Micro-Price Adjustment to the New Currency System in Zimbabwe

by

Mike Nyawo

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Supervisor: Professor Neil Rankin

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own original work, that I am the authorship owner thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Signature: Mike Nyawo

Date: March 2018

Abstract

This dissertation focuses on market integration, pricing and price-setting behaviour of firms with emphasis on disaggregated consumer price data after the introduction of a new currency system in Zimbabwe. The adoption of a new currency system is critical for thinking about the implications of moving to a new currency system on market integration, mechanisms of price adjustment and price setting behaviour of firms particularly after hyperinflation. Chapter 2 measures the dispersion relative to the Law of One Price (LOP) within Zimbabwe and between Zimbabwe and South Africa, Zimbabwe's biggest trading partner. Results indicate that it took 18 months for prices to stabilise within Zimbabwe. When we include the border between Zimbabwe and South Africa in the analysis, the study indicates that price convergence was larger within Zimbabwe than between Zimbabwe and South Africa, suggesting that the adoption of the new currency system played a key role in this adjustment process. The chapter shows that the border effect between Zimbabwe and South Africa narrows over time and that exchange rate volatility explains a substantial portion of the border effect. Trade and exchange rate volatility are important in explaining convergence in prices between Zimbabwe and South Africa, but time variation, as captured by year fixed-effects, remains very important suggesting that there are other important factors not captured in the analysis.

The second substantive chapter, Chapter 3, investigates price setting behaviour, and the change in this behaviour amongst retail firms in Zimbabwe after the introduction of a new currency system. The chapter uses disaggregated price data, and the calculated frequency, size and probability of price changes, to compare 'stylised facts' of price setting behaviour in Zimbabwe to similar countries such as Lesotho and Sierra Leone. There is strong evidence that prices are stickier in Zimbabwe, with retailers on average changing their prices every 3.9 months compared to Lesotho (2.7 months) and Sierra Leone (2.0 months). Furthermore, the paper also analyses the dynamics of price changes over time. Using four month moving averages, results agree with international literature that the variance in inflation is correlated with the size of price changes rather than the frequency of price changes. Lastly, chapter 3 decomposes the frequency of price changes into variation within a given store, variation across stores for a given product and lastly the idiosyncratic shock for a particular product and store. The study illustrates that, across all years, the fraction of variation which is common to all stores selling a particular product accounts for most of the total variation of the frequency of price changes. This gives an indication that retailer characteristics are an important determinant of price changes.

Chapter 4 uses a novel natural experiment – the introduction of bond coins in Zimbabwe, to investigate the importance of the face value of a currency as a source of price stickiness. The study exploits three different econometric techniques to assess the impact of the introduction of coins on price flexibility in Zimbabwe. Descriptive statistics show a discontinuous, sharp rise in the frequency of price changes around March 2015, when bond coins were introduced. Results from difference-in-differences, time-regression discontinuity and interrupted time series design estimators show that the introduction of coins in March 2016 led to the downward shift in prices as retailers had more scope to reprice. The study estimates how much the choice of wrong denomination cost the consumers particularly on lower priced products. Using results from the time-regression discontinuity design, we show that inflation was 0.06 percentage points lower as a result of bond coins.

Overall, the findings indicate that although the adoption of a new currency system arrested price increases, it came with its own challenges. Prices still remain dispersed and the border effect between Zimbabwe and South Africa is still large. Within Zimbabwe, there is some adjustment process with regards to the frequencies to which firms change prices, with coefficient estimates suggesting that there is a trend associated with adjustment to the new currency system. The introduction of coins in March 2015, 6 years after the new currency system was introduced, increased price flexibility and led to a downward shift in prices. The dissertation argues that the choice of denominating currency is important, particularly when a country adopts a currency which is ‘strong’ in value but less fine in terms of denominations.

