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INFLATION FORECASTING MODELS FOR UGANDA: IS MOBILE MONEY RELEVANT?[†]

Abstract

Forecasting inflation is challenging in emerging markets, where trade and monetary regimes have shifted, and the exchange rate, energy and food prices are highly volatile. Mobile money is a recent financial innovation giving financial transaction services via a mobile phone, including to the unbanked. Stable models for the 1-month and 3-month-ahead rates of inflation in Uganda, measured by the consumer price index for food and non-food, and for the domestic fuel price, are estimated over 1994-2013. Key features are the use of multivariate models with equilibrium-correction terms in relative prices; introducing non-linearities to proxy state dependence in the inflation process; and applying a 'parsimonious longer lags' (PLL) parameterisation to feature lags up to 12 months. International influences through foreign prices and the exchange rate (including food prices in Kenya after regional integration) have an important influence on the dependent variables, as does the growth of domestic credit. Rainfall deviation from the long-run mean is an important driver for all, most dramatically for food. The domestic money stock is irrelevant for food and fuel inflation, but has a small effect on non-food inflation. Other drivers include the trade and current account balances, fiscal balance, terms of trade and trade openness, and the international interest rate differential. Parameter stability tests suggest the models could be useful for short-term forecasting of inflation. There is no serious evidence of a link between mobile money and inflation.

JEL Classification: C22, C51, C52, C53, E31, E37 and E52
Keywords: error correction models, mobile money, model selection and modelling inflation

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1. Introduction

As the popularity of inflation targeting has spread, inflation forecasting has become a central element in economic policy-making. Many emerging market and developing economies including Uganda in 2011[1] have adopted inflation targeting since the 1990s. Forecasting inflation is notoriously difficult. Clements and Hendry (2002) argue that structural breaks are the chief cause of forecast failure. Indeed, there have been large structural shifts in the world economy such as trade and financial globalization; and shifts in individual economies, including an increasing economic weight on services. Monetary policy itself has generally shifted to a greater focus onto forecast inflation. Forecasting inflation is especially challenging in emerging markets given the changes in the underlying environment due to structural and institutional adjustments, and the high weight of volatile food and energy in the consumer price index[2], and volatility in food and energy prices and the exchange rate. Energy and food price shocks can be sizeable and their impact non-linear (e.g. the speed of price changes tends to rise with larger shocks). The many structural shifts need to be carefully modelled.

Some structural shifts are still playing out: an example is financial innovation via the rapid spread of mobile money, which has sparked concerns for inflation in East Africa recently.[3] Mobile money refers to financial transaction services potentially available to anyone owning a mobile phone, including the under-banked and unbanked poor who are not a profitable target for commercial banks (see survey by Aron (2015)). To isolate the possible impact of mobile money on inflation in East African countries, it is essential to use well-specified inflation models with comprehensive controls. Failure to include proper controls will lead to biases, and the erroneous attribution of effects to mobile money that belong to omitted economic regressors in the model. Inflation models in advanced countries are often mis-specified (review in Aron and Muellbauer (2013)); there are few adequate inflation models in the African context.

How might mobile money matter for inflation? In the monetarist view, if the spread of mobile money promotes increased velocity of circulation, this will increase ‘effective money’ and hence inflation. This is the mechanism proposed by Simpasa and Gurara (2012), but it reflects the confusion in the literature on the effects of variations in the money stock on inflation, while neglecting possible benign linkages between mobile money and inflation. In the short-run, higher mobile balances might

[1] Uganda’s adoption of inflation ‘targeting-lite’ in 2011 aimed to enhance policy transparency, accountability and predictability, and was partly a reaction to the difficulties encountered by the previous monetary targeting regime, Bank of Uganda (2011).
[2] For instance, the CPI weight since 2008 on food prices in Uganda is 27.2 percent (reduced from 45.2 percent during 2000-2007). This compares with 7.8 percent in 2009 in the US and 10.4 percent in 2008 in Germany.
[3] The inflation fears based on the rapid spread of mobile banking in Kenya seem to be mainly linked to an African Development Bank (ADB) Economic Brief of February 2012 (Simpasa and Gurara, 2012), which suggested (based only on 3 data points and a model with poor controls, see Section 4) that mobile money growth increased inflation in Kenya.

signal plans for impending spending and so proxy a short-term demand increase. Also, the advent of mobile money might transfer spending power to households with a higher propensity to spend, and so reduce saving. But mobile money accounts are secure and might encourage saving. There are further countervailing forces as mobile money improves economic efficiency. Productivity gains and improved competition in markets for goods and services with falling transactions costs due to mobile money could reduce inflation. Finally, the cost reductions may not properly be reflected in mis-measured CPI. It is far from obvious therefore, that well-measured inflation should have risen as a result of the spread of mobile money.

This research aims to model and forecast monthly inflation in Uganda over 1994 to 2014, and to test for the possible effects of mobile money. Our primary focus is to address the question about the effect of mobile money on inflation, but there are useful forecasting implications from our models. We develop 1-month and 3-month-ahead ('multi-step') inflation models for inflation. This is because the 1-month-ahead model is the exact equivalent of a standard component equation of a monthly VAR, and the 3-month-ahead model is approximately the equivalent of a quarterly VAR component (and it turns out that the signal-to-noise ratio is somewhat better over this horizon). Such VAR models are commonly used in forecasting. Our 'multi-step' models have two implications. First, they provide useful components of the small systems used by central banks to forecast inflation as part of their 'suite' of forecasting models. Second, they are easily extended to 6-month or 12-month ('multi-step') single-equation forecasting models that could successfully use broadly the same structure as the short-horizon models.

Our starting hypothesis is that inflation is a *heterogeneous, state dependent process*. Heterogeneity suggests that adjustment to relative price disturbances is part of inflation dynamics. If the probability of price changes is state dependent, this implies that non-linearities are likely to be important. We apply sophisticated econometric forecasting models, successfully used in South Africa and in the US (Aron and Muellbauer (2012, 2013)). These models for both an emerging market and an advanced economy suggest five key factors that improve inflation forecasting performance (and they motivate the relevant economic variables to include for a country like Uganda). First, for US data, Stock and Watson (1999, 2003) claim that univariate models in differences are hard to beat, especially in a stochastic parameter version, Stock and Watson (2007). But Aron and Muellbauer (2013) demonstrate this is not so, even for the US: multivariate approaches fare better, and this is especially likely to hold for emerging market countries like Uganda. Second, although the dominant paradigm in the empirical inflation literature has been to by-pass long-run relationships, if there is a stable co-integrated relationship between the consumer price index (CPI) or its chief components, and other prices, this improves forecasts. Thus, models including long-run information in equilibrium correction model (ECM) component terms forecast better than models specified only in differences[4] for non-stationary data. Third, including long-run trends capturing structural shifts such as trade openness, helps forecasting. Fourth, allowing for non-linearities to proxy state-dependence in the inflation process, when high current or recent rates of inflation are associated with disproportionately higher future inflation, improves forecasts. Finally, replacing the application of the information criterion, commonly used in unrestricted VARs to select lag lengths, with a 'parsimonious longer lags' (PLL) parameterization5 also improves forecast performance by considerably increasing lag lengths.

Since inflation is a heterogeneous process, there are possible forecasting gains from *disaggregation*, as in papers by Espasa and Albacete (2007), Hubrich (2005) and, for South Africa, Aron and Muellbauer (2012, 2014). We develop 1-month and 3-month-ahead inflation forecasting models for food, fuel and non-food inflation separately, given the importance of food in the Ugandan economy. The latter necessitates taking full account of supply shocks – droughts and floods. For an emerging market economy such as Uganda, which has undergone large structural changes, it is important to address these shifts. Figure 1 illustrates the aggregate CPI, food CPI, and non-food CPI in Uganda as log price indices in annual changes. The three main inflation episodes are apparent: a high-inflation period before 1995; a relatively stable period between 1995 and 2007; and the moderate but volatile era of the past 7 years. Our models are formulated for changes in logs of prices with general multi-variate equilibrium correction models, and incorporating shifting trends or other indicators of structural change. The equilibrium correction crucially permits the adjustment of prices to trends in relative prices to be part of the inflation process. We use best practice econometric methods on General Unrestricted Models (GUMs) that "allow the data to speak". Following the earlier work on the US and South Africa, we apply PLL restrictions on longer lags, test for non-linearities, and use automatic model selection to find parsimonious specifications after imposing plausible long-run sign restrictions.[6]

The next section surveys Ugandan inflation studies; Section 3 presents relative price trends and the background to inflation history in Uganda. Section 4 introduces the mobile money market in Uganda. In Section 5, the estimation and forecasting methodology is presented, and in Section 6 the data discussion and model results. Section 7 concludes.

[4] Note that Clements and Hendry (1998, 2002) argue that structural breaks are a key to forecast failure. Differencing can help robustify against breaks, but at cost of discarding longer run information.

[5] This helps overcome the 'curse of dimensionality'. Instead of 12 monthly lags, PLL uses monthly changes for the very recent past, then 3-month, then 6-month changes. Thus, instead of using 12 parameters, just 5 parameters can capture lags up to 12 months.

[6] The use of Autometrics, automatic model selection software by Doornik and Hendry, see Doornik (2009), empowers evidence-based economics, overcoming the profession's prejudice against 'data mining'. Two explanatory references for non-technicians are http://www.voxeu.org/article/data-mining-more-variables-observations and http://www.europeanfinancialreview.com/?p=4075. See further discussion in Section 5.3.

2. Literature survey of Ugandan and related inflation studies

The set of existing models for inflation in Uganda are outdated by the subsequent structural changes in the economy, or are weak, with model mis-specifications and various unsatisfactory features. Earlier studies typically emphasised domestic money and foreign influences on domestic inflation in the period of economic stabilisation (e.g. Kasekende, 1990; Sharer et al., 1995; Barungi, 1997; Abuka and Wandera, 2001). This paper covers the post-stabilisation period from 1994, when one might expect more stable inflation relationships. The more recent period is covered by the following empirical literature.

Kihangire and Mugyenyi (2005) estimate an autoregressive distributed lag model on monthly data from 1994 to 2005. They find evidence that the long-run solution for the log CPI depends on log M2 and the log of the nominal effective exchange rate, with weights of around 0.45 and 0.55, respectively, and a speed of adjustment of 0.43. Although no foreign price level is included in the model, the model is approximately consistent with long-run homogeneity given that these two weights add up to 1.[7] The log CPI also depends negatively on the log of the terms of trade, on log rainfall, on the log of the ratio of the fiscal deficit to GDP and on a measure of exchange rate misalignment. The coefficient on log capacity utilisation in manufacturing is negative and insignificant and that on the log of the Treasury Bill rate is positive and insignificant.

Mugume and Kasekende (2009) estimate monthly Phillips curve models in the New Keynesian tradition, and equilibrium correction models. The former are driven by the next month's inflation rate and are therefore not useful for forecasting or deriving the underlying drivers (i.e. are based on inflation expectations which are not easy to measure). In the main equilibrium correction model, estimated for monthly data from 1995 to 2008, two long-run co-integrating vectors are found. Their equation (18)[8] is the vector interpreted as a long-run equation for log CPI, where M3 is broad money, P^f is a measure of foreign prices, NEER is the nominal exchange rate (where depreciation is a rise), rGDP is real GDP and r is the Treasury Bill yield. Their equation (19) is the corresponding vector for the core price index excluding food prices. The speeds of adjustment are 0.14 and 0.19 respectively, fairly rapid for monthly data. The headline CPI results are not plausible, however, as the exchange rate has very influence on the price level. In this respect the core CPI results are more plausible. For both log price indices, the speed of adjustment of prices to the second co-integrating

[7] Results in their Table 4 for a similar model with base money instead of broad money are less convincing in this regard. Also the coefficient on the fiscal deficit is then positive and significant, and rainfall much less significant.

[8] Their equations (18) and (19), using their nomenclature: $Headline: LgP = -0.21 + 0.3LgM3 + 0.62LgP^f + 0.02LgNEER - 0.225LgrGDP + 0.007r$; $Core: LgCP = -0.2 + 0.08LgM3 + 0.70LgP^f + 0.34LgNEER - 0.17LgrGDP + 0.002r$

vector, interpreted as a demand for money function[9], is small and at the margin of insignificance. The negative coefficients on real GDP could suggest that it is the money stock relative to real GDP which is relevant. Indeed equation (18) suggests (log M3-1.33 log rGDP) as the relevant form in which money affects the price level. The response to the nominal Treasury Bill rate looks perverse in that higher domestic interest rates relative to foreign rates should be deflationary via exchange rate appreciation. Since nominal interest rates in the model tend to be higher when inflation is higher, the positive coefficients probably indicate omitted drivers of inflation.

Opolot and Kyeyune (2012) also estimate equilibrium correction models but for quarterly data from 2000Q1 to 2012Q3. They posit a theoretical model for two long-run solutions. One is for the non-tradable (domestic) price level as a function of the deviation between the nominal money stock and the demand for real money (as a function of real income, a domestic-foreign interest rate differential and the past rate of inflation). This violates a basic homogeneity requirement (lack of money illusion) for a long-run price equation, which mixes the nominal money stock with other variables in real terms.[10] The other solution is for the exchange rate as a function of domestic and foreign prices and the terms of trade. This raises the possibility of a terms of trade channel, with potentially positive effects on the domestic price level. The quarterly speed of adjustment for log CPI is estimated at 0.11 for the vector including the money stock, and 0.05, but not significant, for the exchange rate vector. However, the short-run equation for quarterly inflation from which adjustment speeds are estimated includes the contemporaneous change in log M2, which one might have thought highly endogenous. No attempt is made to include supply shocks, such as rainfall, which impact on food prices and hence on the overall price level.

Kabundi (2012) uses monthly data from January 1999 to October 2011 in a single equation equilibrium correction framework for log CPI. This follows work by Durevall et al. (2012) on inflation in Kenya and Ethiopia, which highlights the role of food prices and foreign as well as domestic influences on food prices in the inflation process. Two equilibrium correction terms are relevant. One is for a demand for money function, specified in real terms, driven by real GDP and the 12-month rate of currency depreciation. The elasticity with respect to real GDP is 1.48 (t ratio is 26). The monthly speed of adjustment of log CPI to the demand for money is 0.03 (t ratio is 2.35). The second equilibrium correction term is the deviation of log domestic food prices from international food prices converted at the exchange rate. The monthly speed of adjustment to this is 0.01 (t ratio is 2.34). These surprisingly low speeds suggest the possibility of omitted variables. The agricultural gap, an output gap measure for production of cereals has a negative coefficient, consistent with

[9] However, this interpretation is doubtful since the log change in broad money apparently reacts insignificantly to this vector for the headline CPI version of the model, and significantly but perversely for the core CPI version of the model.

[10] This can be seen in equation (12) in the paper which specifies an equilibrium correction term as the deviation between the nominal money stock and real variables interpreted as a demand for real money function.

negative supply shocks causing inflation. But, as the agricultural gap is based on annual data, this finding has its limitations. The dynamics include the lagged inflation of the CPI, of foreign food and energy prices, of domestic food prices and of domestic energy prices, and the lagged growth of the nominal money stock. No goodness of fit or diagnostic tests is reported.

Studies for other countries are increasingly paying attention to supply shocks and distinguishing food and non-food inflation.[11] Durevall et al. (2013) study inflation in Ethiopia with particular attention to food prices. They find that international prices are key long-run drivers of prices of cereals, of food more broadly, of non-food and of the overall CPI; the agricultural output gap (based on annual data) is important in the cereals and food price equations. The money stock in Ethiopia is irrelevant in the long-run, but its growth has a transitory effect on non-food prices and hence on the overall CPI. Other elements in the short-run dynamics include lagged energy and world food price inflation. Careful testing and the use of Autometrics (Doornik, 2009), to find parsimonious specifications beginning with very general models, are features of this work. In a paper following a similar methodology on Rwanda, Durevall (2012) finds that local deviations of rainfall from long-run averages have useful explanatory power for food prices, but that world prices, translated into local currency, have the most important long-run effects, and also finds some effects from the money stock.[12]

Adam et al. (2012) model inflation in food, energy, core and overall CPI in Tanzania using monthly data from 2001 to 2011. They find that rainfall has a significant effect on the food price index and on the overall CPI, which are both also driven by foreign food and energy prices in their long-run solutions. There are only marginal long-run effects of the money stock on overall CPI, and no significant effects on food and energy prices. There is evidence of asymmetric adjustment to disequilibria in food and energy prices. For example, high international food prices relative to domestic food prices translate more strongly into domestic prices than do low relative international prices.

Andrle et al. (2013) calibrate a semi-structural new-Keynesian open-economy model with separate food and non-food inflation dynamics for forecasting and monetary policy analysis in low-income countries, and apply it to Kenya. The models for prices do not incorporate equilibrium correction, unlike the recent econometric models discussed above, so that relative prices typically diverge for long periods. Such models, nevertheless, might be useful for the short-run simulation of shocks, for example, under different settings of a monetary policy rule.

[11] Moser (1994) and Ubide (1997) are two of the earliest papers to use rainfall data to measure supply shocks on food price inflation.

[12] Durevall and Sjo (2012) model inflation in Ethiopia and Kenya, and find that agricultural supply – affected by rainfall- has a significant negative effect on inflation in Ethiopia, but is apparently less relevant in Kenya. However, this is probably due to the use of an inappropriate measure of Kenyan food prices (private communication).

3. Trends and background to inflation history in Uganda

We discuss the construction of the aggregate CPI, sectoral trends in the CPI sub-components, and the history of macro-policy management and regime changes.

3.1 Construction of the CPI index in Uganda

The Consumer Price Index (CPI), compiled by Uganda Bureau of Statistics (UBOS), provides the most reliable continuous and disaggregated series of domestic price data for Uganda. It is computed as a 'Modified Laspeyres Index'[13]. However, it has structural breaks given that the base, coverage and weights have had to be revised several times to ensure it remains representative.[14] The series between 1989 and July 2000 covered 89 items and five urban centres (Kampala/Entebbe, Jinja, Mbale, Masaka and Mbarara), and its base was 1989. In August, 2000, the CPI was extended to cover 125 items and 6 urban centres. The weights were revised based on the Uganda National Household Survey (UNHS) (1997/98) and the index constituted into eight sub-groups (Food Crops, Other Foods, Beverages & Tobacco, Clothing & Footwear, Rent, Fuel & Utilities, Household & Personal Goods; Transport & Communication; and Health, Education & Entertainment). In June, 2007, the CPI was again rebased and the Education component separated from Health & Entertainment, to make nine sub-groups, and re-weighted based on the UNHS of 2005/06.[15] The number of items priced in the new CPI increased from 125 to 276. The weights for food crops, and for total food, were significantly lower after 2007 (Table 1). This is partly the result of rising average living standards which tend to reduce the share of food in average budgets, but also reflects the expanded coverage of the index in the areas of education and health and entertainment, which greatly increased the shares of these categories. The weight of

[13] A Laspeyres index is a weighted average of prices of goods and services relative to those prevailing in the base period with the expenditure weights which applied in the base period. At a more disaggregated level, the "Jevons" geometric average method of averaging prices of comparable individual items in the expenditure basket is used. This is preferable to the 'Carli' method of taking the arithmetic average of individual price relatives which tends to result in an upward bias in the index particularly when price are very volatile, see ILO (2004). The Kenyan National Bureau of Statistics (KNBS) switched from the Carli method to the Jevons method in 2009 (KNBS (2010), see p.7-9 for a summary of the issues and of the methodology, now the same as that used by UBOS).

[14] The price information is derived from consumer price surveys. The "Survey of Consumer Prices" is a monthly survey covering a sample of retailers. It is combined with price data obtained directly from insurance companies, electricity companies etc. to obtain prices for the CPI. The weighting system for the CPI is calculated from the "National Household Survey", conducted every 4 years. The most recent survey was for FY 2012/13, conducted in November 2013, and will inform the next round of rebasing for the CPI. The current CPI is still based on the 2005/06 UNHS, which covered 7,400 households, and collected information on approximately 1,000 different goods and services groups. The data from the 2005/06 UNHS was reweighted according to the 2001 Population Census figures to represent all households in Uganda.

[15] During the rebasing exercise, Kampala was decomposed into two baskets. In addition, Arua was incorporated into the Index, which extended coverage to 8 centres, which now include Arua, Gulu, Masaka, Mbarara, Mbale, Jinja, Kampala middle and low income, and Kampala high income.

transport and communication also rose, probably due to the increased use of mobile phones as recorded in the 2005-6 UNHS, compared to the 1997/98 UNHS.

For the All Items (aggregate) CPI, the index constructed with weights in column 3 of Table 1 from May 2007 onwards is used. In April 2007, this is linked to the All Items CPI using the weights in column 2 of Table 1 back to October 1989. For the period before 1998 this is not quite ideal, in that the All Items CPI published at the time instead used the weights shown in column 1. However, from 1995 to 1998, the two series virtually coincide, and still move quite closely together before 1995. For the two sub-components modelled in this study: the food and the non-food sub-components, the same dates of linkage are used as for the All Items index.

The All Items index, used to compute overall inflation, is also referred to as Headline inflation. From June 2007, a core measure of inflation was identified to exclude food crops, electricity, fuel and utilities. The Bank of Uganda uses this measure for the inflation target, in its new "inflation targeting lite".

3.2 Trends in Relative Price Components

The relative price ratios, p_i/CPI for the main components, i, of the CPI are shown in three panels in Figure 2 for food and non-food CPI, and for goods and services sub-components of the latter, from 1990 to the end of the estimation sample in 2014.[16]

The food component

The highest weighted and most volatile component is the food component. Prior to June, 2007, food carried a weight of 45.2 percent in the in the CPI, of which 60 percent was due to food crops, heavily reliant on weather patterns. From June, 2007, the food weight was reduced to 27.2 percent as noted above.

From 1990 until about 2008, food prices largely tended to be low relative to the overall price index. Most food was produced domestically and the regional markets had not yet opened up to a great extent; as long as production was not disrupted, food was relatively cheap. Most movement in the food price was therefore on account of domestic factors, particularly the weather.

From about 2008 until the end of the sample, food prices were relatively high. Partly this was due to the dry spells witnessed every other year. Other important factors were the surges in international food prices in 2008 and 2011, and the impact of increased regional trade, especially after 2005, when the East African Community's customs union came into force and when the Northern

[16] The components comprise goods components: 'Food'; 'Beverages & Tobacco'; 'Clothing & Footwear'; 'Rent, Fuel & Utilities'; 'Household & Personal Items'; and services components: 'Transport & Communications'; 'Education'; and 'Health & Entertainment'.

region was pacified to allow more trade between Uganda and South Sudan and the DRC. The World Bank (2013) has argued that regional trade strengthened the pass-through of international prices into the domestic food market. With rising international food prices in 2008 and 2011, regional demand expanded (particularly in Kenya and the Sudan) with the adjustment to cheaper food sources from Uganda. By April, 2011, the international price of maize had doubled relative to the previous year, and a drought that ravaged the Horn of Africa reduced supply across the region, raising prices in Uganda more significantly than in other countries from the food trade effects. The increased pass-through was exacerbated by the depreciation of the currency through 2011. Food prices were on a declining trend through 2012 and 2013, apart from surges due to short dry spells in early 2013. This was coupled with disinflationary policy that induced an appreciating currency, and a declining trend of international food prices.

