables occurs when supply shocks are relatively larger than demand shock. This proves that in hyperinflation, in order to make real cash balances depend inversely on expected rate of inflation, shocks on the money supply side need to be substantially greater than those on demand side. In other words, the government needs to increase the money supply much more than the public expects, as their expectations form the demand side of the equation.

Additionally, as indicated in den Haan (2001), when variables included in the VAR model are stationary, such as the first differences of real cash balances and inflation, the correlation between the forecast errors converges to the unconditional correlation in the limit. This is due to the fact that, as the forecast horizon approaches infinity and uncertainty increases, the forecast error becomes identical to the series itself (see Watson (1994)). In other words, $Y^{ue}_{t+K,t} = Y_{t+K}$, because there is no reliable information on what will happen so far out in the future, which is why the prediction at time K, $E_t Y_{t+K} = 0$. And, with no cointegration, the estimator is no longer superconsistent, so the confidence interval increases with the forecast horizon, as can be clearly seen from Figure 6b. Here den Haan's procedure is applied to first differences of original series, the ones depicted in Figure 5.

Evidently, these coefficients are lower in absolute value than the ones computed from the VAR model with series in levels. The distinction in results between model with variables in levels and the one with imposed unit root restriction is apparent in all three cases analysed. Computing first differences renders the series less volatile and hence less sensitive to exogenous shocks relative to the original series. The impulse responses are thus stifled, leading to lower correlation of forecast errors and consequently lower comovement.

Figure 6b. The comovement between real cash balances and inflation



CONCLUSIONS

This paper examines the relationship between three pairs of different nominal variables usually studied in hyperinflation – money and prices, exchange rate and prices, and real money balances and inflation rate. A two-variable VAR model was built for each analysis and comovement computed using the procedure developed in den Haan (2000). In the first case, as expected, increasing and rather high positive correlation of money and prices was found, fairly robust to imposing a unit root restriction on the model. Similar comovement pattern was detected with prices and exchange rate, though only after the unit root restriction was imposed. Finally, proving the hypothesis tested in Cagan (1956), an inverse relationship between real cash balances and inflation rate was identified, and correlation, though unmistakably negative, turned out to be somewhat sensitive to model specification, namely whether the analysed series entered VAR in levels or in first differences. Furthermore, studying the comovement of these two variables proved the argument, pointed out in María-Dolores and Vázquez (2007), that in order to achieve identification of a significant, negative correlation in equilibrium supply shocks need to be relatively more important than demand shocks, suggesting that this hyperinflation was unquestionably brought about by volatile money printing.

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