Opsomming

Hierdie proefskrif fokus op markintegrasie, prysbepaling en prysopstelgedrag van firmas met die klem op onderverdeelde verbruikersprysdata na die bekendstelling van 'n nuwe geldeenheidstelsel in Zimbabwe. Die aanneming van 'n nuwe geldeenheidstelsel is van kritieke belang om te dink oor die implikasies van die verskuiwing na 'n nuwe geldeenheidstelsel op markintegrasie, meganismes van prysaanpassing en prysopstelgedrag van maatskappye, veral na hiperinflasie. Hoofstuk 2 meet die verspreiding relatief tot die Wet van Eenprys (LOP) binne Zimbabwe en tussen Zimbabwe en Suid-Afrika, Zimbabwe se grootste handelsvennoot. Resultate dui daarop dat dit 18 maande duur voordat pryse in Zimbabwe stabiliseer. Wanneer ons die grens tussen Zimbabwe en Suid-Afrika in die analise insluit, dui die studie aan dat pryskonvergentie groter was in Zimbabwe as tussen Zimbabwe en Suid-Afrika, wat daarop dui dat die aanneming van die nuwe geldeenheidstelsel 'n sleutelrol in hierdie aanpassingsproses gespeel het. Die hoofstuk toon dat die grens-effek tussen Zimbabwe en Suid-Afrika mettertyd vernou en dat wisselkoersvolatiliteit 'n aansienlike deel van die grens-effek verklaar. Handels- en wisselkoersvolatiliteit is belangrik om die konvergensie in pryse tussen Zimbabwe en Suid-Afrika te verduidelik, maar tydsveranderings, soos vasgestel deur die jaar vaste-effekte, bly baie belangrik en dui daarop dat die analise ander belangrike faktore vang nie.

Die tweede inhoudelike hoofstuk, Hoofstuk 3, ondersoek prysopsetgedrag en die verandering in hierdie gedrag by kleinhandelfirmas in Zimbabwe na die bekendstelling van 'n nuwe geldeenheidstelsel. Hierdie hoofstuk gebruik onderverdeelde prysdata, en die berekende frekwensie, grootte en waarskynlikheid van prysveranderinge, om 'gestileerde feite' van prysinstellingsgedrag in Zimbabwe te vergelyk met soortgelyke lande soos Lesotho en Sierra Leone. Daar is sterk bewyse dat pryse in Zimbabwe stywer is, met kleinhandelaars wat gemiddeld elke 3,9 maande hul pryse verander in vergelyking met Lesotho (2,7 maande) en Sierra Leone (2,0 maande). Verder ontleed die navorsing ook die dinamiek van prysveranderinge oor tyd. Met behulp van vier maand bewegende gemiddeldes stem resultate ooreen met internasionale literatuur dat die variansie in inflasie korreleer met die grootte van prysveranderings eerder as die frekwensie van prysveranderings. Ten slotte ontbind hoofstuk 3 die frekwensie van prysveranderings tot variasie binne 'n gegewe winkel, variasie oor winkels vir 'n gegewe produk en laastens die idiosinkratiese skok vir 'n bepaalde produk en winkel. Die studie illustreer dat die fraksie van die variasie wat algemeen is vir alle winkels wat 'n spesifieke produk verkoop, hoër is as die algemeen en verantwoordelik is vir die grootste deel van die totale variasie van die frekwensie van prysveranderings. Dit gee 'n aanduiding dat kleinhandelaarseienskappe 'n belangrike determinant van prysveranderings is.

Hoofstuk 4 gebruik 'n nuwe natuurlike eksperiment - die bekendstelling van verbandmuntstukke in Zimbabwe - om die belangrikheid van die nominale waarde van 'n geldeenheid as 'n bron van prysstyfheid te ondersoek. Die studie gebruik drie verskillende ekonometriese tegnieke om die impak van die bekendstelling van munte oor prysstyfheid in Zimbabwe te beoordeel. Beskrywende statistieke toon 'n diskontinue, skerp styging in die frekwensie van prysveranderings omstreeks Maart 2015, toe verbandmuntstukke ingestel is. Resultate van verskil-in-verskille, tydregressie-diskontinuïteit en onderbrekende tydreeksontwerpskattings dui aan dat die bekendstelling van munte in Maart 2016 gelei het tot afwaartse prysveranderings, aangesien kleinhandelaars meer ruimte gehad het om te herdruk. Die studie skat hoeveel die keuse van verkeerde denominasie die verbruikers kos, veral op laer pryse. Deur resultate van die tyd-regressie-diskontinuiteitsontwerp te gebruik, toon die studie dat inflasie 0,06 persentasiepunte laer was as gevolg van verbandmuntstukke.