The non-food component

The non-food component comprises the remaining goods and services components. Prior to June, 2007, total non-food carried a weight of 54.8 percent in the CPI. From June, 2007, the food weight was reduced and hence that of non-food increased to 72.8 percent.

The goods and services price components are examined individually relative to total CPI. The original weight of 'beverages and tobacco' in the total CPI index was adjusted from 4.7 percent to 8.6 percent after June 2007. The overall declining trend in the relative price in the sample was reversed by surges in 1990, 1991, 1993, 1994, 2000 and 2004, relating to changes in the tax structure. For instance, the financial year of 1993/94 saw excise duty more than double. The general decline in the relative price from 2002 might reflect rapid productivity growth and the opening of the economy to competing imports, which reduced domestic pricing power.

The 'clothing and footwear' component has a weight of 4.4 percent in the total CPI index since June 2007, slightly below the prior weight of 5.5 percent. A strong decline in the relative price over the sample reflects a global downward trend in the cost of clothing, and the impact of greater competition from the early 1990s, especially from Asian imports, and imported (second hand) clothes and footwear.

The weight of 'rent, fuel and energy utilities' has only slightly increased, from 14.4 to 14.8 percent since June, 2007. The relative price for this component shows no particular trend. The majority of the Ugandan population lives in rural areas where housing is part of the subsistence sector. Housing prices in urban areas have followed the general price trend, as demand remains limited in a segmented housing market (middle income earners mainly build to own, and low income earners have a very modest living standard).

This relative price is also affected by the developments in the fuel and energy utilities sector. Prior to 2005, electricity prices were administered with minimal changes as electricity supply was stable. From 2006, a prolonged drought that reduced the water levels in Lake Victoria cut the hydro-power generation capacity. The impact on energy prices was two-fold. Many firms began to self-generate and thereafter pass increased international oil prices on to the consumer. Secondly, there were direct increases in power tariffs by 35 percent and 45 percent in June and November 2006 as the public grid adopted more expensive thermal generation (World Bank, 2011). The tariffs were reduced by about 8 percent in January, 2010. However, as the international oil prices increased through 2011, the power subsidy became unaffordable. After the 41 percent rise in January 2012, the authorities have adopted a quarterly automatic adjustment process underpinned by the developments in key cost factors like the international oil prices, exchange rate movements and overall domestic inflation, to ensure cost recovery.

Finally, the component 'household and personal goods' has a weight of 4.5 percent in the CPI, similar to before June 2007. There is a downward trend in the relative price, with the component price mostly higher than the general price level. The bulk of goods in this category are imported goods, and with progressive openness from the early 1990s, technological advancement and competitive pressures have been behind the fall in the relative price. The surges in price most likely reflect periodic tariff revisions.

Of the services components, 'transport and communications' has a weight of 12.8 percent, more than double its weight of 6.7 percent prior to June 2007. The relative price rose from the late 1990s to 2002. There is only a limited relationship with the trend of international oil prices, with effects entering with a lag, and blurred by the exchange rate movements and industry practices. From 2007, the relative price declined with greater competitiveness in the telecommunications sector. The communications sector (mobile and other telephone and internet charges) carries a weight of 43 percent of the group weight, and the communications index fell between September and October 2010 from 109.26 to 58.87 due to a regulatory adjustment.

The remaining services components of 'education' and 'health, entertainment and other' carry weights of 14.7 percent and 16.8 percent, respectively. Prior to June 2007, these two components were together in a single component with a weight of 14.7 percent. Relative prices of both categories portray a declining trend from the early 2000s. For the public education sector, the Universal Primary Education that took effect in 2001, and later the Universal Secondary Education which started in 2007, could have had an impact on cost of education, but the increased competition among service providers in the private sector is another factor. In the health sector, the decline could be on account of significant support from not-for-profit non-government organizations, and increasingly cheaper imports of generic medicine, especially from India. Removal of user fees in public facilities is not reported to have had any particular impact on cost as the user fees were replaced by informal payments (Okwero et al., 2010). The surge in prices of the two components in late 2011 was also reflected in the general price level.

3.3 Regime changes and policy

Uganda's inflation developments span three main episodes: a high-inflation period in the 1980s, a relatively stable period during 1995-2007, and the more volatile though moderate inflation era of the past 7 years (see Figure 1). In our empirical modelling of inflation, we examine the role of the money supply, the government deficit, credit growth, capital flows (including aid) and the external account, while the exchange rate is of critical importance throughout. It is useful therefore to summarise key aspects of shifting monetary, fiscal and exchange rate policy.

The first episode to the early 1990s pre-dates the period analysed in this paper. High and volatile inflation was experienced, occasionally exceeding 300 percent per annum. Inflation was fuelled by macroeconomic imbalances, with high external and fiscal deficits, the latter monetized as alternative sources of financing were limited. Acute shortages of key consumer goods resulted in 'black-markets' for the goods that were sold under controlled prices. Interest rates were fixed by the authorities, but had no impact on the quantity of credit as money supply was driven by public sector credit, mainly from the central bank. A thriving parallel market for foreign exchange developed alongside the fixed official exchange rate regime. These domestic developments obscured the influence on inflation from external factors.

In May 1987, a new government began restructuring the economy. Under the Economic Recovery Program, the excess money supply in the system began to be reduced, but money supply growth had accelerated to 70 percent per annum by 1992. The fiscal deficit persisted, peaking at 15 percent of GDP by 1992. The foreign exchange market was reformed towards a market-based system, but the declining terms of trade justified frequent devaluations during 1988-1992 to maintain competitiveness. In 1992 and 1993, stringent measures were adopted to control fiscal spending and the money supply. The central bank gained independence in 1993 under the Bank of Uganda Act. Monetary policy was based on adjustment of reserve requirements and the sale of government treasuries in the primary market as the main instruments of managing liquidity. This implies that even though monetary policy was autonomous, its impact largely depended on fiscal prudence and willingness to coordinate. Cash budget management was applied to fiscal management. The Treasury Bill market was de-regulated and a new auctioning system allowed participation of commercial banks. Partial liberalization of other interest rates allowed them to be linked to the Treasury Bill rate by varying margins until November 1994, when commercial banks were allowed to freely set their own deposit and lending rates. These efforts were rewarded with a return towards stabilization, and inflation fell below 6 percent in 1994.

Between 1995 and 2007, Uganda was relatively stable, with inflation averaging 5.3 percent, large exogenous shocks notwithstanding. Shocks included the coffee price boom of 1994-95, the El Nino rains of 1998, the drought of 1999, and a sharp decline in terms of trade in 1999-2001. From the end of 1993, a floating exchange rate was better able to shield domestic prices from external price rises. Falling domestic food prices also offset inflationary pressures coming from the exchange rate or oil prices for part of the period.

The years 2007 to 2014 have witnessed greater volatility than the previous decade, and inflation returned to double digit levels in 2008-9 and 2011-12. Annual inflation rose to almost 16 percent in August 2008, and rose above 30 percent in October 2011, before declining. Food prices and international oil prices were major contributors to this volatility. Regional factors began to have an important influence on domestic food prices. In 2008, tribal tension in Kenya disrupted food supplies, increasing Kenyan cross-border demand for food, particularly maize, from Uganda. Another source of increased regional demand came from the Sudan as trade routes opened. The regional drought in 2011 and demand from the World Food Programme and import parity pricing in Kenya also impacted on the Ugandan food prices. The co-movement of maize prices in Kenya and Uganda, especially in 2011, is demonstrated in Figure 3. A surge in the fiscal deficit during the financial year of 2010-11 was followed by fast monetary growth and rapid exchange rate depreciation, contributing to inflationary pressure. However, exchange rate appreciation from 2012 pushed the annual rate of inflation down to 4.3 percent in July. Following falls in global food prices in 2014, inflation reached 1.4 percent in September 2014.

One driver of the money supply was increased government deposits with the banking system arising from rising donor financing throughout the period 1993-2002 (except in 2001, where the government position was heavily affected by increased net issuance of Treasury Bills to address a negative terms of trade shock). Tax reforms in 1996 introduced a Value Added Tax and rationalised the tax structure. Together with the slowdown in expenditures, this contained the deficit, reducing it to 5.3 percent by 2007. The bulk of the deficit was funded through external grants and loans in this period, thereby eliminating the need for monetary financing.

The capital account was opened in July 1997, and a change in focus from structural adjustment to poverty reduction saw considerable donor inflows to support higher levels of the government deficit. Despite long-term benefits of this support, it posed short-term management challenges for monetary policy management, requiring a delicate balance between use of domestic securities and sales of foreign exchange to absorb the liquidity arising from expenditures. In April 2002, BOU adopted a new policy instruments-mix to match the dual role of day-to-day monetary policy management and sterilization of donor-induced poverty reducing government expenditure. Under this framework, in addition to the net issuance of Treasury Bills, BOU sells foreign exchange to the market in a uniform and consistent, but discrete manner. These sales, intended to sterilize long-term structural liquidity, are designed to be consistent with benchmarks on liquidity, but are meant to have, at best, minimal impact on the exchange rate. Fiscal and monetary policies were coordinated to manage shocks. In response to the coffee boom of 1994/95, the government increased savings with the banking system and introduced a coffee stabilisation tax. Excess demand was thereby dampened, despite a rise in the value of coffee exports from US$ 200 million in 1993 to US$ 640 million by

1996. Controlling monetary growth through the Reserve Money Programme also helped to control inflation.

4. Mobile money in Uganda

The economics of mobile money is comprehensively surveyed by Aron (2015). Mobile money refers to financial transaction services potentially available to anyone owning a mobile phone, including the under-banked and unbanked global poor who are not a profitable target for commercial banks. An individual installs a mobile phone application on a SIM[17] card and sets up an electronic money account with the mobile money services provider (after providing identity documents), and deposits cash in exchange for electronic money. The electronic money can be stored or withdrawn as cash, or transferred via a coded secure text message to others domestically, without the customer having a formal bank account. Here we cover the history of adoption, the institutional set-up and growth trends in Uganda, illustrating with data on mobile money.[18] We also discuss the proposed links of mobile money with inflation.

The financial sector in Uganda has undergone significant changes over the past two decades. The system has been liberalized and reformed since the late 1980s; but despite growth in the financial system, there was little innovation in the payments system until the 2000s. With the usage of cheques undermined by the historical financial repression, cash remained almost the only mode of payment. Electronic fund transfers, real time gross settlement and credit cards were introduced from 2003, allowing banking transactions to take place outside the confines of a physical bank branch. Subsequently, technological banking innovations such as point of sale devices were introduced. Since 2009, the introduction of mobile money in Uganda constitutes a further important financial innovation.

The adoption of mobile money in Uganda has exploited the proliferation of the mobile phone across the income divide. According to the International Telecommunications Union, there were 16,568,786 mobile cellular subscriptions in 2013 as against 207,474 fixed telephone subscriptions; most adults either own a mobile phone or have access to one. The dual labour market is biased to agriculture which employs over 80 percent of workers, and 90 percent of the population lives in rural areas. Limited alternatives for making domestic money transfers, and especially the lack of affordable low volume payments, has encouraged the use of mobile money for urban-rural money remittances.

Mobile money is a financial innovation that allows money to reach *beyond* the formal banking system. The Bank of Uganda has a Financial Inclusion programme under the Maya

[17] SIM cards are the Subscriber Identification Modules of GSM phones.
[18] See also detailed coverage on Uganda in Gutierrez and Choi (2013) and Ssonko (2011).

Declaration, now in its third year, which aims to "increase access to financial services and empower the users of financial services to make rational decisions in their personal finances so as to contribute to economic growth."[19] As acknowledged by the Governor in 2014[20], referring to the third Finscope survey in Uganda of 2013, the recorded rise of the adult population with access to "formal financial institutions", from 28 percent in 2009 to 54 percent in 2013, is largely attributable to mobile money.[21]

Most definitions of financial inclusion measure the extent of access to the *formal* banking sector (see Aron, 2015). The notion of greater access to formal institutions in Uganda derives from Uganda's regulatory guidelines, where mobile money services are provided by mobile network operators and each is required to partner with one or more licensed banking institutions.[22] The mobile operators operate the telecommunications infrastructure, and contract, train and monitor the widespread networks of agents that interact with the customers, registering users and offering cash deposit and withdrawal functions and payments from electronic accounts held outside the formal banking sector. The partner bank's roles are to hold an "escrow" account backing 100 percent of the money of the participants in the mobile money service who have deposited cash in exchange for electronic money; and to satisfy the institution's fiduciary responsibility in all transactions concerning these escrow funds.[23] In practice, the predominant transactions are *non-bank* payments services such as buying airtime, paying bills and school fees, and transferring money domestically between customers (who could be registered users or not). There is some saving in these electronic accounts, but no interest is paid and there is no protection from inflation. Thus, the current focus on payments means there is at present little inclusion via new formal sector bank accounts or banking products.[24] There remains great scope to innovate and extend mobile money services to include formal sector savings products, small loans and micro-insurance through partner banks, supported by credit ratings from algorithms based on individual's mobile money usage, as has occurred in Kenya (Aron, 2015).

Mobile money was first introduced in Uganda in March 2009 by MTN, then the biggest of the mobile telephone operators in the country. Uganda had fully opened the telecommunications sector to competition in 2007. Five months after MTN, another company, Airtel, launched the Zap mobile

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[19] On the Bank of Uganda's Financial Inclusion Project, see the Strategy Paper on Financial Inclusion (Bank of Uganda (2013a).

[20] A speech: *Regulatory Challenges in the use of ICTs to promote Financial Inclusion,* Prof. Emmanuel Tumusiime-Mutebile, Governor, Bank of Uganda, 21 August 2014.

[21] Note that *formal* financial institutions are defined by Finscope to include mobile money services.

[22] See the Bank of Uganda (2013b) for Mobile Money Guidelines, operational from 1 October, 2013, an interim measure for enabling the operation of the mobile money service (a comprehensive regulatory framework is under preparation). Mobile money service providers may establish partnerships with multiple licensed institutions and vice versa. Each licensed institution is required to apply for a letter of no-objection from the Bank of Uganda. Agreements must not contain exclusivity clauses.

[23] There are requirements for customer identification documentation, daily reconciliation of the escrow account and the electronic money, and the partner bank's authority to distribute the funds in the escrow account to mobile money account holders in case of insolvency or bankruptcy of the mobile money service provider, see the Bank of Uganda Mobile Money Guidelines (2013).

[24] This point is also made variously by Ssonko (2011).

money service. This was followed nine months later with Uganda Telecom (UTL) with its M-Sente. Today, the mobile money market is served by six operators, including MTN, Airtel (formerly Zain, and which has since July 2013 merged with Warid), UTL, Orange, M-cash, and Eezey Money. There is as yet no interoperability of platforms (similar to Kenya), and users of mobile money services have to affiliate with multiple mobile providers (implying there may be multiple mobile cellular subscriptions per user).

Uganda's mobile money industry has grown rapidly, though not at the pace that Kenya has recorded. Both Gutierrez and Choi (2013) and Bank of Uganda (2013), using different evidence, note that the coverage of agents in rural areas is wanting[25]. Ssonko (2011) notes that transaction charges as a proportion of amount sent and received are high on small volumes indicating a potential hindrance of adoption for the poor. There were almost 18 million registered subscribers to the six mobile money providers by September 2014 (compared to 14.2 million subscribers at the end of 2013 and 8.9 million at the end of 2012), and served by 67,000 mobile money agents. A leap in adoption was driven by increased competition, when Warid joined the market (in January 2012) and steered a steep price war. By mid-2014, the value of mobile money transactions was around Shs. 2 trillion[26] per month (compared to around Shs. 0.5 trillion at the end of 2011 and Shs. 150 billion at the end of 2010), or about 30 percent of monthly GDP, see Figure 4. The total annual volume of transactions rose by 1300 percent from 28.8 million transactions in the year to December 2010 to almost 400 million transactions three years later. On average in 2013, 33.3 million transactions worth Shs. 1.5 trillion were executed per month. MTN has remained the largest provider of the service, with 90 percent of the value of transactions by end-December 2013, but only 36 percent of registered customers. Airtel has a 53 percent share of registered customers, but only 8.7 percent of the transactions value of mobile money. Of the remainder, UTL, Orange, M-cash, and Ezeey money, each holds below 2 percent of both the clientele and the transactions value of the market.

Electronic money held on a mobile phone is analogous to a demand deposit (though pays no interest), and can be withdrawn on demand. By virtue of their service, mobile money operators do hold money deposits; as of June 2014, there was a total balance of Shs. 171 billion held on the mobile money accounts of customers of the six mobile money operators in Uganda. The protection of depositors is potentially a concern. However, these electronic balances are fully backed by the escrow accounts in the partner commercial banks, which themselves are subject to prudential regulations.[27] If a mobile money operator were to fail, the electronic money held by its customers could be reimbursed from the escrow account.

[25] The evidence is from a survey by Intermedia (2012), and the Geo-Spatial mapping of financial institutions' (defined to include mobile money) cash in/cash out points, by the Bill and Melinda Gates Foundation.
[26] On 8 April 2015, the exchange rate was Shs. 2980 to US$ 1.
[27] The Financial Institutions Act, 2004 and the regulations issued by the BOU under that Act, as well as the provision of deposit insurance (a nominal insurance of Shs. 4.0 million), applies to such deposits.

The systemic stability of the financial system is not threatened by the present magnitude of mobile money, which is small relative to the entire banking system in Uganda. As of mid-2014, deposits were only 1.4 percent of the total deposits in the banking system, and mobile money transactions constituted less than a tenth of all the financial transactions in the financial system.

A question specifically addressed in this paper is whether the advent of mobile money has had a possible impact on inflation in Uganda. The inflation fears based on the rapid spread of mobile banking in Kenya were mainly linked to an African Development Bank (ADB) Economic Brief by Simpasa and Gurara (2012). This Economic Brief should be treated cautiously from a policy perspective. It reflects some of the confusions in the literature on the effects of variations in the money stock on inflation, while other linkages between mobile money and inflation are not discussed.

The 'monetarist' notion that a demand for money function (derived from an extended version of the Quantity Theory identity) which links demand for money with inflation can be reversed to give an inflation equation, has long been discredited (Hendry, 1985), and the inflation equation lacks micro-foundations. The micro-economics of price setting should give a role to both demand side and supply side factors, and to expectations, whether based on auction markets, competitive markets, oligopoly or administrative price setting. Another reason sometimes advanced justifying a link between money growth and inflation is for the *special case* of hyper-inflation, in Cagan (1956). This *correlation* essentially arises through fiscal stimulus: large, expansionary fiscal deficits, financed by printing money, drive demand for goods and services. Constraints on supply (and hence on government revenue) usually precede the resort to the printing press. The disruption caused by hyper-inflation further contracts supply of good and services. This channel is not likely to generate a time-invariant link (i.e. a stable relationship) between money growth and inflation.

Money growth can for some samples be correlated with the expansion of credit supply to firms or households, resulting in greater private sector spending; and this correlation may be time-varying or absent. However, a causal channel between money growth and inflation can arise because liquid assets are the most spendable part of private sector wealth. This suggests the importance of controlling in the model, where data exist, for the full portfolio of private sector assets and debt and income, taking account of different propensities to spend out of different components to proxy private sector demand. In other words, one needs a better-specified inflation model.

The ADB Economic Brief also ignores the possible countervailing forces. First of all, the spread of mobile banking is likely to lead to significant productivity gains, for example, in agriculture. If supply expands with demand, there need not be inflationary implications. Second, there could well be improvements in competition in markets for goods and services with falling transactions costs, so reducing the pricing power of price setters. Third, increased household saving is also likely with greater security and interest payments, for instance in the M-KESHO accounts in Kenya, which could take pressure off inflation. There is micro-evidence from Demombynes and Thegeya (2012) that household saving has risen as the result of the expansion of mobile banking. Fourthly, the weight of

Information Communications Technology (ICT) in the consumer price index should have increased, while prices of ICT, particularly if quality-corrected, continue to decline. It is far from obvious therefore, that well-measured inflation should have risen as a result of the spread of mobile money.

The fairly simple annual model from 1964-2009 in the ADB's Economic Brief is mis-specified by excluding key variables, *inter alia*. It also covers two different regimes where the structure of inflation was probably different: the inflationary period of the 1960s and 1970s, and the more recent lower inflation period. The work could be greatly improved for the more recent period with quarterly or monthly data. It is far from obvious that the role of the money stock in the ADB research is capturing fundamentals or whether it is merely correlated with the relevant omitted variables. Mobile money began in Kenya in 2007, so that there are effectively 3 annual observations, for 2007-9. The post-election violence after the December 2007 election caused major disruption and an inflation surge in 2008, and 2008-9 were drought years, with higher food prices. Failure to control for such factors could easily lead to attributing higher inflation to mobile money which was growing strongly coincidentally.

5. Theoretical background and methodology

5.1 The NKPC theoretical framework and reduced form equation

The New Keynesian Phillips Curve (NKPC) has long been the dominant paradigm for modelling inflation among macro-economists and central bankers. The NKPC is a modern version of the expectations-augmented Phillips curve, i.e. a relationship between inflation, the output gap or other cyclical demand measure, and expected inflation.[28] In the current, mainstream version of the NKPC proposed by Calvo (1983), micro-foundations are claimed for sticky prices in the adjustment process. It assumes that every firm has the same probability of changing its prices: thus, a firm that has just adapted its prices has the same probability of adjusting prices again as one that has not changed for a long time. Furthermore, this probability is constant over time and independent of the state of the economy. This model implies that the rate of inflation in industrial countries is largely determined by the expected rate of inflation (with a coefficient close to 1) and the output gap (or, in some versions, by the price level relative to unit labour costs). The implication is that any information relevant for forecasting the output gap or unit labour costs should help forecast inflation. There are open economy variants of the NKPC in which import prices or the terms of trade also enter, e.g. Batini et al. (2005).

[28] The classic reference is Woodford (2003), though Clarida et al. (1999) did much to popularise the NKPC. Roberts (1995) discusses its earlier variants.

A hybrid form of the NKPC also includes lagged inflation, with the sum of expected and lagged inflation close to 1 (known as the 'accelerationist' restriction).

The restricted NKPC offers a guide for what should be included in a reduced form model, but is not useful for forecasting because of the reliance on the expectation of next period's inflation rate. Furthermore, there are several difficulties with the practical implementation of a restricted NKPC, especially in a developing or emerging market country. First, empirical evidence is at odds with its key assumptions. Empirical tests against more general models than the closed or open economy versions of the NKPC usually find that the NKPC model restrictions are rejected.[29] There is also empirical evidence against the rational expectations hypothesis embodied in the expected inflation term in NKPC, when using actual inflation forecasts from surveys of households, Forsells and Kenny (2002). In the presence of structural breaks, NKPC models typically fail to model location shifts, so good fit can be an artefact with future inflation acting as a brilliant proxy for breaks to come: see Castle et al. (2014).

A second problem with the NKPC formulation concerns how well the output gap and wage costs can capture the domestic elements of the inflation process. In economies such as Uganda, with a large agricultural sector, the output gap is more likely to capture supply shocks such as droughts or floods which reduce supply, given demand; then below-trend output will be associated with *increased* inflation. Furthermore, wage costs in the *formal* sector of such an economy, even if well-measured, are likely to comprise only a relatively small input into the determination of the CPI.

Third, with heterogeneous drivers, inflation will be strongly influenced by the dynamics of domestic as well as international relative price adjustment. The heterogeneity of different components of the CPI in Uganda has already been observed (Section 3.2), most obviously between food and non-food.

A fourth problem is that inflation is likely to be a *state-dependent* process, for example, with a lower speed of price adjustment in a lower inflation volatility environment. There is a large literature on inflation persistence and price stickiness. This has been intensively studied at the micro as well as macro level, for instance by the *Inflation Persistence Network* set up by the ECB and the main central banks (see Angeloni et al., 2006; Altissimo et al., 2006; and Alvarez et al., 2006). A key issue concerns whether the probability of price changes is state-dependent, as argued by Sheshinski and Weiss (1977), or whether the popular Calvo model, the work-horse of modern monetary economics, applies. Reis (2006) supports state dependence: in his sticky information model, producers re-optimise more frequently when cost changes are more volatile, suggesting a higher speed of adjustment in high inflation periods. One plausible implication of these ideas is that there could be

[29] Examples are Bardsen et al. (2004), Boug et al. (2006), Mavroides (2005) and Rudd and Whelan (2007). In Bardsen et al. (2005, Chapter 8) it is also shown that the NKPC model loses in simple inflation forecast competitions to models incorporating relevant equilibrium correction terms.

non-linearities in the inflation process so that high current or recent rates of inflation are associated with disproportionately higher future inflation.

In some countries with an important agricultural sector, another source of non-linearity in the inflation process can arise if a domestic harvest failure triggers a switch from export parity pricing to more expensive import parity pricing, where transport and distribution costs of imports have to be added to the world price.

5.2 Extending the reduced form NKPC to general, non-linear reduced form inflation models

Our inflation models are cast in forecasting mode, for forecasts at 1- and 3-month horizons, using information dated t and earlier. At the 1-month horizon, this is equivalent to the standard formulation of a single equation in a Vector Auto Regression (VAR) model. At longer horizons, these 'multi-step' forecasting models can be regarded as single equation, reduced-forms of the related VAR systems.[30]

Our approach models the economic drivers of the inflation process in a developing or emerging market country, and treats the food and non-food CPI components separately. The most general form of the equation incorporates an equilibrium correction term, non-linear terms, trends, and a broader set of variables than an NKPC-based reduced form equation:

$$
\begin{aligned}
&\Delta logCPI_{t+h}^{i} \\
&= \alpha + \textstyle\sum_{j=0}^{k} \omega_j \, \Delta logCPI_{t-j}^{i} && \textit{Information Set 1} \\
&+ trends\ and\ dummies && \textit{Information Set 2} \\
&+ \textstyle\sum_{j=0}^{k} \gamma_j outgap_{t-j} && \textit{Information Set 3} \\
&+ \textstyle\sum_{g=1}^{m} \sum_{j=0}^{k} \varphi_{g,j} \, \Delta logOTHERPRICES_{g,t-j} + \sum_{l=1}^{n} \sum_{j=0}^{k} \beta_{l,j} \, \Delta X_{l,t-j} && \textit{Information Set 4} \\
&+ \textstyle\sum_{g=1}^{m} \varphi_g \, (logOTHERPRICES_{g,t} - logCPI_t^i) + \sum_{l=1}^{n} \beta_l \, X_{l,t} && \textit{Information Set 5} \\
&+ non\text{-}linear\ terms && \textit{Information Set 6} \\
&+ \varepsilon_{it} && (1)
\end{aligned}
$$

where ε_{it} is white noise, plus a moving average error component when the forecast horizon exceeds one period. In the dependent variable, for h=1, CPI_{t+h}^{i} is the 1-month-ahead value of the i^{th} CPI price index, where *i* is either food CPI or non-food CPI.[31] The closed economy NKPC-based reduced form empirical equation is effectively encompassed by the independent variables in *Information Sets 1* to *3*, though with the addition of trends and dummies. The second line of the equation represents the

[30] These models have the advantage over a full VAR model of simplicity, and often of economic interpretability. While a single equation of a conventional VAR model can forecast one month ahead, forecasting further into the future using recursive substitution requires, in general, all the remaining equations of the VAR system.

[31] Both headline and core CPI can be modelled in the same way, as can other sub-components of the CPI, but then also introducing sectoral drivers.

simplest univariate information set, *Information Set 1*, using a linear combination of current and past inflation terms. The fourth line adds the output gap (to introduce a basic variant of the Phillips Curve) in *Information Set 3*.

Expanding to *Information Sets 4* and *5* includes the vectors: $OTHERPRICES_{g,t}$ and $X_{l,t}$. The former comprises a range of *other prices*: import prices; oil prices, maize prices, and world or regional food prices; and potentially unit labour costs, domestic producer prices and house prices[32]. Note that the import price is a component of an open economy NKPC reduced form model. The set $X_{l,t}$ includes: the real effective exchange rate, *REER*; the terms of trade; other measures of the output gap such as rainfall, and potentially the unemployment rate[33]; measures of money, private sector credit and mobile money; the interest rate yield spread relative to the USA; the fiscal surplus; and the current account and trade account surpluses. In *Information Set 4*, only the *changes* in these variables are included. In the next line, *Information Set 5* adds equilibrium correction components given by log ratios of other prices relative to CPI_t^i, and by the levels of the log real exchange rate[34] and of the log terms of trade, and the other variables.

Long run homogeneity is imposed through the potential equilibrium correction components. The long-run solution for $logCPI_{t+h}^i$ is then a weighted average (weights adding to 1), of the I(1) elements of $OTHERPRICES_{g,t}$ and $X_{l,t}$, and with trends as potential shift factors in the relationship.

Another advantage of the single equation multi-step forecasting framework is that one is not restricted to the linear specification of a standard VAR system. The penultimate line adds non-linear terms to create *Information Set 6*. As discussed above, if the frequency of price change is state dependent, as in sticky information models such as that of Reis (2006), high recent rates of inflation could be associated with more rapid pass-through of inflation shocks: greater volatility of shocks increases the frequency of price change, as the cost mounts of leaving prices unchanged because of menu costs or 'inattention'. This might suggest that the parameters in equation (1), which incorporate the speed of adjustment, should vary with recent inflation experience. This would produce a complex model, non-linear in both variables and parameters. A simpler model that captures some of the same

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[32] This obviously depends on data availability. For instance, there are no measures of unit labour costs in Uganda; the Ugandan import price (IUV) includes petroleum products; there are no house price indices; and monthly producer prices have been published in Uganda only since 2005.

[33] The unemployment rate is seldom a useful measure in developing and emerging markets, see work on South Africa (Aron and Muellbauer, 2012).

[34] Note that both the real exchange rate and the terms of trade are already relative prices and therefore satisfy price homogeneity (homogeneous of degree zero). The log level of the real exchange rate is defined to increase with appreciation: log nominal trade-weighted exchange rate + log trade-weighted foreign price indices- log domestic prices, and uses the consumer price index (CPI). It is included in the *X* vector rather than the $OTHERPRICES$ vector, but it is a close approximation to an equilibrium correction price component consisting of the log ratio of the foreign CPI in domestic currency to the weighted food CPI plus non-food CPI. Similarly, the log level of the terms of trade, defined as the log of the ratio of export unit value to import unit value, is included in the *X* vector.

ideas and possible asymmetries in price adjustment includes additive terms of a non-linear transformation of recent changes in log prices.[35]

The trends could include slowly evolving variables such as trade openness. Other dummies could capture impulse events and step changes, e.g. in indirect taxation.

5.3 Sign priors, lag structure and the estimation of single equation models

Following our earlier work on the US and South Africa, sign priors, guided by economic theory, are imposed before model selection. The sign prior restrictions are on the ECM terms, on the variables in levels, on growth rates, but not on the price dynamics. This helps achieve parsimony in models and reduces the possible damage from unresolved co-linearities, particularly in shorter samples.

The equilibrium correction components in equation (1), given by the **relative price terms** (log ratios of other prices relative to CPI_t^i in the $OTHERPRICES_{g,t}$ vector, *Information Set 4*), should all have positive coefficients. This also applies to the **log of the real exchange rate index** (in the $X_{l,t}$, vector, *Information Set 5*), which measures international competitive pressure on domestic price setters. This variable should have a positive sign since the weaker is the Ugandan shilling relative to other currencies, and the higher are foreign prices, the dearer are imports and the easier it is for domestic price setters to push through price increases.[36]

Sign priors for other variables in the $X_{l,t}$ vector (*Information Set 5*) are sometimes less clear cut. The **log of the terms of trade** has an ambiguous effect: on the one hand high export prices can result in an inflationary domestic boom; on the other, a favourable shift in the terms of trade can appreciate the currency, with negative effects on domestic inflation.

Proxies for **excess demand** in an industrial economy should have a positive coefficient, since with higher excess demand, consumer prices may increase relative to costs. In an economy with a large agricultural sector, however, a negative **output gap** may indicate supply shocks due to droughts, expected to raise inflation. In the *absence* of controls for rainfall, therefore, the output gap should have the opposite sign to that expected for an industrial economy. The **trade surplus relative to GDP**

[35] In one version of non-linearity, the residual is extracted from the regression of the *squared* 3-month change in logs of food prices or of foreign maize prices, for example, on the 3-month change in logs of these prices and a constant. The residual and its lags potentially capture the non-linearities from recent inflation experience. This residual has the virtue of being orthogonal to the change in logs, so avoiding co-linearity. In another version of non-linearity, asymmetry of reaction to key equilibrium correction terms is tested, for example for the international maize price or food prices in Kenya. There might be a faster price response when these prices are high relative to domestic prices than when they are low, see Adam et al. (2012) for evidence of asymmetry for Tanzania.

[36] Recall that the exchange rate is defined so that a rise represents appreciation.

serves partly as an excess demand indicator[37], and partly as a predictor of exchange rate movements. For both cases a negative sign is expected. On the other hand, the **current account surplus relative to GDP**, because it also captures financial flows such as aid which add to domestic demand, should have a positive sign when controlling for the trade surplus.

Inflationary financing of a **fiscal deficit** suggests a positive sign for a deficit on the fiscal balance. In the absence of good fiscal data, the real money stock can then serve as a partial fiscal deficit proxy[38], though it also responds to aid flows. The real money stock is also a proxy for components of private sector wealth when these data are lacking (as they usually are for emerging market countries, see Davies (2008)). For both reasons, a positive coefficient is expected on the included **real money stock**. The ambiguous effect of the financial innovation represented in the growth of **mobile money**[39] was discussed in Section 4. The sign of the level of real **debt** (or relatedly, **private sector credit**) is also ambiguous. There is potentially a dual effect of debt, since a high level of debt is a constraint on the private sector, but the rapid growth of debt often indicates optimism or temporary credit liberalisation.

The sign on the **real interest rate** is also ambiguous. Although higher real interest rates might be expected to have a negative effect on inflation, this may already be reflected in excess demand proxies in the model. The 'cost channel' of monetary policy via the real prime rate, see Barth and Ramey (2001), argues for a positive coefficient on current interest rates in economies with a highly developed banking sector: for example, business costs may increase when interest rates rise. A related mechanism by which higher interest rates may raise subsequent inflation is where reduced investment and bankruptcies contract capacity, which constraint may increase inflation in subsequent upturns. Furthermore, if the Central Bank has information about future inflation not reflected elsewhere in the model, interest rates may be raised to head off higher inflation. The sign is clearer on the **yield spread** (defined as the yield on 3 month Treasury bonds minus the 3-month US Treasury Bill rate): if domestic interest rates are higher relative to foreign rates, the outcome should be deflationary via the exchange rate appreciation that is induced by yield-sensitive inflows.[40]

Finally, we turn to the trends and dummies in *Information Set 2*. Impulse dummies can capture unpredictable shocks such as the onset of a drought or flood. Step dummies can capture a regime change such as the onset of inflation targeting from July, 2011. Interaction effects might be

[37] If there is a negative supply shock which is inflationary, the trade surplus worsens through greater imports and reduced exports. If there is a positive demand shock which is inflationary, again the trade surplus falls through increased imports.

[38] In Uganda, fiscal data are annual and less responsive in a monthly model than monthly money aggregates.

[39] Mobile money could be measured as a ratio of mobile transactions or of mobile balances to broad money holdings.

[40] Even if the interest rate spread works mainly via the exchange rate, if it also helps forecast the exchange rate two or three months ahead, then it has independent information content for forecasting inflation three months ahead (and even if the exchange rate at t is included in the equation). The spread could also have domestic effects.

important between particular variables and regime change measures or trade openness (e.g. the effect of the real exchange rate may change with greater openness or under a different monetary policy regime). Greater **trade openness** may reduce inflation in some goods through increased import competition. If increased trade openness reflects the opening of previously closed foreign markets to some domestic producers, however, demand could rise and hence domestic inflation in those goods. The opening of regional export markets to Ugandan food producers from 2005 provides an example.

By contrast with the levels variables, no sign priors are imposed on price dynamics. Negative coefficients on lagged cost changes have several possible interpretations. When an ECM component is present in the equation, they can indicate longer lags in the reaction of the consumer price index to costs (i.e. that the ECM should be lagged as appropriate). They can indicate the lagged effects of a policy response to inflation; or the negative effect on excess demand of lagged cost changes, for example in the price of oil. They may also reflect a temporary squeeze in profit margins, followed by an inflationary restoration of margins.

We are able to test for long lags without loss of parsimony, using "parsimonious longer lags" (PLL), see Aron and Muellbauer (2013). This helps overcome the well-known problem with degrees of freedom, as experienced using Vector Auto Regression (VAR) models. VAR models aim to preserve generality by not imposing an *a priori* structure on models, but suffer from the 'curse of dimensionality' as increases in lag lengths or in the number of variables rapidly raises the parameters to be estimated. In practice, the gain in generality from using a VAR comes at the expense of restricting the number of variables and the lag lengths that can be considered. In most VARs, lag lengths are restricted to only a few periods, which is particularly restrictive for monthly data.

PLL in the context of equation (1) takes the following form: for variables in differences, full generality of lags is permitted at lag lengths of 0, 1 and 2; lag 3 is restricted to the 3-month change; and lag 6 is restricted to be the six-month change. The dynamics in a regressor, *Z*, are represented by ΔZ_t, ΔZ_{t-1}, ΔZ_{t-2}, $\Delta_3 Z_{t-3}$, and $\Delta_6 Z_{t-6}$. Thus, compared to employing unrestricted lags from 0 to 12 months, when using PLL, the 12 parameters for the differenced variables are here replaced by only 5 parameters. In the specifications using PLL, the significant lags amongst these are retained. For a variable such as the terms of trade, subject to erratic movements, annual or biannual changes tend to smooth out erratic jumps in the data, and capture the diffuse impact of shocks at longer lags.

We use automatic selection with Autometrics[41] subject to the above sign priors to produce parsimonious models from a general specification in equation (1), partly to have an objective research tool. The results are reproducible using the same data, the same specification of the 'general unrestricted model' (GUM) and the same settings in Autometrics. We take advantage of its various

[41] Autometrics is an objective and easily reproducible tool, not affected by the subjective choices of the modeller. This software examines a full set of general to simple reduction paths to select a parsimonious form of the GUM to satisfy a set of test criteria. The test criteria include tests for normality, heteroscedasticity, ARCH residuals, residual autocorrelation, parameter stability in the form of a Chow test, and the RESET test.

methods to help identify structural breaks, including dummy saturation techniques and dummies for large outliers. Outliers can easily arise because of unpredictable changes in energy and other commodity prices. The overlapping nature of the dependent variable for a forecasting horizon of more than one period means that residuals will be auto-correlated and so the corresponding tests, including portmanteau tests, are then switched off. Model selection, given a GUM, involves two potential errors: omitting relevant variables and including irrelevant variables. Heavy protection against the latter error results in smaller models being chosen. The 'medium size' setting is chosen, limiting the probability to 0.025 of including an irrelevant variable, see Doornik (2009) for further details.[42]

Having obtained a fairly parsimonious specification using these methods, one can then check if an even more parsimonious model can be obtained by judicious choice of lag for the equilibrium correction or other long-run terms, including sometimes using moving averages.[43] Clues from the short-run dynamics can sometimes be helpful in choosing the appropriate lag for the GUM when re-running the search algorithm. This final step typically makes little difference to the long-run solution and fit of the model, and is carried out mainly to produce simpler and therefore more easily understood models.

6. Results

We take a comprehensive view of the economic drivers of the inflation process in Uganda, using single equations that may be combined to form a small system. The samples post-date key elements of policy regime changes, including the floating of the Ugandan currency in November 1993, the liberalization of interest rates in 1994, the opening of the current account in 1994 and the shift from direct to indirect instruments of monetary management in 1992. This avoids the complications of modelling these important regime shifts. There is a trade-off between avoiding such major structural breaks and having enough variability in the shorter sample to isolate drivers of inflation; but there is also more co-linearity in the shorter samples. Stability testing of the models is conducted using recursive stability tests (running forwards) and also comparing estimates over different samples.

We chose not to model the aggregate CPI: there are very large weights changes in the period (see Table 1) and hence one is less likely to find a stable model over a longer sample. Instead we model domestic fuel prices and the food and non-food CPI components separately in single equations,

[42] When dummy saturation is used as a model check, higher levels of significance such as 0.01 or 0.005 are chosen.

[43] For example, $(-\Delta Z_t + Z_t)$ simplifies to Z_{t-1} saving one degree of freedom; and $(-(1/2)\,\Delta Z_t + Z_t)$ simplifies to the 2-month moving average of Z, or $(Z_t + Z_{t-1})/2$.

and using 1-month-ahead[44] and (multi-step) 3-month-ahead forecasting models that incorporate the information sets shown in equation (1). Domestic fuel prices turn out to play a significant role in driving both food and non-food prices.

Previous research suggests circumstances when multi-step forecasting can be superior to recursive forecasting from a VAR model, especially where negatively-correlated moving average errors or structural breaks are present in the VAR system (Weiss, 1991; Clements and Hendry 1996, 1998; Chevillon, 2007). These features may well have relevance for modelling the inflation process in Uganda. Our experience is that the 3-month horizon usually gives a somewhat clearer picture of the underlying long-run solution for the price level, with a better signal to noise ratio than at the 1-month horizon. We expect the same variables to appear in the long-run solution, whether we model at the 1 or 3-month horizon, and this broad consistency is something we look for in the selected models.

For the food sub-component of the CPI, with the largest of the component weights, the longest period over which stable models can be achieved is 1994 to 2013. For the non-food component of the CPI, which is more heterogeneous with non-food services and goods, and thus heavily affected by large weights changes, the longest period for stable models is 1997-2013. For domestic fuel prices, the longest period for stable models is 1994-2013.

These three equations potentially form the constituent parts of a small system, all conditional on the exchange rate, which could be solved for all three endogenous domestic prices in terms of international prices, the exchange rate and domestic supply and demand factors. The next priority would be to add an exchange rate equation. The single equation analysis provides clues on long-run variables and structural breaks, helping to devise restrictions that could be applied to a system.

Discussion of data issues and statistical tests are presented in Section 6.1. The evidence from single equation multi-step forecast equations is presented in Section 6.2.

6.1 Data and statistics

The underlying construction of the variables is described in a data paper, Aron, Muellbauer and Sebudde (2014). A summary is provided in Table 2, where statistics are given and stationarity tests are reported for the longest estimation sample. As noted above, the sample begins just after the period when the key policy regime shifts took place.

The augmented Dickey-Fuller test statistics are based on specifications including a linear trend where significant. The tests suggest that each log price is I(1), for food and non-food components of the Ugandan CPI, domestic fuel prices, foreign prices (translated at the appropriate exchange rate) for world oil, maize, and coffee, the food CPI component in Kenya and the US

[44] The 1-month-ahead model replicates a VAR model on monthly data (and, given the PLL structure, see above, with fewer degrees of freedom problems).

wholesale price as a proxy for global manufactured goods. This implies too that the dependent variables, $\Delta logCPI^{i}_{t+h}$, where CPI^{i}_{t+h} is the 1-month or 3-month-ahead value of the i^{th} CPI price index component, where i is either food CPI or non-food CPI, are I(0), and equivalently for $\Delta logDomFuelP_{t+h}$, where $DomFuel_{t+h}$ is the 1-month or 3-month-ahead value of domestic fuel prices. Other long-run explanatory variables are I(1), as expected: the log of the real effective exchange rate, the log of the terms of trade, the log of private credit and a measure of real trade openness. The scaled real per capita broad money variable is I(1); so are the two mobile money proxies, the logs of mobile money balances or value of mobile money transactions, relative to broad money. The output gap and the deviation of rainfall from its long-run mean are stationary, as are the current and trade account balances to GDP ratios, the fiscal balance to GDP ratio and the US-Ugandan Treasury Bill rate differential. Similarly, changes in log private credit, in log terms of trade and in all log prices used as regressors in this empirical work, are I(0).

6.2 Single equation forecasting equations for Uganda

The variables included in equation (1), discussed in Section 5.3, are defined in Table 2 for Uganda, and some are illustrated in Figure 5. It is important to note that relative to the ideal set of variables for establishing the determinants of the CPI inflation, several key components are missing for Uganda (see data paper, Aron, Muellbauer and Sebudde (2014)). Chief amongst these are the domestic unit labour costs and producer or wholesale price indices, which prove so relevant in our work on South Africa (Aron and Muellbauer, 2012) and the USA (Aron and Muellbauer, 2013). Admittedly, given the dominant role of agriculture in the economy, unit labour costs would play a less important role in Uganda, even if timely data existed.

The dependent variables in single equation equilibrium correction models are the monthly change in logs of a weighted domestic fuel price and of the food CPI and the non-food CPI, one month and three months ahead. The longest sample is from January 1994 to the end of 2013. Results are reported for the domestic fuel price equations in Table 3, for the food CPI equations in Table 4 and for the non-food CPI equations in Table 5. The long-run coefficients are reported first, followed by other non-stationary determinants, the short-run dynamics and dummy effects. The results of recursive stability tests are found at the end of each section.