Algeheel toon die bevindings dat, hoewel die aanvaarding van 'n nuwe geldeenheidstelsel prysstygings getem het, bring dit sy eie uitdagings. Pryse bly steeds versprei en die grens effek tussen Zimbabwe en Suid-Afrika is steeds groot. Binne Zimbabwe is daar 'n aanpassingsproses met betrekking tot die frekwensie waarmee maatskappye pryse verander, met koeffisient skattings wat daarop dui dat daar 'n tendens is wat verband hou met aanpassing aan die nuwe geldeenheidstelsel. Die bekendstelling van munte in Maart 2015, 6 jaar na die invoering van die nuwe geldeenheidstelsel, het prysprysbaarheid verhoog en het gelei tot 'n afwaartse prysverskuiwing. Die proefskrif beweer dat die keuse van geldeenheid denominasie belangrik is, veral wanneer 'n land 'n geldeenheid aanvaar wat sterk, maar minder fyn in terme van denominasie is.

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1 CHAPTER ONE

Introduction and research aims

In January 2009, Zimbabwe adopted a new currency system in an attempt to end hyperinflation. Five foreign currencies were granted official status as the medium of exchange – the United States (U.S.) dollar; the South African Rand; the British Pound ; the Botswana Pula and the Euro. Zimbabwe chose the U.S. dollar over the South African Rand as a reference currency, and with this came a higher face value on the currency. The change to a new currency system arrested price increases and created price stability. However, the move came with its own challenges particularly for the adjustment of prices. When the U.S. dollar was introduced the smallest denomination note was $1 which meant that there was no 'official' medium of exchange that could be used as change for products not priced in round numbers. This introduced a form of price stickiness which has not been investigated in literature. Experiments like this are very rare, but the availability of disaggregated consumer price data in Zimbabwe soon after the introduction of the new currency system provides us an opportunity to examine the price adjustment process at a much disaggregated level.

Since the adoption of the Euro in 1999, there has been significant work studying the mechanisms of price adjustment and price convergence associated with countries moving to a new currency system (see Goldberg & Verboven (2005); Engel & Rodgers (2004); Angeloni, Aucremanne, & Ciccarelli (2006); Waldmann, Allington, & Kattuman (2005)). Many countries moved into the Euro zone to promote macroeconomic stability and to reduce exchange rate volatility (Engel & Rogers, 2004) and empirical research using consumer price data for these countries has been on the rise. However, in emerging economies, where economic shocks are common and markets are segmented, studies of this nature are rare, and much of this type of work has been done on countries with relative price stability. Ecuador is the only exception, but the events leading to dollarisation in the South American country are quite different to that of Zimbabwe.

Empirical literature in Africa has been limited to countries with established currencies (see Nchake, Edwards & Rankin, (2014); Creamer, Farrell, & Rankin (2012); Kovanen (2006)). Much of this literature studies price setting behaviour of firms and identifies stylised facts of price setting at a disaggregated level in a stable environment. Zimbabwe is a unique situation – it adopted a new currency system in January 2009 after a decade of hyperinflation and economic crisis. The adoption of a new currency system is critical for thinking about the implications of moving to a new currency system on market integration, mechanisms of price adjustment and price setting behaviour of firms particularly after hyperinflation. In addition, I use a unique natural experiment – the introduction of bond coins in Zimbabwe – to understand how dollarisation and the lack of low denomination coins affected price-stickiness.

1.1 Background and context of study

Zimbabwe abandoned its own currency in January 2009 after a period of hyperinflation and economic crisis. Official statistics released by the Zimbabwe Statistics Agency (Zimstat) indicated that year-on-year inflation reached 230 million percent by July 2008, with the International Monetary Fund estimating the inflation rate to be 471 billion percent as of September 2008 (IMF Country Report, 2009). Table 1.1 presents month-on-month and year-on-year inflation for Zimbabwe from March 2007 to November 2008.