6.2.1 Modelling domestic fuel prices.

The fuel price index proves to be important in modelling food and non-food prices, and therefore needs itself to be modelled. An index of domestic fuel prices was constructed from three price indices: Premium Motor Spirit, Automotive Gasoline, and Diesel Bulk Illuminating Kerosene, using sales (but initially, import) share weights. Fuel is imported through other countries, and particularly via Kenya.

The Kenyan Pipeline Company pipes fuels from the Mombasa ocean terminal to western Kenya, from which trucks transport fuels to Uganda. In the past, congestion and pipeline breakdowns have sometimes caused fuel supply shortages in Uganda, which is one reason for high price volatility, the others being the volatility of raw oil prices and hence of processed oil products, and exchange rate volatility.

The model for the 3-month-ahead change in log domestic fuel prices is derived from a general unrestricted model (GUM). Potential long-run variables include equilibrium correction terms of log relative prices of domestic fuel to the world (Dubai) price of raw oil, to a US producer price index of oil refinery products, and to the broad US wholesale price index, with foreign prices translated into Ugandan shillings. Other potential long-run terms are the log relative price of domestic fuel to the domestic non-food CPI and to the domestic food CPI, and a scaled measure of real broad money per capita. The potential I(0) variables include domestic credit growth, the government fiscal surplus to GDP ratio and the current account and trade surplus to GDP ratios. General short-run dynamics include changes in the logs of the above prices, including the US broad wholesale price index denominated in US dollars as a measure of world inflationary trends, the change in the log of the bilateral Uganda/US exchange rate and the Kenyan overall CPI inflation rate.

A lagged measure of the rainfall deviation is included since the production of hydro-electricity is affected by variations in rainfall – extended droughts deplete reservoirs which reduce electricity supply, and so raise demand for diesel and other fuels.

It is often argued that fuel prices tend to react more quickly when raw oil prices rise than when they fall. To take account of this possibility, an asymmetric measure is introduced of the log change of the Dubai oil price in shillings, which takes its value when positive and is zero when the price falls.

The model selected by Autometrics is quite parsimonious, and, with two outliers, a fairly stable equation could be found for data back to 1994. In the 3-month-ahead equation, in the long run, the price of domestic fuel depends only on the Dubai oil price and the non-food CPI. The speed of adjustment to the long-run is around 60 percent. The I(0) variables appearing are the domestic credit growth, the rainfall deviation, and the ratios to GDP of the current account and trade balances.[45] In the short-term dynamics, there are lagged rates of change in domestic fuel prices, the current month's rate of change in the bilateral exchange rate with the US, and the global inflation rate (proxied by the US WP inflation rate).The model's fit and the recursive estimation charts is shown in Appendix Figure A1. Parameter stability back to 1994 is reasonable, though there appears to be some increase in the influence of global inflation in 2009, possibly reflecting the impact of the global financial crisis.

[45] A 2-month lag on the current account and trade balances reflects the fact that the raw data are originally quarterly: hence, the 3-month moving average requires lagging in order to be in the data set available to economic agents at time t.

The 1-month-ahead equation contains the same factors with some differences in lag structures, including the simple long-run solution; in addition, there are three outliers and a significant asymmetric effect. The asymmetry was not significant at a 3-month horizon, and so this finding suggests that passing on rises in the shilling price of oil more rapidly than price falls is only a temporary phenomenon. The recursive stability charts again detect an increase in the influence of global inflation around 2009.

The long-run solution implied by the 1-month-ahead equation for the domestic fuel can be represented as follows:

$$\log(domestic\ fuel\ price) = 0.85\log(nonfood\ CPI) + 0.15\log(world\ coffee\ price) + constant \qquad (2)$$

This suggests that domestic fuel prices contain a good deal of local cost content and probably also an element of pricing-to-market, relative to international raw oil prices. Local transport costs are particularly large for Uganda so the local cost content is unsurprising. The international prices of fuels which are imported at the Mombasa terminal do not move one-for-one with raw oil prices, since refinery prices also involve other costs; there are shipping costs, and regional supply and demand fluctuations can deviate from global fluctuations. Credit growth in Uganda and the trade and current account data capture some of these local demand fluctuations.

Plots of the 3-month-ahead inflation rate for domestic fuel against groups of factors are shown in Figure 6a and Figure 6b. Figure 6a shows the combined equilibrium correction terms to domestic non-food prices and Dubai oil prices expressed in shillings; the short-term dynamics in prices and the exchange rate; and the two outliers. The major fall and recovery in domestic fuel prices in 2009 is explained in roughly equal measure by the equilibrium correction terms (mainly the temporary fall in the Dubai oil price) and the short term price dynamics (mainly the temporary collapse in the US producer price index). Figure 6b shows the effects of rainfall; of credit growth; and of the combined current account and trade balances to GDP.

6.2.2 Modelling the food component of CPI

Food prices are highly volatile and challenging to forecast, in part because of supply shocks. One of the distinguishing features of our model is the important role played by the deviations of rainfall from the historical average. No previous econometric study of food price inflation in Sub-Saharan Africa has found such powerful effects. Once these supply shocks are well controlled for, demand and relative price effects can be measured much more accurately.

The long-run solution is quite rich: there are a number of equilibrium correction terms and some of them are subject to time-varying coefficients. The single most important equilibrium correction element is the log relative price of non-food to food. The non-food price level should be an ingredient in wages and other costs faced by food producers and retailers.

Also important in the long run are logs of world prices for coffee and maize and of food prices in Kenya (all in Ugandan currency terms), and domestic fuel prices, each taken relative to domestic food. First, coffee is Uganda's single largest export crop. When international coffee prices translated into shillings are high compared with food prices for domestic consumption, cash incomes will be high, creating demand for domestic food. Also, though coffee trees take years to mature, when coffee prices are low, farmers will divert more of their labour into producing crops for domestic consumption. This increases the supply and should lower food prices, other things being equal. Farmers need to trade food for non-food items, and need fuel for household consumption, farming and for transporting food to market. It thus makes sense that fuel prices and non-food prices should have an important influence on food prices. However, since domestic fuel prices are already represented in the index of non-food prices, they should matter only if their cost weight in producing food exceeds their weight in the index (and this is an empirical question).

Second, maize is a Ugandan export, for which increased international demand can occur at times of regional drought through the United Nation's World Food Programme. The UN will then buy up maize and other easily transportable foods in the nearest locations to the drought-affected areas, for distribution to those areas.

Third, relative food prices in Kenya, translated into shillings, have an important time-varying effect. Given the increased regional integration resulting from the EAC Customs Union beginning in January 2005, one expects Kenyan food prices to have a greater effect on Ugandan food prices after about 2006. To capture this integration, a transformation variable is defined which equals the relative log price of food in Kenya to that in Uganda if this relative price is above average over the sample, and zero if it is below average. Since the transformed variable is zero before 2007 (apart from a few months in 2006), it captures the greater effect Kenyan food prices have on Uganda thereafter. This variable proves to be very significant.

Finally, the evidence also suggests a shift in the impact of domestic fuel prices on food prices in about 2006 or 2007. The discussion of historical developments in Uganda (Section 3.3) noted that from around 2006, there was a large increase in the use of diesel generators because of increasingly precarious electricity supplies, initially triggered by droughts. This suggests a potentially increased role of fuel costs in explaining food prices about then. Indeed, the evidence is consistent with a zero effect on food prices before 2007 once the non-food price index is taken into account. Presumably this is because the weight of fuel costs in the non-food component of the CPI is broadly the same as its cost impact on food production. However, from 2007, there is clear evidence of a positive effect in addition to that already in the non-food index.

Note that exchange rate effects are deeply embedded in these variables: foreign coffee and maize prices and Kenyan food prices are translated at the relevant exchange rates, and, as shown in

Section 6.2.1, domestic fuel prices are strongly influenced by foreign oil prices translated at the exchange rate. Moreover, non-food prices are also affected by the exchange rate (Section 6.2.3).

The long-run solution further includes a measure of trade openness with a positive coefficient as expected, a negative effect from a time trend and a step-shift in 2007. (The measure of the real broad money stock relative to GDP proved insignificant.) The step shift in 2007 reflects a break in the data, which may reflect structural changes, including the radical weight changes in the CPI introduced in 2007, see Section 3.1 and further discussion below.

Trade openness in the food equation has a positive impact. As trade openness is measured by trade volume scaled by real GDP, the rise in trade openness reflects increasing trade integration with Uganda's neighbours. Much of the growth of real exports relative to GDP in Uganda represents food exports. Growing regional demand for food produced in Uganda has been a factor increasing relative food prices in Uganda, also reflected in the significance of the relative Kenyan to Ugandan food price.[46]

The long-run solution implied by the 3-month-ahead equation for the food component of the CPI from 2007 onwards can be represented as follows[47]:

$$\begin{aligned}\log(food\ CPI) = {} & 0.43\log(Kenyan\ food\ price) + 0.28\log(nonfood\ CPI) + 0.02\log(world\ maize\ price)\\ & + 0.09\log(world\ coffee\ price) + 0.18\log(domestic\ fuel\ price)\\ & + 0.24\ (tradeopeness) - 0.052(2007\ step\ dummy) - 0.043(timetrend/100)\\ & + effects\ of\ rainfall\ \&\ other\ stationary\ variables\end{aligned} \tag{3}$$

There are several stationary or I(0) determinants of food price inflation. Supply shocks are extremely important for food prices, and are measured by deviations of monthly rainfall from long-run averages of rainfall for the four main regions of Uganda. A simple national average of the regional deviations was taken. This constructed variable is highly significant in the food price equation. Instead of twelve separate monthly effects, the data are very adequately summarised by four quarterly effects, using quarterly averages of monthly data. The strongest effect is for the current three months, with the coefficients progressively declining over the four quarters of the year. Since Kenyan food prices are also affected by regional droughts, they indirectly proxy further weather-related supply shocks. Regional droughts are correlated with the droughts in Uganda. With a bigger role for the relative price

[46] There is also a cointegration interpretation of this positive coefficient. There is a cointegration relationship between the relative prices of non-food to food and trade openness, inter alia. Since short-run changes in the food equation and in the non-food equation react with opposite signs to this cointegrating relationship, the positive trade openness effect in the food equation is probably partly a mirror image of the negative coefficient of trade openness in the non-food equation.

[47] Note that before 2007 both domestic fuel and Kenyan food prices drop out, and the other long-run coefficients rise to compensate.

of food in Kenya to the Ugandan food price from 2007, see above, a somewhat reduced impact of Ugandan rainfall from 2007 on Ugandan food prices might be expected. Indeed, this appears to be the case and is addressed by including an interaction effect between the 6-month average rainfall deviation in Uganda and a step dummy equal to one from 2007.

The spread between Uganda's Treasury Bill rate and that of the US likely reflects the impact of tighter monetary policy on inflation, especially via an appreciated exchange rate, and appears to operate at a lag of about 3 months on the 3-month-ahead food inflation rate. With relatively low US inflation, US interest rates were quite stable, except during the global financial crisis when they fell to zero. The main fluctuations in the spread are thus due to the Ugandan rate. Also, nominal credit growth over the previous six months boosts food prices. Interestingly, credit growth also proved significant in both the domestic fuel and the non-food CPI equations, suggesting that it is an important proxy for demand influences on inflation.

Other I(0) influences, acting partly via their effect on the exchange rate, are the ratios of the trade and current account balances relative to GDP. A trade surplus (i.e. positive balance) decreases food inflation while there is a smaller offset in the opposite direction from the current account surplus, since the latter includes aid flows which increase the demand for goods.[48] In addition to the direct impact on the exchange rate, and hence indirect effect on inflation, the trade surplus to GDP is an output gap indicator. Unlike a conventional output gap, there is no ambiguity with signs for demand and supply shocks (see Section 5.3). In the non-food price equation (Section 6.2.3), the Treasury Bill spread and the trade and current account balances operate in the same way, supporting the hypothesis of a common inflationary effect, in part via the exchange rate. The trade and current account balances also had a similar effect on inflation in the domestic fuel price equation (Section 6.2.1).

The final I(0) influence is the government surplus to GDP ratio (excluding oil-related revenues and expenditures), which has a negative impact on food inflation. We find a similar effect on non-food inflation (see Section 6.2.3). High government deficits tend to increase inflation, which is not surprising since they stimulate demand. However, the data are at an annual frequency, and the measure is a monthly moving average, so that the timing of the effect may not be very accurately captured.

For the short-run dynamics, the 'parsimonious longer lags' (PLL) specification was used, which allowed lags up to 12 months with 5 parameters. There is a high degree of negative feedback from food inflation in the previous three months suggesting a tendency for overshooting in food inflation that is partially corrected. This could be the result of farmers bringing more fresh produce onto the market in response to higher prices, or of food stocks being released in response to higher prices. Another interpretation is that for some foods, price changes might occur infrequently, say once

[48] We could have used the trade balance, and the difference between trade and current account balance to measure the capital flows component. Both would be highly significant in most equations.

every six months. Then a substantial part of the dependent variable being explained is 'really' the six-month change in the log food price. Splitting the six-month change into two 3-month changes (as in the reported equation) will then induce a negative coefficient on the current 3-month change when the dependent variable is the forward three-month change.

Changes in the log terms of trade and in log coffee prices have a positive effect on food price inflation. This is plausible, as prices of food exports, such as coffee, dominate the terms of trade. The 3-month change in log Kenyan food prices has a positive effect, in addition to the equilibrium correction effect already discussed.

Finally, there is some evidence of non-linearity or state dependence in the inflation process (see Section 5.2). A simple proxy for the greater volatility of shocks is the lagged squared change in log food prices. Measured over a three month interval, the residual is generated from a regression of the squared change on the change itself, to avoid co-linearity with lagged inflation. The 3-month lag of the residual for food prices proved significant. A similar proxy for maize price volatility was not significant.

Turning to the important question of whether there might be a link between mobile money and food inflation, it is worth emphasising that mobile money in Uganda was introduced only in 2009 and then grew rapidly at time when there were other highly volatile influences on food inflation. Examples include local and regional droughts, rises in regional and international food prices and oil prices and episodes of currency depreciation. To avoid the risk of spurious correlation with mobile money, these inflation drivers need to be properly controlled for in the inflation model. In the original GUM, the ratio of mobile money balances to M3 was included as the current ratio and with four lags on the monthly changes. None of these variables was selected by Autometrics for the parsimonious specification, and they are jointly completely insignificant. When the level ratio is forced to be retained in the equation, its coefficient is insignificant (t=1.8). Similar findings hold for the ratio of the value of mobile money transactions to M3, where the level ratio, when forced to be retained in the equation, has a t-ratio of 1.5, and the set of variables is jointly completely insignificant. As far as food inflation is concerned, therefore, there is thus no evidence of a link with mobile money.

As noted earlier, initial specifications suggested lags or moving averages of some of the long-run terms to simplify the structure of the chosen parsimonious model. The GUM was then reformulated to encompass such specifications and Autometrics used for a reduction to a simpler, more easily interpretable model. Six-month moving averages of volatile relative prices of fuel, coffee and Kenyan food prove to be effective restrictions which simplify the lag structure, and were introduced into a reformulated GUM. The equation standard error is 0.025 for the 3-month-ahead equation. The fit, the residuals and the recursively-estimated parameters and Chow tests are shown in Appendix Figure A2. The sample begins in 1994 and the recursive estimates begin in 2004. Given the many shocks and structural changes Uganda has experienced, stability looks satisfactory, when controlling for the several parameter shifts introduced into the model.

The contribution of the key determinants of the 3-month-ahead food inflation in Table 4, are illustrated in Figures 7a to 7d. For expositional purposes, we plot the less volatile 6-month food inflation rate, 3-months-ahead. This leaves the estimated model completely unchanged but is visually clearer: it is equivalent to adding the current 3-month rate of food inflation to both sides of the equation.

Figure 7a plots the 6-month food inflation rate against three groups of factors. The first, showing a downward trend since 2002, particularly after 2008, is the combined equilibrium correction effect of relative non-food and domestic oil prices, the latter only relevant from 2007. As food prices have risen against non-food and domestic fuel, so equilibrium correction should come into play, other things being equal, to bring down food prices. However, the second factor, combined equilibrium correction terms for Kenyan food prices, have pushed in the opposite direction: with increased regional trade integration, the rise in Kenyan food prices relative to those in Uganda drove up food prices in Uganda after 2008. The third factor, equilibrium correction terms for international maize and coffee prices converted into shillings provide another reason for rising food inflation rates in Uganda from 2003 to 2011.

Figure 7b plots the 6-month food inflation rate against two groups of factors. The first is the combined effect of changes in log prices, including the domestic food price, the terms of trade, and (shilling) coffee and food prices in Kenya. The second is the combined effect of a linear trend, trade openness and the 2007 step dummy. There is a slight upward drift in the combined effect suggesting that regional trade integration helps explain higher relative food prices in Uganda. In principle, the 2007 step dummy could represent a structural break associated with the large change in weights in the CPI starting in June 2007. It is also possible that this negative shift is compensating for a positive mean shift induced by the effects of the relative food price in Kenya and domestic fuel price in Uganda (relative to the Ugandan food price); these relative prices only come into play with positive effects from 2007. Though the recursively-estimated betas shown in Appendix Figure A2b demonstrate satisfactory evidence of reasonable parameter stability, the coefficient on the 2007 June step dummy shows a distinct downward drift as the mean effects of the relative prices of food in Kenya and of domestic fuel drift up over time. This suggests that the current formulation of the model is an approximation to a slightly more complex model (which could not be estimated in Autometrics).[49]

Figure 7c shows two further groups of factors. The first is the combined effect of variations in deviations of rainfall. This shows a striking correlation with food price inflation, though in the model the effect moderates somewhat after 2007. This is because the rising influence of Kenyan food prices from about 2006 indirectly captures the influence of regional droughts, necessarily correlated with

[49] The current model has the untested implication that the speed of adjustment of prices to the long-run solution jumps in 2007. A more sophisticated model, non-linear in parameters, would allow this hypothesis to be tested.

droughts in Uganda. The directly-estimated effect of rainfall in Uganda on food prices in Uganda is thereby reduced. The second group is the combined effect of credit growth and the fiscal surplus to GDP ratio, making notable contributions to inflation in 1999-2000 and 2010-11.

Figure 7d plots the 6-month food inflation rate against the combined effects of the trade balance and current account balances to GDP ratios, the spread between the Ugandan and US Treasury Bill rates, and the combination of seasonal effects plus one outlier. The net effect is almost always positive, reflecting the prevailing trade deficits, which offset the deflationary effects of aid and other financial flows that tend to reduce current account deficits. Since domestic Treasury Bill rates were always higher in the sample than those in the US, the spread acts as an offsetting negative influence on domestic inflation. The chart indicates a tendency for high food inflation rates to be followed by rises in interest rates, presumably part of the policy reaction function.

The 1-month-ahead food price equation has very similar implications but differs in lag structure and other small details. One further innovation in the dynamics of the 1-month-ahead equation is to make an allowance for floods. While higher rainfall generally boosts food supplies and reduces subsequent food prices, floods can sometimes disrupt food production and transport of food, which can lead to temporarily higher prices, even for the national food price index. To construct a proxy for floods, we take the positive deviation of rainfall from its average and square it to capture extremely high values of rainfall. The current month's indicator is relevant for next month's food price. For the 3-month-ahead food price inflation, the flood indicator has only a marginal influence and was therefore not retained in the parsimonious model selected by Autometrics. Clearly, floods have weaker and much more transitory influences on food prices than do droughts, whose effects last over a year.

All the same elements enter the long-run solution for the 1-month-ahead food price equation as for the 3-month-ahead food price equation, though in some cases with slightly different lags. The coefficients are generally about 30 to 40 percent of those in the 3-month-ahead equation, as one would expect since, on average, 3-month inflation is three times as large as 1-month inflation. Mobile money variables remain insignificant. The equation standard error for the 1-month-ahead equation is lower at 0.017 than for the 3-month-ahead equation, given the extra uncertainty associated with the longer horizon.

6.2.3 Modelling the non-food component of the CPI

The general unrestricted model (GUM) for non-food inflation has a broadly comparable structure to that for food inflation, though equilibrium correction components are taken relative to non-food prices. An innovation in this equation is to take account of the large shifts in tax rates, particularly for beverages and tobacco, and shifts in regulated transport (and communications) prices. Indirect tax rates on the former rose in July 2001, April 2005 and August 2011. Transport and communication prices fell sharply in October 2010 and rose sharply in September 2011. To take account of these shifts, a series of transformed step dummies are included in the 1-month and 3-month-ahead equations. This is explained in Appendix 2. This gives five dummies, with positive coefficients at all the dates above, except October 2010, when prices fell. The coefficients on these transformed dummies represent the long-run effect on log non-food CPI of these tax and regulatory changes.

Following the reduction procedure from the GUM, we obtain the long-run equation for the non-food CPI shown below[50]:

$$\begin{aligned}\log(nonfood\ CPI) = {} & 0.14\log(US\ WholesaleP) + 0.24\log(food\ CPI) + 0.15\log(scaled\ M3\ per\ capita) \\ & +0.08\log(\mathrm{WMaizeP}) + 0.24\log(world\ tradeweighted\ CPI) \\ & +0.15\log(domestic\ fuel\ price) - 0.34\,(tradeopeness) + 0.12(2007\ step\ dummy) \\ & -0.18(timetrend/100) + effects\ of\ stationary\ variables\ \&\ transformed\ dummies \end{aligned} \tag{4}$$

Non-food prices thus depend on five other sets of prices: the food CPI, domestic fuel prices, the international maize price (in shillings), the US wholesale price index (in shillings) and a trade-weighted measure of foreign CPIs (in shillings) implied by the real effective exchange rate[51]. Other long-run influences are the scaled money stock, negative effects from trade openness and a linear trend. A step dummy for 2007 has a positive effect, the opposite sign to its sign in the equation for food prices, raising the possibility of a common factor in the long-run solution for the relative price of non-food to food. The ratios to GDP of the trade surplus and current account surplus have the same signs as in the food price equation. A step dummy for the introduction of 'inflation-targeting-lite' in July 2011 is not significant, even when forced to be retained in the equation (t=-0.2). The fiscal surplus relative to GDP has a negative effect, as in the food price equation, consistent with an inflationary effect of government deficits (even after possible spill-over effects on the money stock have been taken into account).[52]

Of the I(0) variables in the equation, the Uganda-US Treasury Bill spread has the same sign as in the food price equation. The deviation of rainfall from its long-run mean, averaged over 6 months and lagged 5 months, appears with a negative coefficient. It is plausible that this variable represents the effect of rainfall on the hydro-electric generation of electricity, as it takes considerable

[50] As discussed in Section 5.3, many long-run terms in the GUM have been formulated as moving averages as this simplifies the dynamics and makes the equation more easily interpretable.

[51] Equation (4) is constructed as the post-2007 long-run solution for the non-food component of CPI. The pre-2007 solution looks marginally different with a slightly higher weight for the food price and lower weights for the other elements owing to the change in the CPI weights in 2007 (see Table 1). Adjustments are made as the *total* CPI enters both the "world" trade-weighted CPI (entering via the real effective exchange rate) and the scaled broad money variables (see Table 3 for definitions).

[52] Limitations of annual fiscal data are likely to have reduced the accuracy with which this effect is estimated.

time for reservoir capacity to be drained by droughts. In contrast, food production is more rapidly impacted by droughts: in the food price equation, the peak effect of rainfall occurs in the first 3 months, and gradually decays over the rest of the year. The effects of contemporaneous droughts are already picked up through the importance of food prices in this equation. The very length of the lags on the rainfall effects in the non-food equation signifies it is doubtful that the rainfall effect represents inflation expectations consequent on droughts.

The dynamic terms in the equation include the change in the log of the terms of trade and in the Kenyan All Items CPI[53], as well as lags in non-food inflation rates.

In testing for mobile money, the ratio of mobile money balances to M3 is again insignificant when included in the original GUM; when forced to be retained in the selected equation, it has a barely-significant t-ratio of *negative* 2.0. Although this variable is not significant in the chosen model, if anything, it points to efficiency gains *reducing* inflation. Similar findings result for the measure based on mobile transactions relative to M3. This suggests that the possible mechanisms by which mobile money might have increased inflation (see Section 5) are absent.

The fit, the residuals and the recursively-estimated parameters and Chow tests are shown in Appendix Figure A3. Plots of the 3-month-ahead inflation rate over a 6-month period[54] for the non-food CPI against groups of factors are shown in Figures 8a to 8c. Figure 8a shows three groups of effects. The first is the combined effects of trend, trade openness and the June 2007 step dummy, with a pronounced downward trend. This trend is offset by the upward trends in the other two groups: the combined ECM terms for food, maize and domestic fuel, and the combined ECM terms for US wholesale prices and for the "world" trade-weighted CPI (entering via the log real exchange rate). The three groups of terms shown in Figure 8b are the combined effects of scaled broad money, which imparts an upward trend, the growth rate of private credit, and the government surplus to GDP; the combined effects of current and trade balance to GDP ratios; and finally the Treasury Bill spread relative to the US. The first of three groups of terms shown in Figure 8c consists of seasonals plus the effects of dummies for large indirect tax or regulatory changes. The second is the combined effects of price dynamics, which shows evidence of negative feedback even when plotted against the 6-month rate of change of the non-food CPI: evidently some non-food prices tend to change less frequently then every six months – probably annually in some cases. The last term shown is the effect of rainfall, very clearly a stationary variable even when measured as the 6-month moving average.

The estimated 1-month-ahead non-food equation is very consistent with the 3-month-ahead equation discussed above. The main differences are that some of the key drivers enter with lags placed

[53] From cross-border trade with Kenya in non-food items, the Kenyan CPI might be expected to have an influence on the Ugandan non-food CPI. Uganda is land-locked and most imports enter via Kenya, so Kenyan wage costs, distribution and transport costs in exporting to Uganda may feed into Ugandan prices.

[54] Visually the 6-month interval is more appealing than the 3-month interval, given the strong negative feedback for the 3-month rate revealed in Table 5.

further back, as the 1-month-ahead model is necessarily 2 months behind a 3-month-ahead model. For instance, the rainfall measure enters as the 3-month moving average lagged 6 months (instead of the 6-month moving average lagged 5 months, in the 3-month-ahead equation). As for the 3-month-ahead equation, account is taken of indirect tax and regulatory changes regarding particular price components of the CPI, using a series of transformed step dummies. For the 1-month case, this is also explained in Appendix 2. All but one of the five step dummies representing the long-run effect on log non-food CPI of indirect tax and regulatory changes is significant.

The dynamics of the selected equation also contain squared residuals of food price inflation at lags of 1 and 3 months, suggesting that the frequency of non-food price changes rises with rapid food price inflation. The standard error of the 1-month-ahead equation at 0.0047 is only a little less than the 0.0055 standard error for the 3-month-ahead equation. This is indicative of the lower volatility and easier forecastability of the non-food CPI compared to the food CPI.

7. Conclusion

This paper has presented 1-month and 3-month-ahead forecasting equations for domestic fuel, food and non-food inflation in Uganda. Automatic model selection from general dynamic specifications was used to find models with stable parameters consistent with economic priors. All the equations, but particularly for food inflation, take account of major structural breaks and non-linearities. Relative price adjustment plays a critical role and includes non-food and fuel prices in the food equation and food prices and fuel prices in the non-food equation. We have argued against an excessive focus on the inclusion of irrelevant variables in empirical models at the expense of the often more serious error of excluding relevant variables. We have aimed to encompass the popular theories in a general specification by including the most likely relevant variables, in order to reduce the risk of keeping irrelevant ones. The 'parsimonious longer lags' technique for allowing lags up to 12 months but with a parsimonious use of parameters, has proved useful in overcoming the 'curse of dimensionality'. A pure cointegration analysis would be difficult given the severe structural breaks in all equations, but particularly in the food equation, and especially around 2007; however, using only post-2007 data for analysis would create too short a sample.

Previous research on inflation in Uganda has emphasised the domestic M3 money stock and foreign prices, but, with one exception, has neglected supply shocks associated with variations in rainfall; there are various other misspecifications and errors, see Section 2. Our findings confirm the importance of foreign prices translated at the exchange rate for fuel, food and non-food inflation rates. Contrary to earlier work, we find M3 is irrelevant for food inflation, but that rainfall deviations play huge role. However, M3 is found relevant for non-food inflation, though with far less importance than earlier studies of Ugandan inflation have suggested. Rainfall deviations also appear to affect fuel and non-food prices, probably through the effect of droughts on hydro-electric generating capacity. Domestic credit growth is important for all three inflation rates, domestic fuel, food and non-food.

A measure of trade-openness has a clear disinflationary effect on non-food inflation, but the reverse holds for food, partly because increased regional trade integration has raised the demand for Ugandan food. Both food and non-food inflation equations incorporate the US-Uganda differential in Treasury Bill rates, the current account and trade balances to GDP ratios, and the (non-oil) government surplus to GDP ratio. The trade balance to GDP ratio has a negative effect on subsequent inflation, being both a proxy for the output gap and an influence on the exchange rate. However, the current account balance, which incorporates aid and other international financial flows, has a small positive effect on subsequent inflation, probably because of the demand-boosting effects of these flows. The same combination of terms with similar relative coefficients affects domestic fuel inflation, and is seemingly a common factor across all the inflation equations.

The relevant foreign prices include those of maize, coffee and other elements of the terms of trade, Kenyan food and oil, the US wholesale price index and a trade-weighted average of foreign CPIs. Increasing regional trade integration probably explains the increased influence of Kenyan food prices on Ugandan prices from about 2007. Increasingly-constrained electricity production capacity and the greater use of mobile generators probably explains the increased influence on food prices of domestic fuel prices, over and above their role in the price index for non-food. The inflation models take foreign prices and the exchange rate as given. In future work, modelling the exchange rate itself needs to have first priority, followed by models for the domestic Treasury Bill rate and for M3.

The output gap measure derived from the index of industrial production proved insignificant. It seems that variables incorporated in the model, such as the trade balance to GDP ratio and credit growth on the demand side, and the rainfall data on the supply side, capture demand side and supply side influences on inflation quite well. There are alternative ways of bringing in influences from foreign prices to those selected in this modelling exercise. For example, forecasting equations which are not much worse can be obtained incorporating import unit values. However, if we regard this exercise as an important step towards designing a larger model of inflation for Uganda, the downside of using import unit values is that this would be another endogenous variable to be modelled. The advantage of the US wholesale price index and the trade-weighted foreign CPIs, which enter via the real exchange rate, is that they are plausibly exogenous to Uganda.

There is indirect evidence of some state-dependence in the inflation process. Large food price shocks tend to be followed by disproportionately higher food and non-food inflation rates. This finding of non-linearity is consistent with the sticky information model of Reis (2006), in which price setters increase the frequency of price adjustment when the perceived loss from not adjusting rises.

While our primary focus has been to address the question about the effect of mobile money on inflation, there are useful forecasting implications from these models. Except for the structural breaks and non-linearities, the 1-month-ahead model is like a standard component equation of a monthly VAR (in which a variable dated t is explained by other variables dated t-1 to t-k, for k lags). The 3-month-ahead model is approximately the equivalent of a quarterly VAR component, and it turns out that the signal-to-noise ratio is somewhat better over this horizon. The 3-month-ahead model therefore discriminates better for selection of relevant variables. For longer forecasting horizons with monthly data, equations for the exchange rate, broad money and perhaps the Treasury Bill rate could be added, and forecast simulations run on this small system conditional on assumptions about the exogenous variables. It is fairly obvious from our empirical model that a single-equation 6-month or 12-month 'multi-step' forecasting model for non-food could successfully use broadly the same structure as the short-horizon models. For food, however, the 12-month-ahead model would be very noisy if rainfall is unforecastable, though probably would still have some information content. In practical out of sample forecasting settings, one could replace the 2007 dummy, trade openness and time trend by a smooth stochastic trend. Then there would be only five economic variables in the long-run solution. The coefficients would probably evolve somewhat over time but maintain a similar basic structure and tell the same story.

Turning to the role of mobile money, for food inflation, the ratios of mobile balances to M3 and mobile transactions value to M3 have no significant effect, given the controls in the equations, and are not selected in the automatic selection process. If the ratio of mobile balances to M3 is *forced* to be retained in the food equation, the levels effect has a t-ratio of 1.8 (the t-ratio is lower still if the mobile money measure forced to be retained is the ratio of mobile transactions value to M3).

For non-food inflation, mobile money effects are again insignificant and neither measure of mobile money is retained in the automatic model selection process. If the levels ratio of mobile balances to M3 is forced to be retained, its effect is negative with a t-ratio of -2.0. The ratio of mobile transactions value to M3 also has a negative coefficient if forced to be retained.

These findings suggest that concern regarding the potential velocity-inflation linkage of mobile money is misplaced. The hypothesis that mobile balances relative to M3 represent a planned build-up of liquidity just ahead of a significant increase in expenditure which might be inflationary is also not supported. There is no evidence that the advent of mobile money might transfer spending power to households with higher propensity to spend, so reduce saving and increasing demand. Increases in mobile balances relative to M3 more probably reflect the expansion of the mobile money infrastructure and its more widespread acceptance. It is more likely that the productivity and efficiency gains of mobile money have reduced inflation, even when quality improvements may not be fully measured in the CPI (Section 3.1). For example, mobile money could make the effects of droughts and floods less disruptive by improving the matching of supply and demand of goods and services, and with lower transactions costs. With only five years of data since mobile money was introduced in Uganda, there must be considerable uncertainty over its long-term consequences for efficiency gains. But our evidence strongly suggests there is no reason for any alarm over its potentially inflationary consequences.

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Figure 1: Annual inflation in Uganda for various aggregates

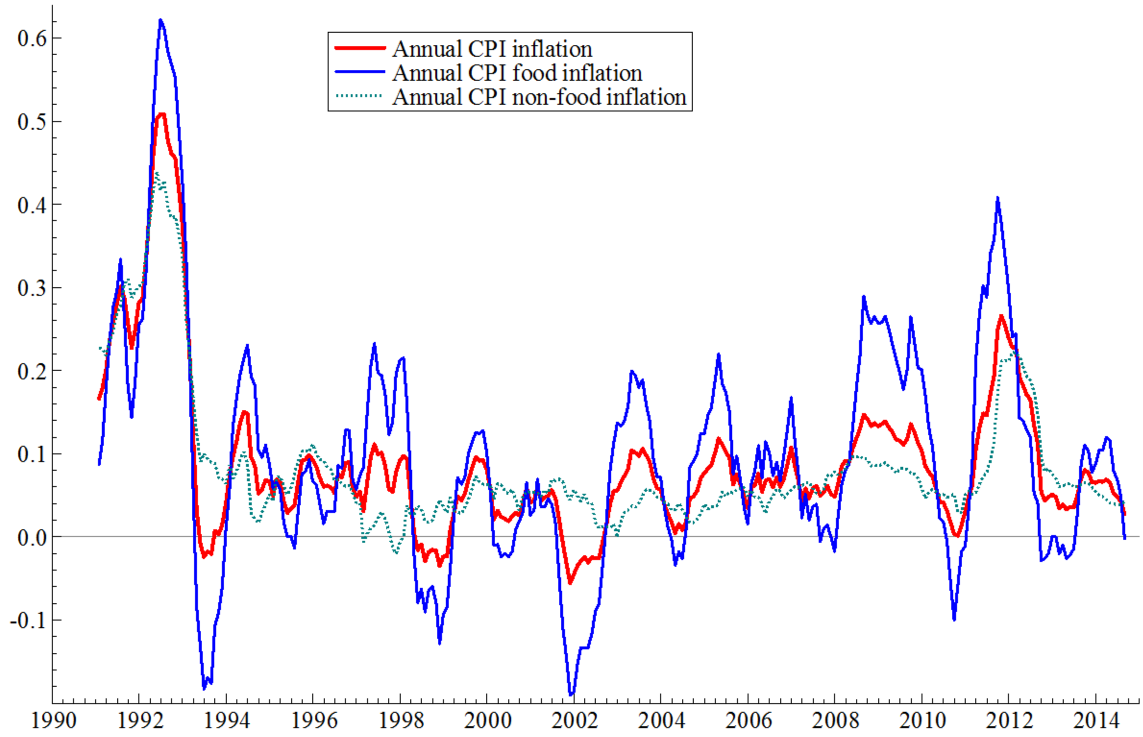
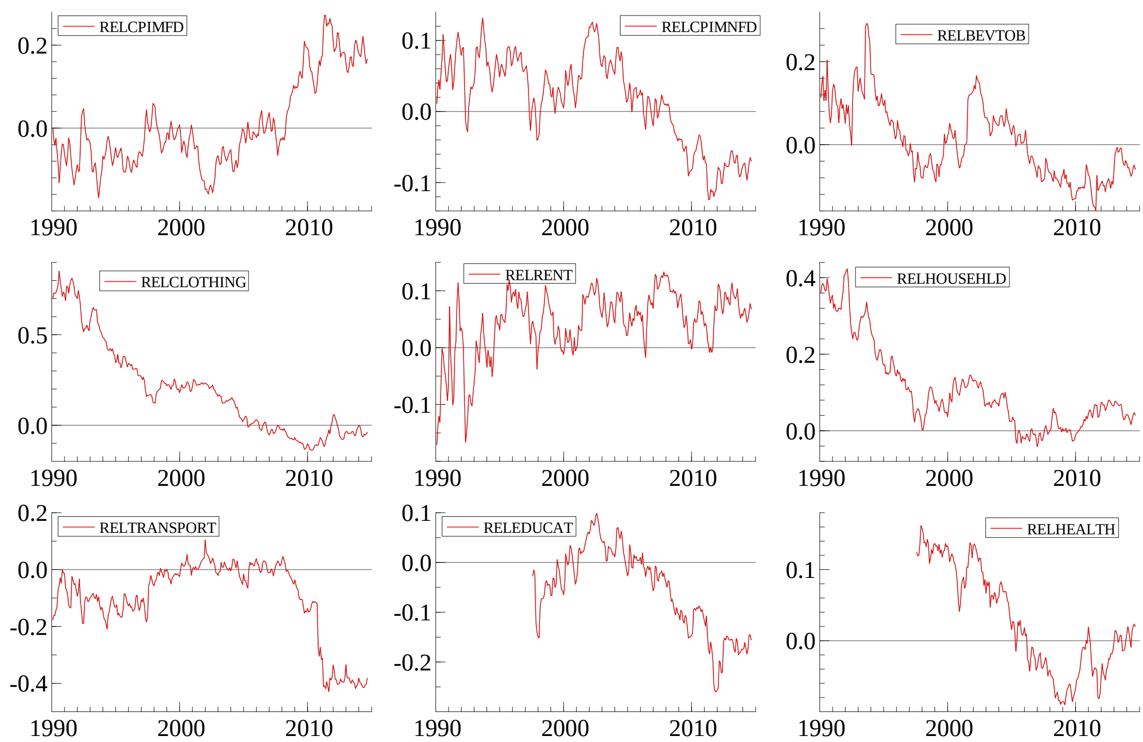
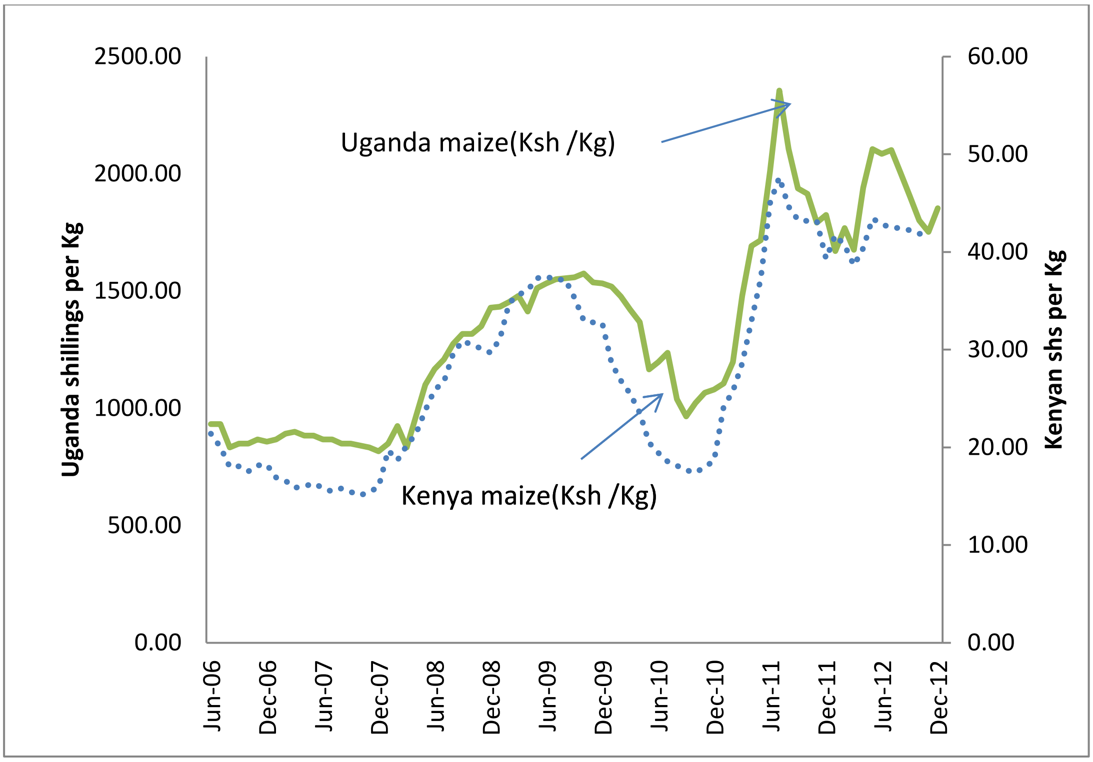


Figure 2: Trends in Relative Price Components



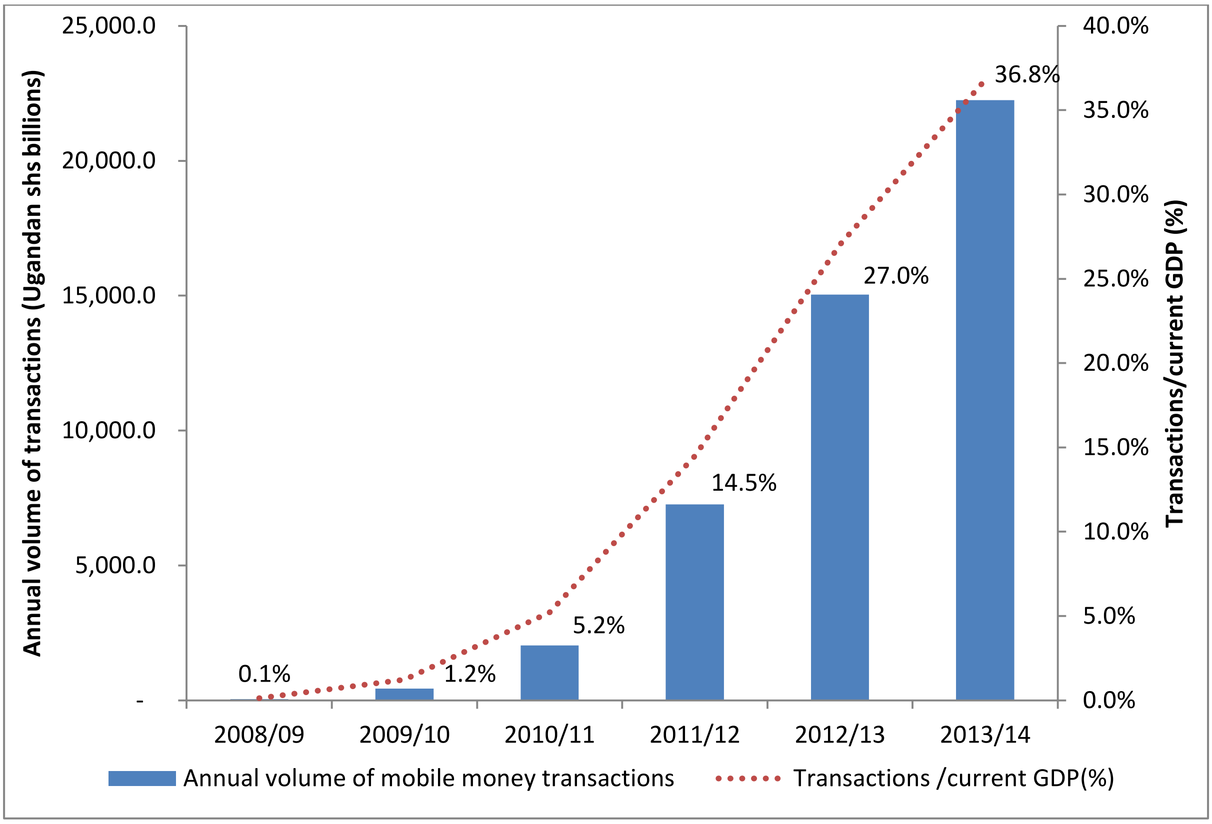
Notes: Relative price ratios, p_i/CPI for the main components, i, of the CPI: food, non-food, beverages and tobacco, clothing, rent, household goods, transport, education, and health.