Table 1.1: Month-on-month and year-on-year inflation, March 2007 to November 2008

Date	Month-on-month	Year-on-year
Mar-07	51	2 200
Apr-07	101	3 714
May-07	55	4 530
Jun-07	86	7 251
Jul-07	31	7 635
Aug-07	12	6 593
Sep-07	39	7 982
Oct-07	136	14 841
Nov-07	131	26 471
Dec-07	240	66 212
Jan-08	121	100 580
Feb-08	126	164 900
Mar-08	281	417 823
Apr-08	213	650 599
May-08	433	2 233 713
Jun-08	839	11 268 758
Jul-08	2 600	231 150 889
Aug-08	3 190	9 690 000 000
Sep-08	12 400	471 000 000 000
Oct-08	690 000 000	3 840 000 000 000 000 000
Nov-08	79 600 000 000	89 700 000 000 000 000 000 000

Note: The Zimbabwe National Statistics reported inflation until July 2008. From August 2008 to November 2008 we use estimations by (Hanke & Kwok, 2009) *and (IMF Country Report, 2009)*

To restore credibility in the financial system, five foreign currencies were granted official status as the medium of exchange – the United States (U.S.) dollar; the South African Rand; the British Pound and the Euro. Prices were quoted in U.S. dollars, implying that when transacting, these parallel currencies were directly converted to U.S. dollars with the prevailing exchange rates at the point of sale machines. Inflation sharply dropped to -3.4 percent by March 2009 with prices of commodities beginning to stabilise (Hanke & Kwok, 2009).

Before the adoption of the new currency system, there were several instances where firms and the public were allowed to use foreign currency. For example, in October 2008, the Reserve Bank of Zimbabwe (RBZ) introduced Foreign Currency Licenced Wholesalers and Retail Shops. This was done to increase availability of foreign currency to selected firms who were involved in the importing of certain products since there were shortages in the domestic market. However, the central bank restricted this facility for some basic commodities – firms had to demonstrate that they imported the goods before gaining permission to trade in foreign currency.

By December 2008, a total of 1000 retailers were licenced with the emphasis of spreading licencing to trade in foreign currency out across outlets across the country. Other firms who were not licenced began to trade in foreign currency illegally since they had to constantly go to the parallel market to convert their Zimbabwe dollars into foreign currency. The Zimbabwean dollar began to be rejected by the public as a medium of exchange (Hanke & Kwok, 2009). The government was left with no option but to adopt the U.S. dollar as the medium of exchange. On 29 January 2009, the Government of Zimbabwe (GoZ) released a government gazette, giving legal tender to the use of the U.S. dollar as a medium of exchange, hence completing dollarisation. The adoption of multiple currencies as the medium of exchange poses several questions, particularly on market integration, the mechanisms of price adjustment after hyperinflation and how denomination matters when a country adopts a strong currency as a medium of exchange.

1.2 Motivation and research aims

Standard open economy models predict that changing currency has little or no impact on relative prices once prices have time to adjust (Cavallo, Neiman, & Rigobon, 2014). In theory, if the change is not associated with other policies governing the external environment such as tariffs and other trade restrictions, then relative prices self-adjust once given the time. However, in most instances, there are always disparities between theory and empirical evidence particularly in emerging economies. More often, economic shocks are more frequent, exacerbated by poor infrastructure and distribution networks, creating frictions to the adjustment of prices. Therefore, experiments on emerging economies normally challenge established theories as well as open economy models.

The adoption of a new currency system in Zimbabwe in January 2009 is unique, since these natural experiments are rarely available in macroeconomics. The policy change came with its own challenges particularly on the adjustment of prices. The move was not well communicated and there was no agreement on the reference currency. The Short-Term Emergency Recovery

Program (STERP) of 2009 had initially suggested to use the South African Rand as the reference currency but the U.S. dollar gained prominence and traders started quoting prices in U.S. dollars. However, for a country like Zimbabwe, adopting a 'strong' currency such as the U.S. dollar arrested price increases, but came with challenges particularly on pricing and price adjustment as there was shortage of currency denominations. This thesis is the first study to investigate the mechanisms of price adjustments, as well as how the denomination of a strong currency matters when a country adopts a 'strong' currency which is less fine in terms of denominations.

Against this background, I consolidate three related studies on market integration, pricing, and price setting behaviour of firms, with an emphasis on disaggregated consumer price data and the implementation of credible econometric methodologies, to track the adjustment process as Zimbabwe moved further away from the date on which the new currency system was introduced. In order to allow for a detailed analysis, each of the research aims forms a separate chapter. Similarly, the theoretical underpinnings for each study is discussed separately within each chapter. The following will discuss each research aim and how it adds to the existing body of literature.