Figure 3: Neighbouring country food prices



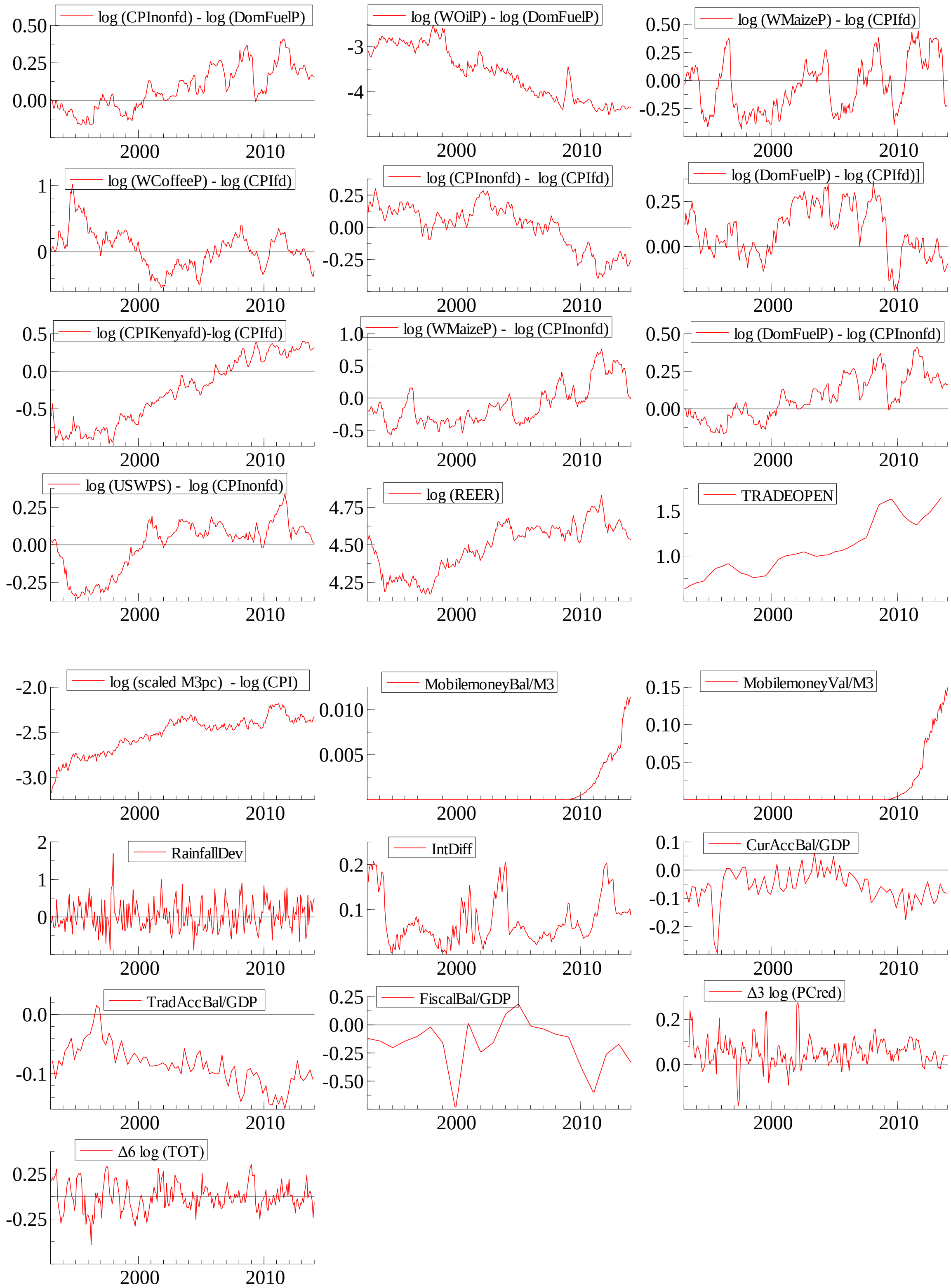
Source: Uganda National Bureau of Statistics; Kenya National Bureau of Statistics.

Figure 4: Evolution of mobile money in Uganda



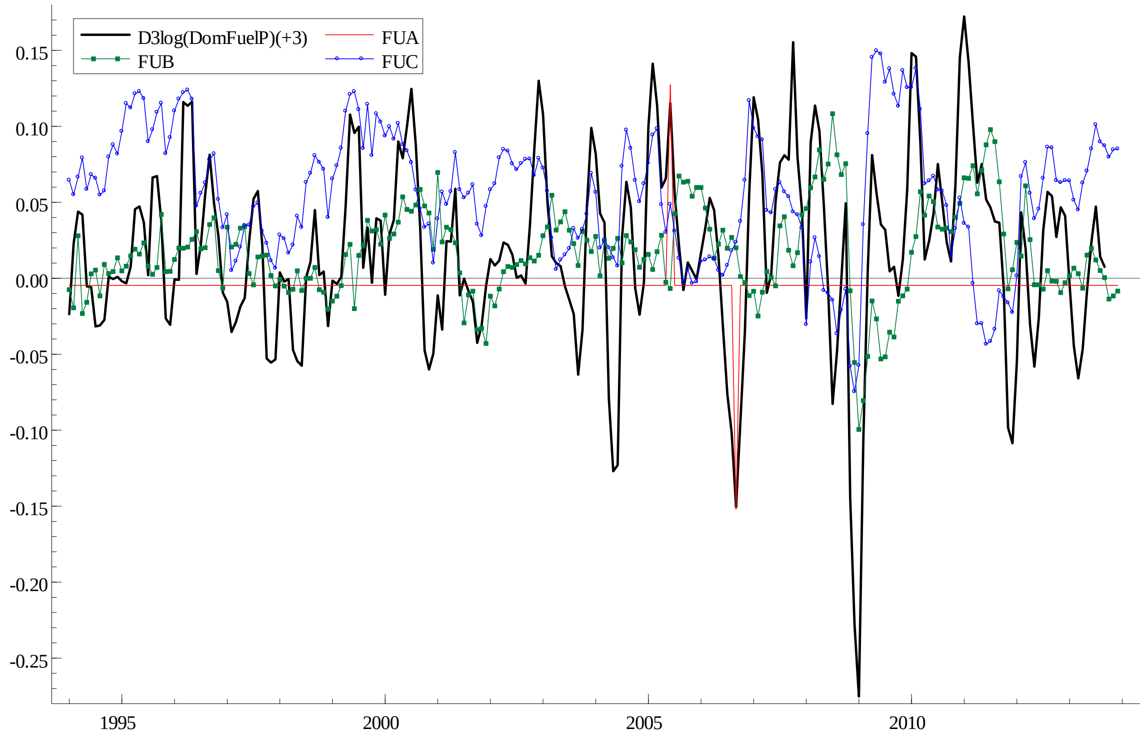
Source: Bank of Uganda data

Figure 5: Long-run and I(0) variables relevant in the aggregate domestic fuel price, CPI food and CPI non-food equations

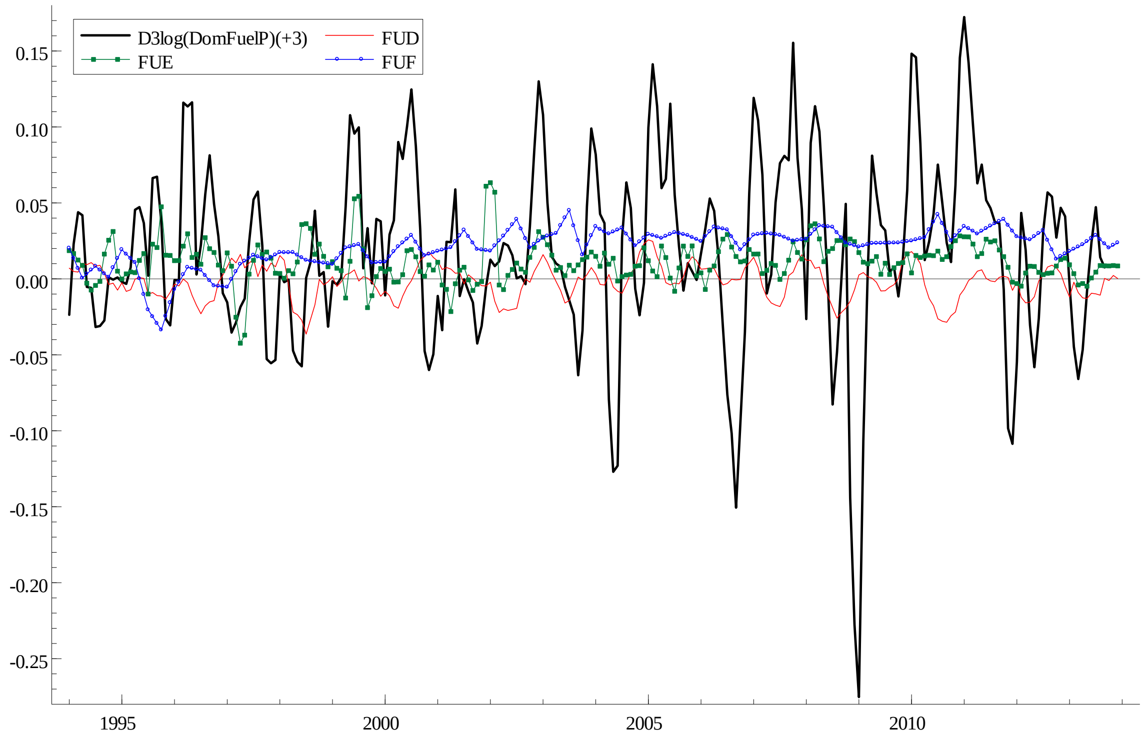


Notes: See definitions of variables in Table 2.

Figures 6a-b: Contributions to domestic fuel price inflation

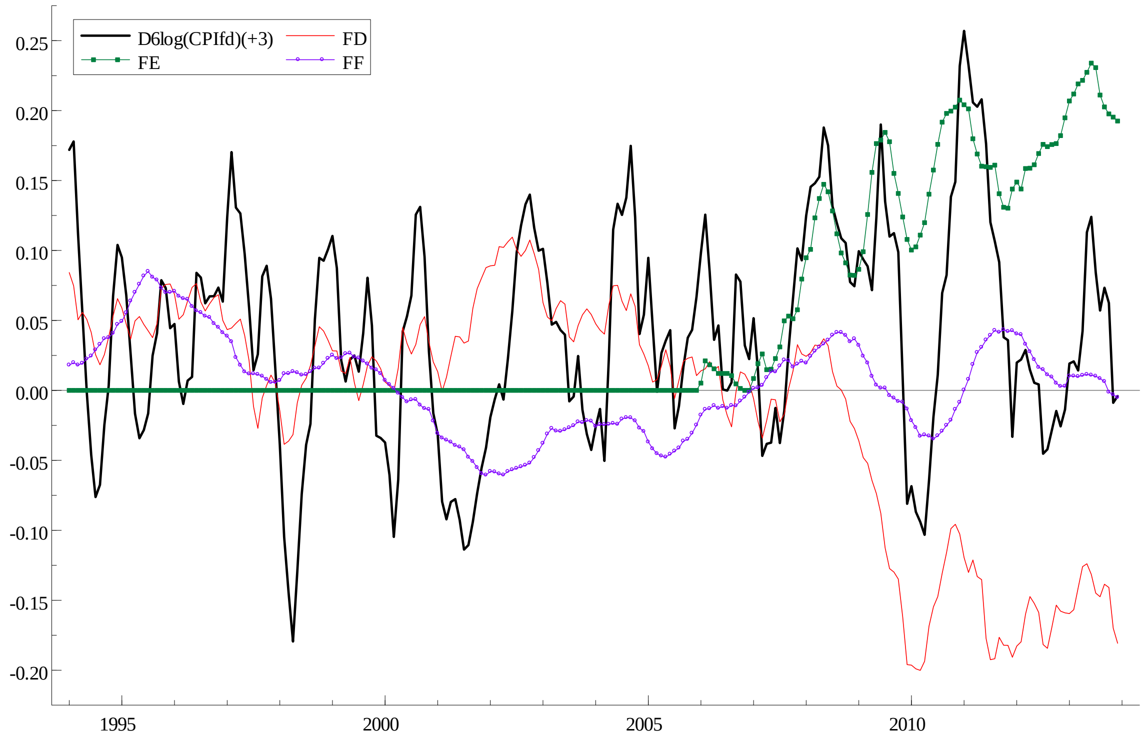


(a) FUA is intercept and outliers; FUB is the combination of price dynamics ; FUC is the composite equilibrium correction.
Note: D3log(DomFuelP)(+3) is the dependent variable in Table 3: $\Delta_3$log (DomFuelP)(+3).

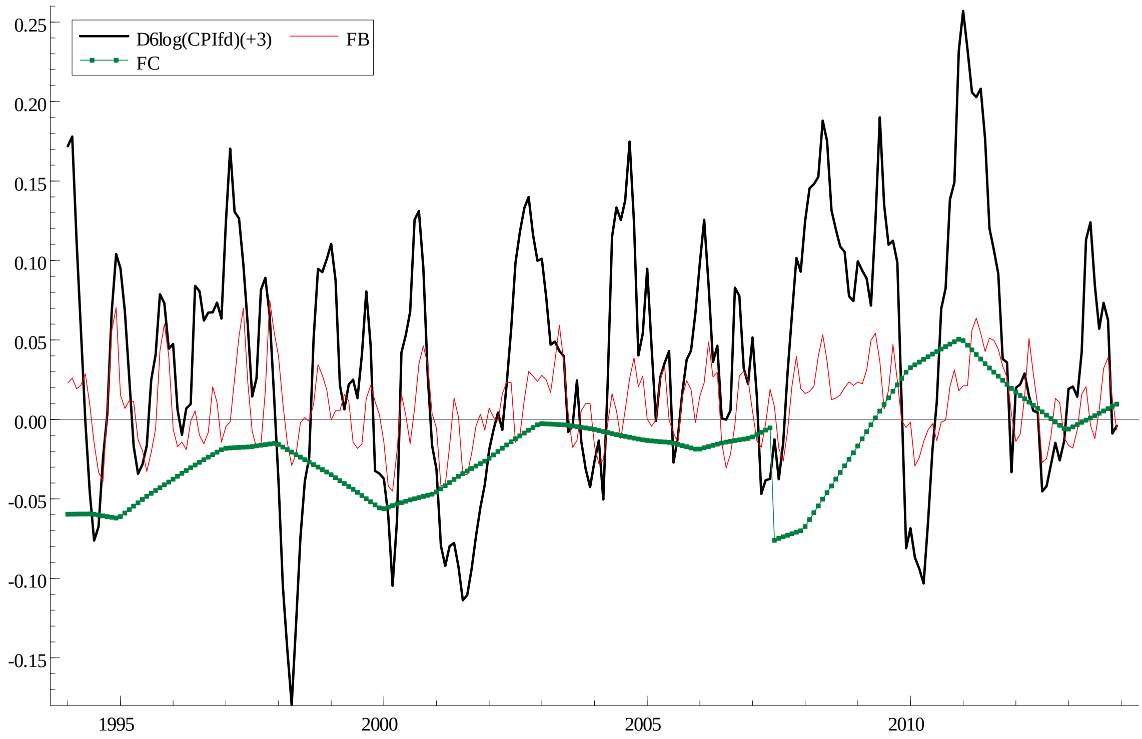


(b) FUD is rainfall; FUE is credit growth; FUF combines current and trade account balances to GDP. Note: D3log(DomFuelP)(+3) is the dependent variable in Table 3: $\Delta_3$log (DomFuelP)(+3).

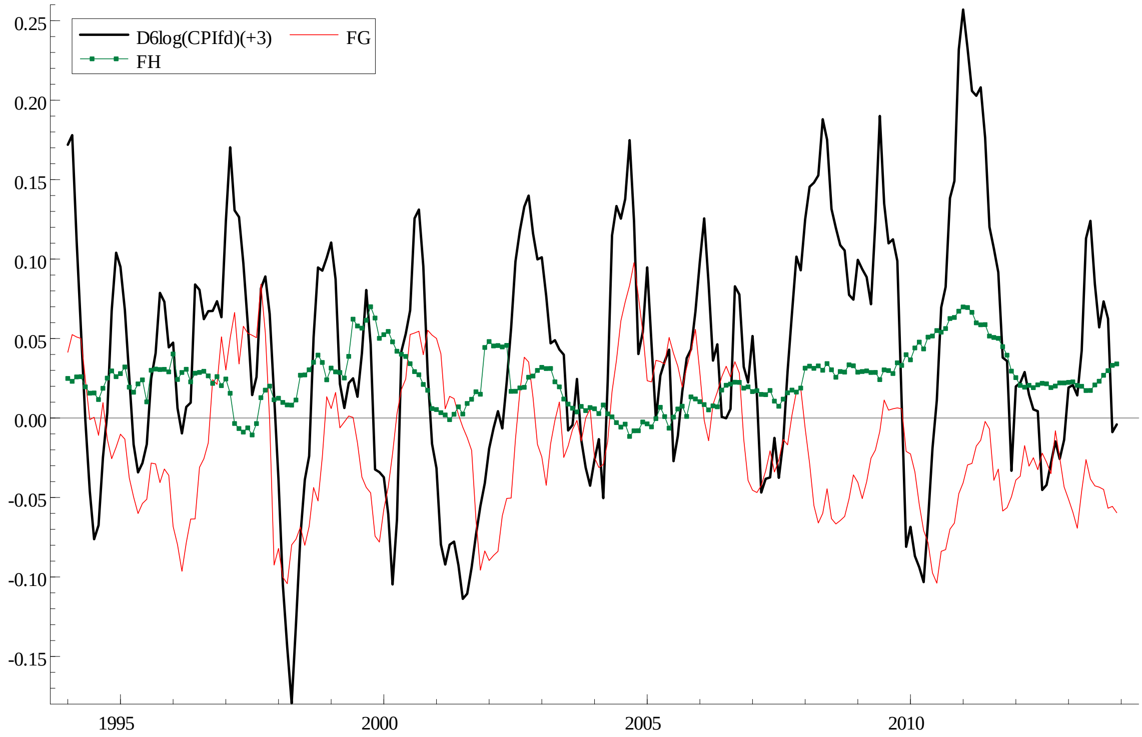
Figures 7a-d: Contributions to food inflation



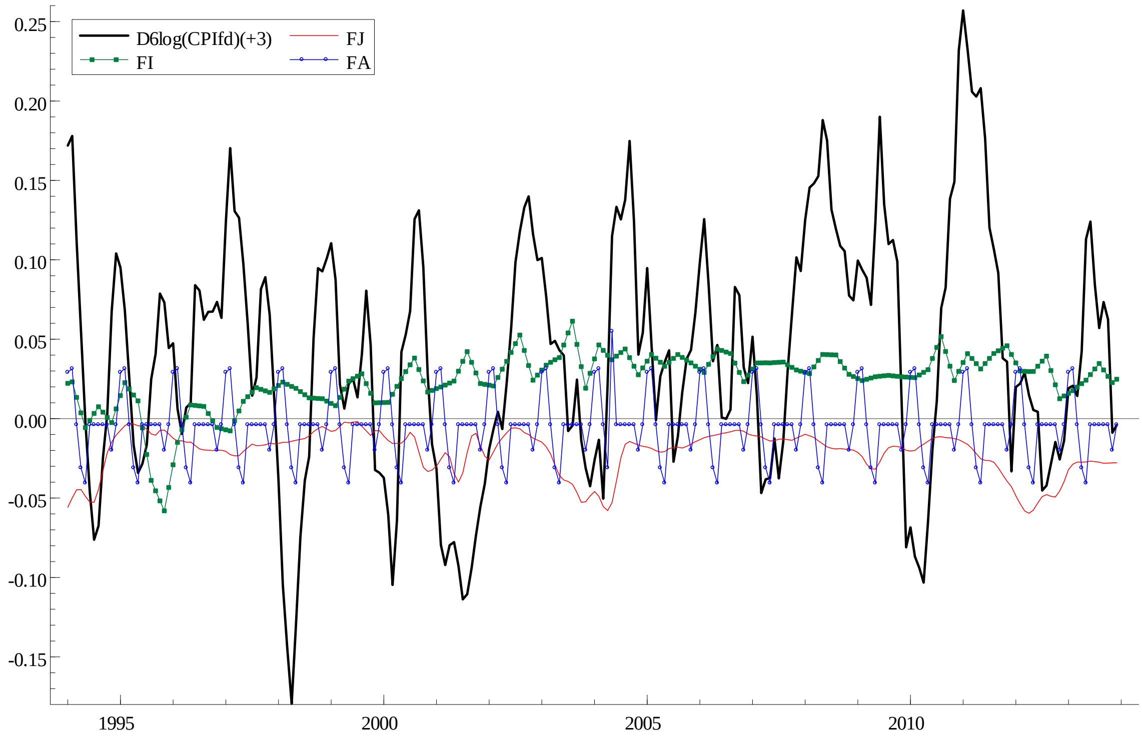
(a) FD combines relative non-food prices and domestic fuel; FE combines relative food prices in Kenya; FF combines relative maize and coffee prices.
Note: D6log(CPIfd)(+3) is the dependent variable in Table 4: $\Delta_3$log (CPIfd) (+3) + $\Delta_3$log (CPIfd).



(b) FC is the combination of constant, trend, 2007 step dummy and trade openness; FB is the combination of price dynamics.
Note: D6log(CPIfd)(+3) is the dependent variable in Table 4: $\Delta_3$log (CPIfd) (+3) + $\Delta_3$log (CPIfd).

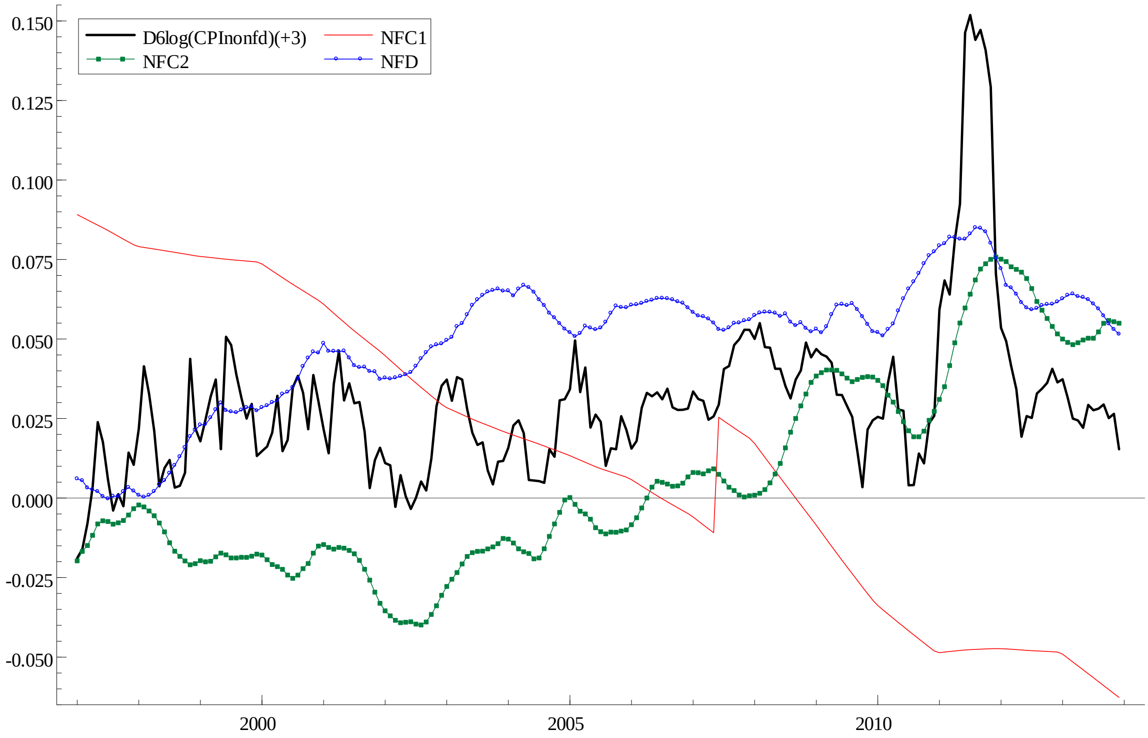


(c) FG is combined rainfall; FH combines credit growth and the government surplus to GDP.
Note: D6log(CPIfd)(+3) is the dependent variable in Table 4: $\Delta_3$log (CPIfd) (+3) + $\Delta_3$log (CPIfd).