1.2.1 Price dispersion and new currency systems

There is strong evidence that adopting a stable currency lowers price dispersion within and between countries. The Eurozone is a good example of an area where several countries opted to introduce a common currency. Since the introduction of the Euro in 1999, empirical literature has tried to measure price dispersion within and between countries in the Eurozone using disaggregated consumer price data (see Engel & Rodgers (2004); Reiff & Rumler (2014); Goldberg & Verboven (2005); Allington *et al.* (2005); Cavallo *et al.* (2014); Dvir & Strasser (2014)). The key findings in this body of literature suggest that moving to a stable currency lowers price dispersion both within and between countries in the same currency union.

Pesantes (2005) investigates retail price dispersion for Ecuador, a developing country which dollarized in 1999 after it was rocked by external shocks and drop in oil prices. The study analyses both within country and between country price dispersion before, during and after dollarisation. Using several econometric techniques, the paper demonstrates that all the cities became more integrated with the capital city, Quito, in terms of price levels after dollarisation. In addition, the study argues that, for within country price dispersion, relative price volatilities took a long time to die out.

Chapter 2 extends this literature on emerging economies, after hyperinflation. The study measures the dispersion to the Law of One Price (LOP) within Zimbabwe and its change, over the period immediately after the introduction of a new currency system. Using a methodological approach, which has now become standard in this literature (and also used in the case of Ecuador), we calculate the mean absolute price deviation between city pairs in Zimbabwe. The study extends the analysis to include cities in South Africa to determine how much of the convergence is driven by prices in Zimbabwe's biggest trading partner. I examine the border effect – the difference in prices between the same products on either side of a political border. The objective is to investigate whether there is substantial evidence to show that the border narrows overtime and if so, what economic factors can possibly explain it. Furthermore, the study assesses the role of trade in price dispersion, with the objective of isolating how much price dispersion is attributed to trade. Time variation, as captured by year fixed-effects, explains much of the observed price dispersion between Zimbabwe and South Africa. This indicates that time varying factors, such as economic growth rates may be important to explain the border effect.

1.2.2 Pricing and price setting behaviour of firms

Several studies have identified 'stylized facts' on pricing and price setting behaviour of firms using disaggregated price data in advanced economies (see Bils & Klenow (2004); Klenow & Kryvstov (2005); Nakamura & Steinsson (2008); Baudry *et al.*, (2007), Klenow & Malin (2010)). Recently, the availability of disaggregated consumer price data across a number of African countries has extended this type of analysis within the region (see Creamer, Farrell & Rankin (2012); Nchake *et al.*, (2014a); Kovanen, (2006)). However, this literature focuses on countries with established currencies and there has been no study which identifies and presents 'stylized facts' for a country which moves to a new currency system after hyperinflation in a developing country context.

Chapter 3 investigates this price setting behaviour, and the change in this behaviour amongst retail firms in Zimbabwe after the introduction of a new currency system. Using the methodology common in literature, we calculate the frequency of price changes, the average size of price changes and the probability of price changes at the retail outlet level. This is particularly relevant since it addresses the 'stylized facts' of price setting behaviour in Zimbabwe, comparing it to similar countries, such as Lesotho and Sierra Leone, where price-based studies have been conducted. Furthermore, the paper also analyses the dynamics of price changes over time. Using four month moving averages, our results agree with international literature that the variance in inflation is correlated with the size of price changes rather than the frequency of price changes. Lastly, Chapter 3 decomposes the frequency of price changes into variation within a given store, variation across stores for a given product and lastly the idiosyncratic shock for a particular product and store. The study illustrates that, across all years, the fraction of variation which is common to all stores selling a particular product accounts for most of the total variation of the frequency of price changes. Store and store by product variation account for almost a similar amount of variation. This means that prices are coordinated across stores compared to across products.

1.2.3 The face value of a currency as a source of price stickiness

When Zimbabwe introduced a new currency system, it chose the U.S. dollar over the Rand as the reference currency and that came with a higher face value on the currency. The smallest denomination was $1, resulting in no 'official' medium of exchange that could be used as change for products not priced in round numbers. Although sources of price stickiness are widely discussed in the literature (Bils & Klenow, 2004), very little of this focuses on the choice of the 'face value' of the medium of exchange as a source. Chapter 4 uses a novel natural experiment – the introduction of bond coins in Zimbabwe, to investigate the importance of the face value of a currency as a source of price stickiness. Understanding the choice of denomination as a source of price stickiness is important in contexts like Zimbabwe where countries choose 'strong' currencies as a medium of exchange. However, as the paper argues, there are also costs in getting the choice of denomination wrong which may be asymmetrically distributed across the population. The study exploits three different econometric techniques to assess the impact of the introduction of bond coins[1] on price flexibility in Zimbabwe.

Using non-experimental designs, the chapter shows that the introduction of bond coins led to a downward shift in prices and prices becoming more flexible. Using initial prices as an intensity of treatment, the paper argues that lower initially priced products increased flexibility after the coins were introduced as compared to higher initially priced products. In addition, there is a discontinuity or sharp rise in the frequency of price changes in March 2015 (the time when bond coins were introduced). It takes approximately a year for lower priced products to catch up with higher priced products in terms of flexibility.

1.3 The data

This research is only possible due to access to a novel dataset and this thesis is the first to use this data for research purposes. This study uses disaggregated consumer price data from

[1] Bond coins are a currency of coins backed by a bond that were introduced by the Reserve Bank of Zimbabwe (RBZ) in December 2014 and in March 2015 respectively with the aim of easing transaction change problems

multiple data sources, all of which complement each other in understanding the mechanisms of price adjustments. Firstly, the main agency for collecting disaggregated consumer price data in Zimbabwe is Zimbabwe National Statistics (Zimstat). Every month, Zimstat sends enumerators to collect price data in each district across the country. Prices for products where there is little variation are collected centrally, for example water and electricity charges. The data is aggregated for each product and a geometric average is calculated for each province, which then forms the monthly retail price. Each individual price record corresponds to a uniquely defined product sold at a particular retail outlet at a given point in time. This allows us to track the price of each individual product item overtime, within the same retail outlet. Each individual price record includes the following information: date (month and year); retail outlet (represented by a unique number, which in terms of confidentiality purposes does not allow us to identify the outlet by its name, but we are able to track it overtime); product (with brand names in some cases); province; unique codes and the price of that item.

Secondly, we complement this dataset with unpublished data obtained directly from the National Incomes and Pricing Commission (NIPC) in Zimbabwe. Raw data is collected by the NIPC on a weekly basis in the Harare Metropolitan Province and comes in excel files. Since there are some missing weeks in the data, data is converted into monthly price data with the middle of the month price as the reference price for that particular month. In the case of a missing price during the middle of the month, the closest price to the range (middle of the month) is used as the reference price for that particular month. Products with less than 100 observations are dropped from the final dataset since they provide little variation and might be potentially problematic during analysis. Lastly, the thesis uses the 2013 Zimstat Consumer Price Index (CPI) weights to reweight the NIPC dataset since it only constitutes only 30 percent of the consumer price basket.

1.4 Summary and thesis outline

Overall, the findings indicate that although the adoption of a new currency system arrested price increases, it came with its own challenges. Chapter 2 shows that while there is evidence of markets within Zimbabwe converging with time, prices still remain dispersed and the border effect between Zimbabwe and South Africa is still large. In Chapter 3, there is some adjustment process with regards to the frequencies with which firms change prices, with coefficient estimates suggesting that there is a trend associated with adjustment to the new currency system. Chapter 4 shows that the introduction of coins in March 2015, 6 years after the new currency system was introduced, increased price flexibility and led to a downward shift in prices. The dissertation argues that denominating currency is important, particularly when a country adopts a currency which is strong in value but less fine in terms of denominations.

The rest of the thesis is structured as follows: Chapter 2 measures the dispersion to the Law of One Price within Zimbabwe and extends the analysis to South Africa, while Chapter 3 identifies 'stylized fact' on price setting behaviour in Zimbabwe. Chapter 4 examines the face value of a currency as a source of price stickiness and Chapter 5 concludes the thesis.