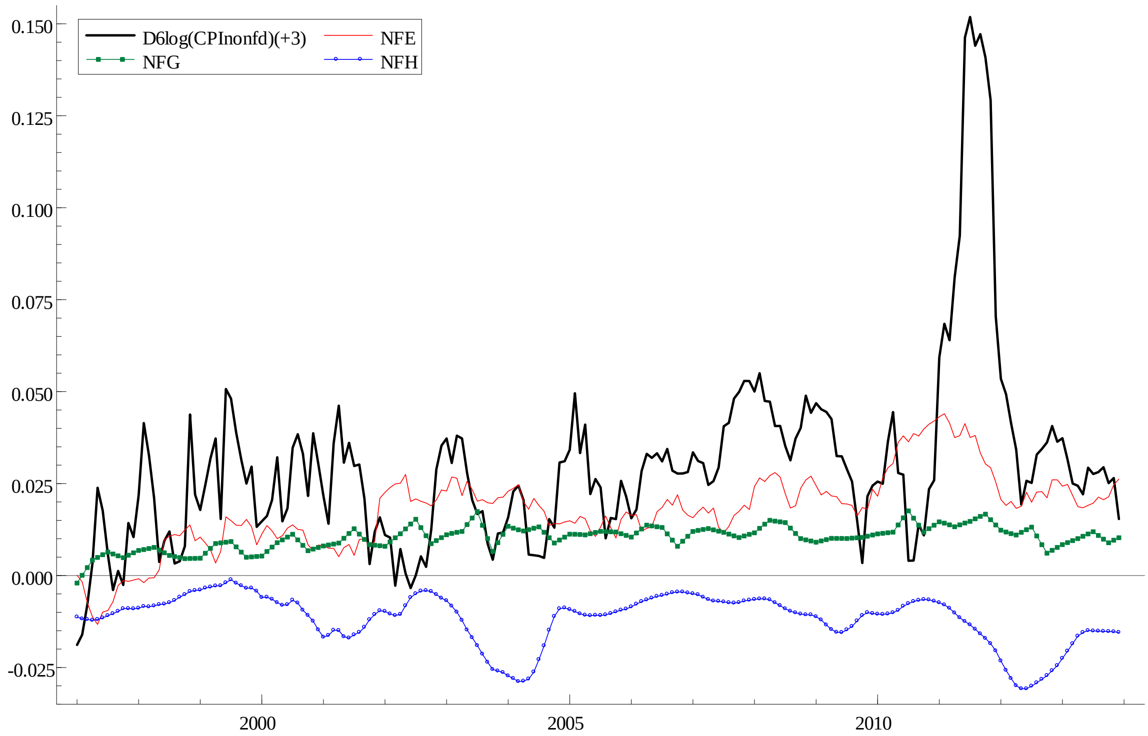


(d) FI combines the current account and trade account balances to GDP; FJ is the interest rate spread; FA is seasonals and outlier.
Note: D6log(CPIfd)(+3) is the dependent variable in Table 4: $\Delta_3$log (CPIfd) (+3) + $\Delta_3$log (CPIfd).

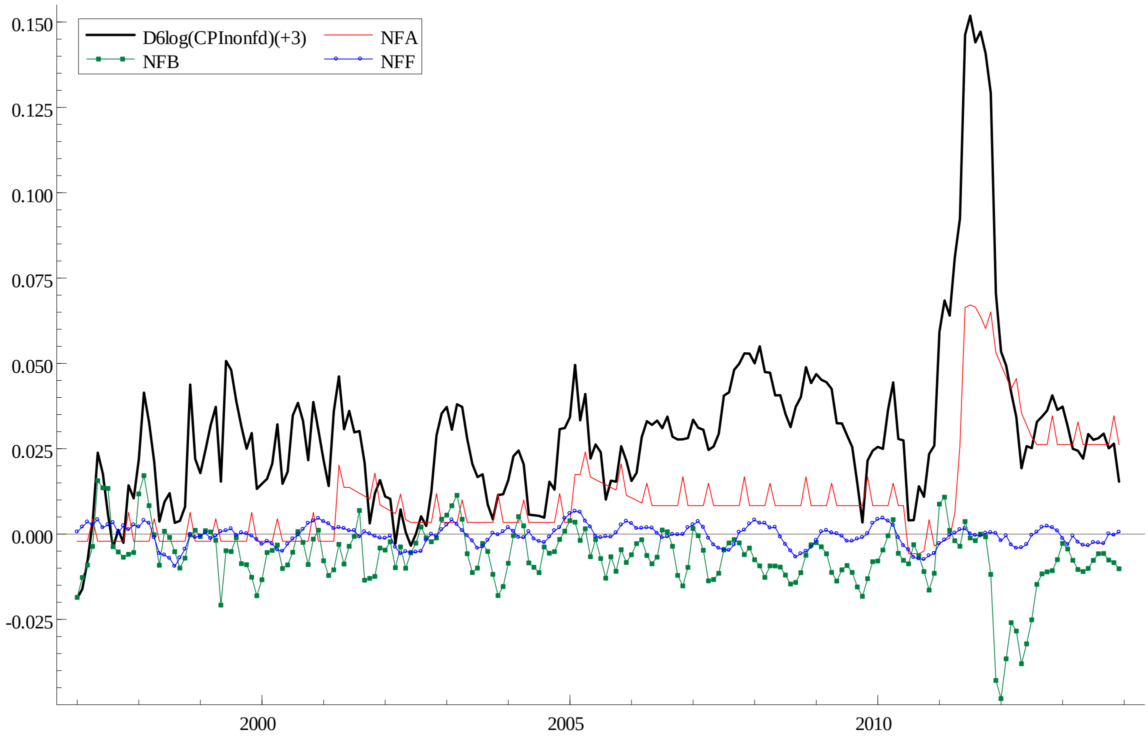
Figures 8a-c: Contributions to non-food CPI inflation



(a) NFC1 is trend, trade openness and 007 step dummy; NFC2 combines the ECMs for food, maize and domestic fuel; NFD combines US wholesale prices and real exchange rate. Note: D6log(CPInonfd)(+3) is the dependent variable in Table 5: $\Delta_3$log (CPInonfd)(+3) + $\Delta_3$log (CPInonfd).



(b) NFE is the combination of scaled money, credit growth, and government surplus to GDP; NFG combines current and trade account balances to GDP; NFH is the Treasury Bill spread.
Note: D6log(CPInonfd)(+3) is the dependent variable in Table 5: $\Delta_3$log (CPInonfd)(+3) + $\Delta_3$log (CPInonfd).



(c) NFA combines seasonals plus dummies for large indirect tax changes; NFB combines price dynamics; NFF is deviation of rainfall from the long-term mean.
Note: D6log(CPInonfd)(+3) is the dependent variable in Table 5: $\Delta_3$log (CPInonfd)(+3) + $\Delta_3$log (CPInonfd).

TABLE 1

Weights for Groups, Sub-groups and Items of Consumer Price Index

	Group	*Weights Sep 1989- July 2000*	*Weights Aug 2000 to May 2007*	*Weights June 2007 to date*
Goods	Food(total)	50.06	45.2	27.2
	-Food crop	33.60	27.4	13.5
	-Other foods	16.46	17.8	13.7
	Beverages and Tobacco	9.97	8.6	4.7
	Clothing and Footwear	6.55	5.5	4.4
	Rent, Fuel and Power	10.82	14.1	14.8
	Household and Personal goods	10.71	5.3	4.5
Services	Transport and Communication	4.30	6.7	12.8
	Health, Education and Entertainment	7.80	14.6	-
	Education	-	-	14.7
	Health, Entertainment and other	-	-	16.8
	Total Items	100.0	100.0	100.0

Source: Uganda Bureau of Statistics

Notes: The composition of the deflators:
Food: Includes staples, fresh fruit, fresh vegetables, dry vegetables, meat&poultry, fish, milk and eggs, bread, sugar, tea, and oils and fats.
Beverages and Tobacco: Includes non-alcoholic and alcoholic beverages, nd tobacco.
Clothing and Footwear: Includes mens' clothing, womens' clothing, children's clothing, other clothing, and footwear.
Rent, Fuel and Power: Includes rent, fuel, electricity and water, hi use repair & maintenance.
Household and Personal goods: Includes soap, toiletries, textiles and furniture, and household and personal equipment.
Transport and Communication: Includes transport fares, communication, and other related costs.
Education: Includes pre-primary, primary, secondary lower, secondary upper, tertiary, and other education expenses.
Health and Entertainment: Includes health, other goods and services, meals in restaurants.

TABLE 2

Statistics[1] and variable definitions

Variable	Definition of variable	Source, frequency	Mean	Std Dev.	I(1)[a]	I(2)[a]
log (CPIfd)	Log of food component of the consumer price index. Use the series with the 1999-2006 weights from 1989 up to April 2007; then splice to the more recent series.	Monthly, Uganda Bureau of Statistics.	4.57	0.453	0.524	-4.44**
log (CPInonfd)	Log of non-food component of the consumer price index Used the series with the 1999-2006 weights from 1989 up to April 2007; and then spliced to the more recent series.	Monthly, Uganda Bureau of Statistics.	4.59	0.312	1.89	-3.53**
log (CPIKenyafd)	Used food price index for Kenyan Lower Income Group Index of Consumer Prices (Nairobi); then spliced to the CPI component Food & Non-Alcoholic Beverages when it becomes available. Converted to local currency using the bilateral Kenyan/Ugandan exchange rate.	Monthly, Kenyan National Bureau of Statistics, and IMF.	8.18	0.853	-3.42	-8.30**
log (CPIKenyaTot)	Total CPI, converted to local currency using the bilateral Kenyan/Ugandan exchange rate.		7.30	0.593	-4.61**	-13.0**
log (WorldCPI)	"World" CPI: trade-weighted measure of foreign CPIs (in shillings) implied by the real effective exchange rate, where log (real exchange rate) is calculated as log (nominal trade-weighted exchange rate) + log (trade-weighted foreign CPIs) – log (domestic CPI).					
log (ImpP)	Log of import prices (which include oil), measured as an import unit value.	Monthly, Bank of Uganda.	4.74	0.282	-0.755	-6.36**
log (WMaizeP)	Log of (Shilling) world maize price, using the bilateral shilling/$ exchange rate.	Monthly, IMF IFS.	12.3	0.607	-2.305	-5.90**
log (WOilP)	Log of (Shilling) world Dubai oil price, using the bilateral shilling/$ exchange rate.	Monthly, IMF IFS.	11.0	0.991	-3.84*	-4.58**
log (DomFuelP)	Log of the domestic fuel price index, with index constructed as a weighted average of 3 price indices: Premium Motor Spirit, Automotive Gasoline, and Diesel Kerosene, using sales (earlier import) share weights.	Monthly, Uganda National Bureau of Statistics.	7.38	0.436	-3.77*	-11.6**
log (WCoffeeP)	Log of (Shilling) world coffee price calculated as: 0.85*WPRobusta + 0.15*WPArabica, using the bilateral shilling/$ exchange rate.	Monthly, IMF IFS.	7.91	0.499	-1.99	-12.4**
log (USWP)	Log of $ US wholesale price.	Monthly, IMF IFS.	4.56	0.180	-2.52	-4.82**
log (USWPS)	Log of (shilling) US wholesale price using the bilateral	Monthly, IMF IFS.	12.0	0.464	-2.64	-4.25**

Variable	Definition of variable	Source, frequency	Mean	Std Dev.	I(1)[a]	I(2)[a]
	shilling/$ exchange rate.					
TRADEOPEN	Trade policy measured in real terms: ratio of real exports plus real imports to real GDP, scaled so is 1 in 2001:1.	Annual trade data, Bank of Uganda, converted to monthly data and 12 month moving average taken of each component. Annual GDP data, Bank of Uganda, converted to monthly data and 12-month moving average taken.	1.11	0.281	-4.41*	-4.68**
log (NER)	Log of the nominal bilateral exchange rate index.	Monthly, IMF IFS.	4.52	0.298	-1.45	-4.83**
log (REER)	Log of the real effective exchange rate.	Monthly, IMF.	4.49	0.167	-1.37	-4.48**
log (TOT)	Log of the terms-of-trade.	Monthly, Bank of Uganda.	4.66	0.167	-3.92**	-4.05**
INTDIFF	Domestic-international interest rate differential between the Uganda government 91 day T bill rate/100 and the USA T bill rate/100.	Monthly, IMF IFS.	0.0694	0.0464	-3.512**	-5.039**
OUTGAPIP	The output gap measured as: log (Industrial Production Index) adjusted with a Hodrick Prescott filter (lambda=14400) for log potential IP.	Monthly, Bank of Uganda.	0.00148	0.0562	-3.39*	-6.52**
RainfallDev	Equally-weighted measure of the deviations of actual rainfall in the four principal growing regions from the long-term average (computed by the Meteorological Department as the average rainfall that has been received over a period of 30 years), divided by 100.	Monthly, Ugandan Meteorological Authority.	0.0341	0.381	-6.63**	-8.65**
RainfallDevENT	The above deviation for the Entebbe region alone.		0.0593	0.785	-12.7**	-7.03**
FiscalBal/GDP	Non-oil primary fiscal balance relative to GDP.	Annual, Ministry of Finance, Planning and Economic Development, converted to monthly data, converted from fiscal to calendar year and 12-month moving average taken.	-0.0166	0.0186	-3.04	-5.66**
CurAccBal/GDP	Current account balance in US$ converted using the bilateral shilling/$ exchange rate, relative to calendar year current GDP.	Monthly, IMF, for exchange rate. Quarterly, Bank of Uganda, for current/trade account balance converted to monthly data and 3-month moving average taken. Annual, Bank of Uganda, for GDP data, converted to monthly data and 12-month moving average taken.	-0.0565	0.0545	-2.76	-6.28**
TradAccBal/GDP	Trade Balance in US$ converted using the bilateral shilling/$ exchange rate, relative to calendar year current GDP.		-0.0854	0.0341	-1.73	-4.52**
log (PCred)	Claims on private sector.	Monthly, IMF, for credit.	6.99	1.16	0.0636	-14.9**
log (scaled M3pc) - log (CPI)	Log ratio of nominal per capita broad money, M3, to the CPI, and subtracting 1.5* log real per capita GDP.	Monthly, Bank of Uganda for M3 and CPI. Annual, Bank of Uganda, for GDP	-2.50	0.176	-1.51	-5.54**

Variable	Definition of variable	Source, frequency	Mean	Std Dev.	I(1)[a]	I(2)[a]
	Previous models for Uganda, e.g. Kabundi (2012), find the elasticity of the demand for broad money to be around 1.5. As income per head rises, there is an increase in financialisation of the economy. Without the correction there would be a substantial upward drift in the measure, more difficult to link with trends in inflation in Uganda.	data, converted to monthly data and 12-month moving average taken. Annual, IMF IFS for population.				
MobilemoneyBal/ M3	Mobile money balances on customers' accounts (Shs), relative to nominal M3.	Monthly, Bank of Uganda.	0.00387	0.00343	2.21	-6.57**
MobilemoneyVal/ M3	Mobile money value of transactions (Shs), relative to nominal M3.	Monthly, Bank of Uganda.	0.0528	0.0493	0.126	-9.43**
Non-linear term: $(\log(z) - \log(\bar{z})) > 0$	Positive values only are taken. If this is with respect to a levels variable, z, the mean of the variable is first extracted.	Monthly.	-	-	-	-
Non-linear term in $(\Delta_3 \log(z))^2$	The residual of the following OLS regression is used: $(\Delta_3 \log(z))^2_t$ = constant + $\Delta_3 \log(z)_t + \varepsilon_t$.	Monthly.	-	-	-	-
Mx	x=1 to 12 are seasonals.	Monthly.	-	-	-	-
DstepJan07	Step dummy = zero before January 2007 and 1 thereafter, capturing effects of lower hydro-electric capacity from January 2007.	Monthly.	-	-	-	-
DstepJun07	Step dummy = zero before June 2007 and 1 thereafter, capturing the period of new CPI weights from June 2007.	Monthly.	-	-	-	-
DstepJul11	Step dummy = zero before July 2011 and 1 thereafter, capturing the period of inflation targeting.	Monthly.	-	-	-	-
DStepJul01	Dummies for indirect taxation[b]. Step dummy, SD = 0 before each date indicated and 1 thereafter. Enters as SD_{t+3} - 0.65 $SDma12_t$ in the 3-month-ahead equation and as SD_{t+1} - 0.425 SD_t - 0.4 $SDma12_t$ in the 1-month-ahead equation. See Section 6.2.3.	Monthly.	-	-	-	-
DStepApr05			-	-	-	-
			-	-	-	-
DStepAug11			-	-	-	-
DStepOct10	Dummy for regulatory changes in mobile telephony. Step dummy enters in the same form as dummies for indirect taxation. See Section 6.2.3.	Monthly.	-	-	-	-
DStepSep11						
DimpulseMay96	Impulse dummy for outlier.	Monthly.	-	-	-	-
DimpulseMay04	Impulse dummy for outlier.	Monthly.	-	-	-	-
DimpulseJun04	Impulse dummy for outlier.	Monthly.	-	-	-	-
DimpulseJun05	Impulse dummy for outlier.	Monthly.	-	-	-	-
DimpulseSep06	Impulse dummy for outlier.	Monthly.	-	-	-	-

Variable	Definition of variable	Source, frequency	Mean	Std Dev.	I(1)[a]	I(2)[a]
DimpulseDec07	Impulse dummy for outlier.	Monthly.	-	-	-	-

Notes: The statistics are produced for the monthly sample, 1994-2013, except for the mobile money data which begin in 2009-03. Statistics are reported to three significant figures. Asterisks * and ** denote rejection at 5% and 1% critical values.

a For a variable X, the augmented Dickey-Fuller (1981) statistic is the t ratio on π from the regression: $\Delta X_t = \pi X_{t-1} + \sum_{i=1}^{k} \theta_i \Delta X_{t-i} + \psi_0 + \psi_1 t + \varepsilon_t$ where k is the number of lags on the dependent variable, ψ_0 is a constant term, and t is a trend. The k^{th}-order augmented Dickey-Fuller statistic is reported, where k is the last significant lag of the 11 lags employed. The trend is included only if significant. That coefficient should be zero under the null hypothesis that X is I(1). For null order I(2), ΔX replaces X in the equation above. Critical values are obtained from MacKinnon (1991). Stationarity tests are performed for the variables in levels before time-transformation i.e. before taking moving averages and changes. For trade openness and the fiscal balance the tests are performed on annual data.

b Indirect tax rates rose in July 2001, April 2005 and August 2011. Transport and communication prices fell sharply in October 2010 and rose sharply in September 2011.

TABLE 3

Results for 1-month-ahead and 3-month-ahead domestic fuel equations

Estimation sample: 1994-01 to 2013-09	*Dependent variable:* Δ_3 log (DomFuelP) (+3)			*Dependent variable:* Δ_3 log (DomFuelP) (+1)		
Variables	*Transformation and lags*	*Coefficient*	*t-HACSE*	*Transformation and lags*	*Coefficient*	*t-value*
Long-run coefficients						
Constant		-0.335	-8.31		-0.1063	-5.76
log (CPInonfd) - log (DomFuelP)		0.531	8.76	(t-1)	0.154	6.33
log (WOilP) - log (DomFuelP)		0.0967	7.24	(t-1)	0.0289	4.87
I(0) determinants						
CurAccBal/GDP	(t-2)	0.162	2.51	(t-2)	0.0453	1.45
TradAccBal/GDP	(t-2)	-0.351	-1.68	(t-2)	-0.103	-1.27
Δ_3 log (PCred)		0.231	4.61		0.0788	2.95
RainfallDev	ma6 (t-4)	-0.0634	-3.14	ma6 (t-5)	-0.0216	-2.44
Short-run coefficients						
Δ log (NER)		0.490	4.17		0.221	3.29
Δ_3 log (DomFuelP)	(t-3)	0.164	2.60			
Δ_6 log (DomFuelP)	(t-6)	0.141	2.40	(t-6)	0.0434	2.15
Δ log (USWP)				(t-1)	0.309	2.02
Δ_3 log (USWP)				(t-3)	0.362	5.45
Δ_6 log (USWP)		0.552	4.36			
Non-linear term: [Δ log (WOilP)] > 0					0.129	3.58
Dummies/regime changes						
DimpulseMay96					0.0936	3.94
DimpulseJun04					-0.0902	-3.8
DimpulseJun05		0.132	10.2			

DimpulseSep06		-0.147	-12.8			
DimpulseDec07					0.09887	4.18
Diagnostics						
Standard error	0.0415			0.0233		
Adjusted R^2	0.550			0.450		
Number of observations	237			237		
Number of parameters	13			15		
AR 1-2 test:	[0.0000]**			[0.3761]		
ARCH 1-1 test:	[0.0001]**			[0.4377]		
Normality test:	[0.3453]			[0.0093]**		
Hetero test:	[0.0032]**			[0.1030]		
Hetero-X test:	[0.0005]**			[0.0007]**		
RESET23 test:	[0.0162]*			[0.0475]*		
Chow (70%)	0.0928			0.01271		

Notes: Statistics are reported to three significant figures. Given the autocorrelation in the 3-month-ahead model, HACSE t-ratios are reported; ** means significant at the 1% level; * means significant at the 5% level.

TABLE 4

Results for 1-month-ahead and 3-month-ahead CPI food equations

Estimation sample: 1994-01 to 2013-12	*Dependent variable:* Δ_3 log (CPIfd) (+3)			*Dependent variable:* Δ_3 log (CPIfd) (+1)		
Variables	*Transformation and lags*	*Coefficient*	*t-HACSE*	*Transformation and lags*	*Coefficient*	*t-value*
Long-run coefficients						
Constant		-0.254	-5.34		-0.0923	-4.27
Trend/100		-0.0610	-5.65		-0.0214	-2.79
DstepJun07 (new CPI weights)		-0.0721	-4.05		-0.0356	-4.02
TRADEOPEN	ma36 (t-6)	0.340	6.28	ma36 (t-6)	0.105	3.93
Non-linear term: [log (CPIKenyafd)- log (CPIfd)] > 0	de-meaned	0.215	3.42		0.0907	2.63
Non-linear term: [log (CPIKenyafd)- log (CPIfd)] > 0	de-meaned, ma6 (t-1)	0.388	6.00	ma6 (t-1)	0.179	4.67
log (CPInonfd) - log (CPIfd)	(t-3)	0.385	8.23	(t-3)	0.152	6.41
log (WMaizeP) - log (CPIfd)	(t-6)	0.0306	2.26			
log (WCoffeeP) - log (CPIfd)	ma6 (t-1)	0.0559	2.92	ma6 (t-1)	0.0157	1.69
log (WCoffeeP) - log (CPIfd)	ma6 (t-7)	0.0683	3.79	ma6 (t-7)	0.0347	3.27
Hydro-electric capacity proxy: DstepJan07 x [log (DomFuelP) - log (CPIfd)]	Relat. price is de-meaned, ma6 (t-1)	0.174	3.44			
Hydro-electric capacity proxy: DstepJan07 x [log (DomFuelP) - log (CPIfd)]	Relat. price is de-meaned, ma6 (t-7)	0.0775	2.18	Relat. price is de-meaned, ma6 (t-7)	0.0649	2.99
I(0) determinants						
RainfallDev	ma3	-0.138	-13.8	ma3	-0.0535	-8.25
RainfallDev	ma3 (t-3)	-0.120	-14.2	ma3 (t-3)	-0.0432	-6.83
RainfallDev	ma3 (t-6)	-0.0774	-8.69	ma3 (t-6)	-0.0252	-4.27
RainfallDev	ma3 (t-9)	-0.0408	-3.22	ma3 (t-9)	-0.0159	-2.69
Non-linear term: $[(\text{RainfallDev}) > 0]^2$					0.0154	2.79

Regional rainfall: DstepJan07 x RainfallDev	de-meaned, ma6	0.0943	4.46	ma6	0.0243	1.55
FiscalBal/GDP	ma12	-0.768	-3.69	ma12	-0.170	-1.61
CurAccBal/GDP	(t-3)	0.259	3.94	(t-3)	0.128	3.89
TradAccBal/GDP	(t-3)	-0.455	-2.23	(t-3)	-0.294	-3.88
IntDiff	ma3 (t-3)	-0.298	-4.07	ma3 (t-3)	-0.0873	-2.82
Δ_6 log (PCred)		0.115	3.55		0.0455	2.38
Short-run coefficients						
Δ log (CPIfd)					0.277	4.56
Δ_3 log (CPIfd)		-0.682	-12.1		-0.277	-7.54
Non-linear term in (Δ_3 log (CPIfd))^2	(t-3), see Table 2	1.49	3.73	(t-4), see Table 2	0.944	3.41
Δ_6 log (TOT)	(t-6)	0.0535	3.30			
Δ log (CPIKenyafd)				(t-1)	0.127	3.81
Δ_3 log (CPIKenyafd)		0.0917	2.62			
Dummies/regime changes						
DimpulseMay04		0.0956	6.87			
Seasonals						
Diagnostics						
Standard error	0.0256			0.0174		
Adjusted R^2	0.821			0.645		
Number of observations	240			240		
Number of parameters	32			30		
AR 1-2 test:	[0.0000]**			[0.2351]		
ARCH 1-1 test:	[0.2588]			[0.5020]		
Normality test:	[0.9392]			[0.0176]*		
RESET23 test:	[0.0195]*			[0.1725]		
Chow (70%)	0.91000			0.26780		

Notes: Statistics are reported to three significant figures. Given the autocorrelation in the 3-month-ahead model, HACSE t-ratios are reported; ** means significant at the 1% level; * means significant at the 5% level.

TABLE 5

Results for 1-month-ahead and 3-month-ahead CPI non-food equations

Estimation sample: 1997-01 to 2013-12	*Dependent variable:* Δ_3 log (CPInonfd) (+3)			*Dependent variable:* Δ_3 log (CPInonfd) (+1)		
Variables	*Transformation and lags*	*Coefficient*	*t-HACSE*	*Transformation and lags*	*Coefficient*	*t-value*
Long-run coefficients						
Constant		-0.0821	-0.999		0.158	2.98
Trend/100		-0.00751	-12.7		-0.0306	-7.38
DstepJun07 (new CPI weights)		0.0375	8.23		0.0189	7.55
TRADEOPEN	ma36 (t-6)	-0.110	-9.83	ma36 (t-6)	-0.0760	-8.09
log (USWP) - log (CPInonfd)		0.0462	3.67		0.0344	4.63
log (WMaizeP) - log (CPInonfd)	ma6 (t-6)	0.0243	2.75	ma6 (t-7)	0.0194	4.04
log (CPIfd) - log (CPInonfd)	ma3	0.0746	4.53	ma3	0.0453	4.43
log (CPIfd) - log (CPInonfd)	ma3 (t-3)	0.0480	3.02	ma3 (t-3)	0.0251	2.69
log (DomFuelP) - log (CPInonfd)	ma6 (t-6)	0.0489	5.25	ma6 (t-6)	0.0425	5.41
log (REER)	ma6 (t-1)	0.103	7.24	ma6 (t-3)	0.0225	2.57
log (M3pc) - log (CPI)	M3pc is scaled, see Table 2	0.0646	4.92	M3pc is scaled, see Table 2	0.0541	4.58
I(0) determinants						
RainfallDev	ma6 (t-5)	-0.0165	-5.16	ma3 (t-6)	-0.00537	-3.39
FiscalBal/GDP	ma12	-0.110	-2.22	ma12 (t-1)	-0.0932	-2.45
CurAccBal/GDP	(t-2)	0.0548	2.64	(t-2)	0.0358	2.29
TradAccBal/GDP	(t-2)	-0.140	-2.53	(t-2)	-0.184	-5.12
Δ_6 log (PCred)		0.0381	5.29	(t-2)	0.0110	1.88
IntDiff	ma6 (t-3)	-0.165	-8.77	ma6 (t-4)	-0.0624	-3.74
Short-run coefficients						
Δ log (CPInonfd)		-0.176	-3.6			
Δ_3 log (CPInonfd)		-0.721	-14.5		-0.494	-11.8

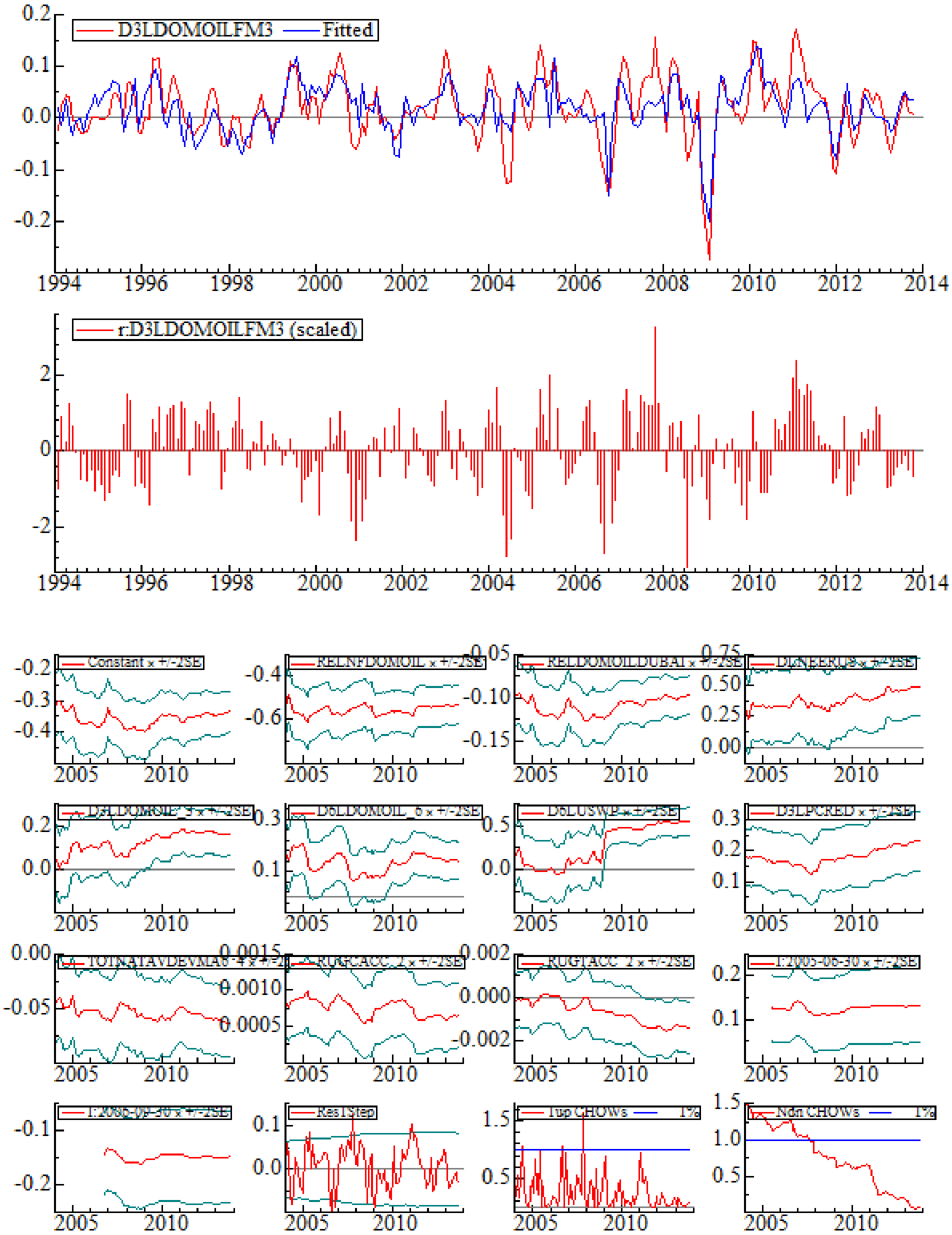
Δ_3 log (CPInonfd)	(t-3)	-0.433	-10.4	(t-3)	-0.295	-8.22
Δ_6 log CPInonfd)	(t-6)	-0.130	-5.11	(t-6)	-0.146	-6.31
Non-linear term in (Δ_3 log (CPIfd))^2	(t-2), see Table 2	0.238	2.10	(t-1), see Table 2	0.206	2.52
Non-linear term in (Δ_3 log (CPIfd))^2	see Table 2			(t-3), see Table 2	0.286	3.36
Δ_6 log (TOT)		0.00967	2.30			
Δ_3 log (CPIKenyaTot)		0.0245	2.16			
Dummies/regime changes						
Seasonals						
DStepJul01 (indirect tax)	See Table 2[a]	0.0158	4.83	See Table 2[a]	0.0214	3.67
DStepApr05 (indirect tax)		0.0140	5.03		0.0259	4.83
DStepOct10 (regulatory mobile telephony)		-0.0141	-3.25		-0.0269	-5.14
DStepAug11 (indirect tax)		0.0257	4.96		0.0157	1.62
DStepSep11 (regulatory mobile telephony)		0.0396	9.74		0.0547	5.41
Diagnostics						
Standard error	0.00554			0.00470		
Adjusted R^2	0.877			0.671		
Number of observations	204			204		
Number of parameters	31			29		
AR 1-2 test:	[0.0009]**			[0.9534]		
ARCH 1-1 test:	[0.2710]			[0.5196]		
Normality test:	[0.0675]			[0.0202]*		
Hetero test:	[0.2143]			[0.3007]		
RESET23 test:	[0.9035]			[0.0027]**		
Chow (70%):	0.83058			0.64897		

Notes: Statistics are reported to three significant figures. Given the autocorrelation in the 3-month-ahead model, HACSE t-ratios are reported; ** means significant at the 1% level; * means significant at the 5% level.

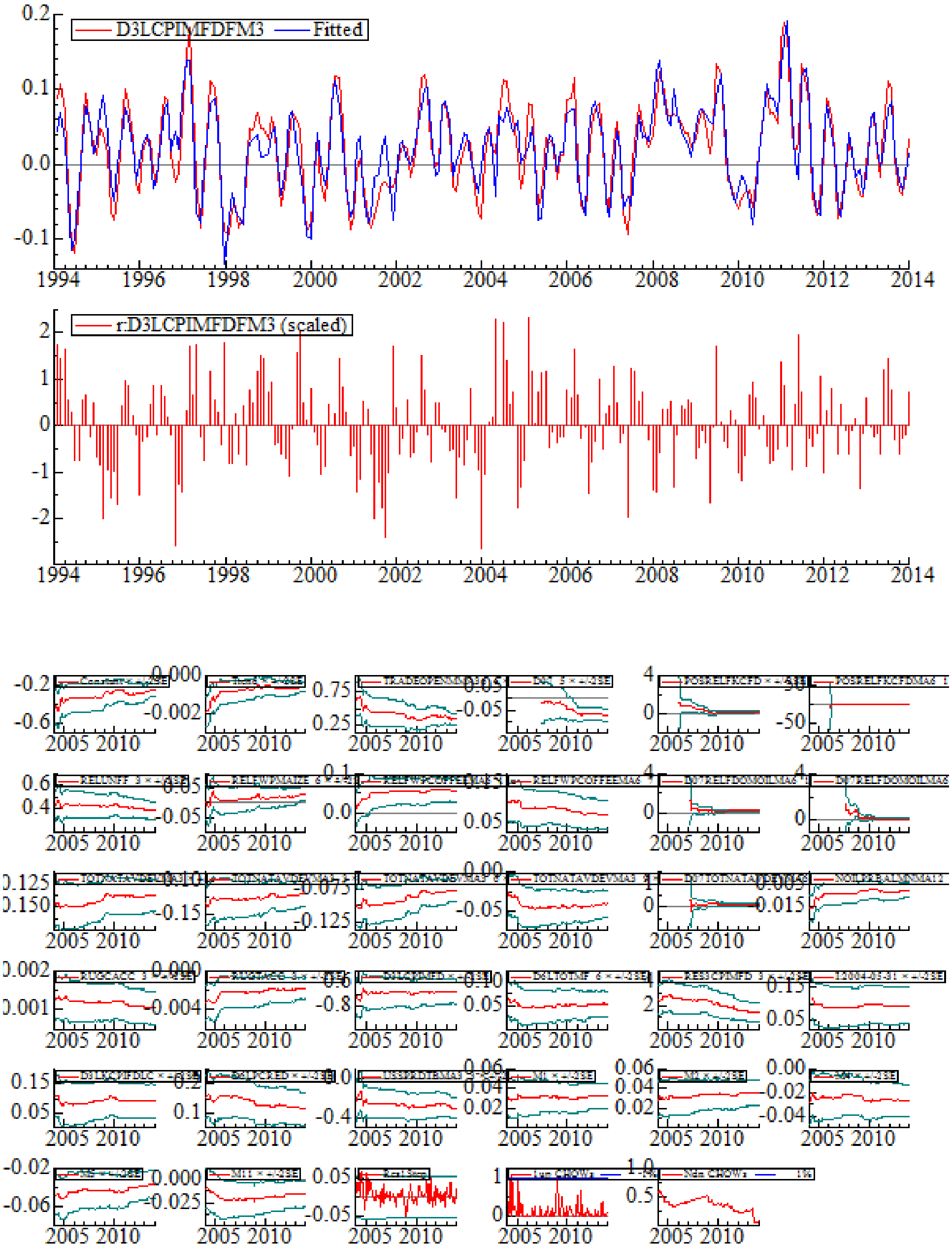
a Different transformations of Step dummies for 3-month and 1-month equations, see Table 2.

APPENDIX 1: DIAGNOSTICS OF FORECASTING REGRESSIONS

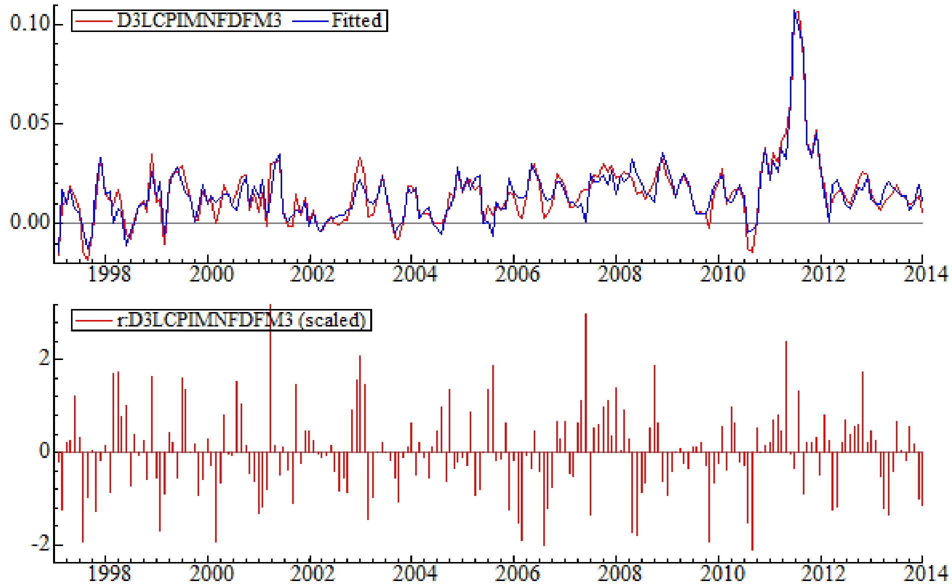
Figures A1: Fit and recursive graphics: 3-month-ahead domestic fuel equation

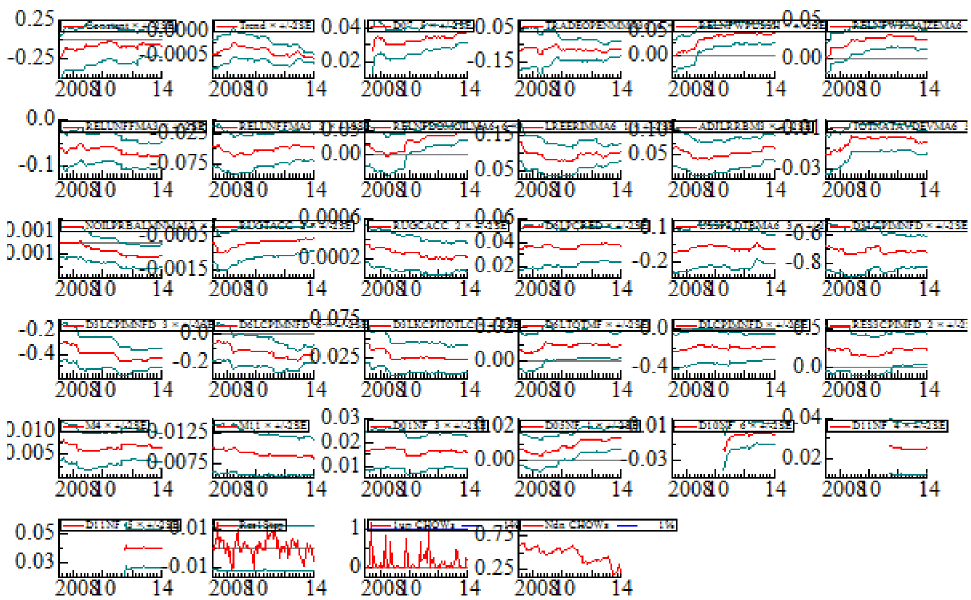


Figures A2: Fit and recursive graphics: 3-month-ahead CPI food equation



Figures A3: Fit and recursive graphics: 3-month-ahead CPI non-food equation





APPENDIX 2: TREATMENT OF SHIFTS IN INDIRECT TAX RATES AND REGULATED TRANSPORT AND COMMUNICATIONS PRICES IN THE NON-FOOD CPI EQUATION

An innovation in the non-food CPI equation is to take account of the large shifts in tax rates, particularly for beverages and tobacco, and shifts in regulated transport (and communications) prices. Indirect tax rates on the former rose in July 2001, April 2005 and August 2011. Transport and communication prices fell sharply in October 2010 and rose sharply in September 2011. Taking account of these shifts entails using a series of transformed step dummies in the 1-month and 3-month-ahead equations.

Adding the coefficients of the long-run terms for the 3-month-ahead model in Table 5 that include log (CPInonfd) gives 0.35. But since the dependent variable is the 3-month change, translation to levels results in a coefficient of 0.65 on the sum of the levels terms distributed over 12 months in the equation below. The dynamic form of the estimated 3-month-ahead equation can thus be approximated as follows:

$$y_{t+3} = f(x_t) + 0.65(yma12_t - zma12_t) + z_{t+3} \qquad \text{(A2-1)}$$

where *y* is the log of non-food CPI, $f(x)$ are other determinants, and $yma12$ is the 12-month moving average of $\log(nonfood\ CPI)$and z indicates a shift in the non-food CPI due to tax or regulatory changes (of which five such shifts are enumerated above).

The shifts are captured by step dummies. The economic interpretation of this formulation is that the economic drivers of log non-food CPI act on the part of the index other than that affected by such tax or regulatory changes. To account for a step-change at t+3, we therefore need (*SD(t+3)* – 0.65 *SDma12(t)*) to be included among the regressors in the GUM for each of the five shifts, where *SD(t+3)* is a step dummy (0 before t=T, and 1 from t=T, and T is the date of the shift, see Table 2). This gives five significant dummies, with positive coefficients at all the dates above, except in October 2010, when prices fell. The coefficients on these transformed dummies represent the long-run effect on $\log(nonfood\ CPI)$ of these tax and regulatory changes.

The sum of the coefficients on equilibrium correction terms involving $\log(nonfood\ CPI)$ for the 1-month-ahead model shown in Table 5 is approximately 0.175= 1 - 0.425 - 0.4. Converting to an expression in the level of the log of non-food CPI and including dynamic terms, the dynamic form of the 1-month-ahead equation can be approximated as follows:

$$y_{t+1} = f(x_t) + 0.425(y_t - z_t) + 0.4(yma12_t - zma12_t) + z_{t+1} \qquad \text{(A2-2)}$$

where *y* is the log of non-food CPI. Therefore, the step dummies to capture step-changes in heavily-taxed or administered non-food components take the form [*SD(t+1)* -0.425 *SD(t)* – 0.4 *SDma12(t)*]. All but one of the five step dummies is significant (Table 5).