2 CHAPTER 2

Within and Between Country Price Dispersion in Developing Countries. The Role of Borders, Geography and Exchange Rate Volatility

2.1 Introduction

How does the introduction of a new currency system, after a period of high inflation, affect product market integration[2] within a country? Inflation distorts price signals and clouds the information contained in these signals. High inflation in turn may mean that the dispersion of prices of similar products is high across the country. A new currency system can end periods of high inflation and re-establish these price signals.

The introduction of a new currency system in Zimbabwe in January 2009 provides an opportunity to examine the adjustment of prices at the end of hyperinflation in more detail. In this study we demonstrate that a new currency system does have positive effects on the extent to which prices are integrated both within and between countries. Firstly, we measure the dispersion to the LOP within Zimbabwe and its change, over the period immediately after the introduction of a new currency system (January 2009 to August 2014).

We extend the analysis to include South Africa to determine how much of the convergence is driven by prices in Zimbabwe's biggest trading partner. We examine the border effect and how it is related to price dispersion. Our objective is to investigate whether there is substantial evidence that the border effect narrows over time and if so, what economic variables can possibly explain this. To do this we use a panel dataset of traded products used in the computation of the Consumer Price Index (CPI) in Zimbabwe and South Africa.

We present evidence that soon after the introduction of a new currency system (January 2009) price dispersion fell over time, both within Zimbabwe and between Zimbabwe and South Africa. We show that much of the fall in price dispersion is related to the new currency effect. We control for exchange rate volatility on the international market and confirm results from previous findings that international borders matter – the coefficient of exchange rate volatility is positive and statistically significant, implying that higher exchange rate volatility is

[2]Product market integration is the process in which differences of prices of related products in different locations tends to zero after factoring in transportation costs. Knetter & Slaughter (2001) argues that product market integration can be measured by assuming that equilibrium outcomes, in terms of prices and quantities generated in different markets should be consistent with a marked change in the magnitude of barriers separating national markets for goods.

associated with higher price dispersion. We argue that both exchange rate volatility and trade have an important impact on the extent to which product markets are integrated both within and between countries.

2.2 Background and motivation

On 29 January 2009, the Government of Zimbabwe announced a transition to a new currency system dominated by the United States dollar after more than a decade of hyperinflation and economic crisis. The introduction of the new currency system came with additional changes in policies governing inflow of goods[3]. As the then Finance Minister of Zimbabwe, Tendai Biti, stated in the 2009 budget statement:

"*Following the import liberalisation policy, we have started to witness some benefits in improved supply of goods and services. Prices in foreign exchange which were initially far above import parity levels, reflecting shortages and monopolistic behaviour, have now started to stabilise and in some cases gravitating towards import parity levels. This trend reflects improvement in stocks as well as competition.*"

The import liberalisation policy meant increased trade flows and competition for markets between the two countries. Furthermore, increased trade flows and competition led to the re-establishment of information signals particularly on the pricing system which were lost during hyperinflation. The main aim of this chapter is to measure the dispersion to the LOP within Zimbabwe, and between Zimbabwe and South Africa, and to investigate the mechanisms through which the fall in price dispersion might have occurred.

Our motivation is driven by this policy change, and also on earlier work by Engel & Rodgers (1996); Parsley & Wei (2001) and Brenton, Portugal-Perez, & Regolo (2014). For example, in a seminal paper on price dispersion, Engel & Rodgers (1996) show that deviations from the LOP for similar goods increases with distance between city pairs for the United States and Canada, and that there is a substantial 'border effect' – crossing the border between the U.S. and Canada adds as much volatility to prices as adding '2500 miles' between cities in the same country. Other notable studies which examined the deviations from the LOP in developed and developing economies include Parsley & Wei (2001); Crucini & Shintani (2008); Lee (2010); Reiff & Rumler (2014) and Baba (2007). A few studies have attempted to explore the extent to

[3] It is important to note at this stage that the bulk of Zimbabwe's imports come from South Africa.

which markets are integrated in Africa (see Versailles (2012); Balchin *et al.*, (2015); Edwards & Rankin (2012)).

This new evidence from Africa exploits micro price datasets, used in the computation of the Consumer Price Index (CPI) to examine the extent to which product markets have integrated. The results from this existing body of literature are mixed, with strong evidence confirming earlier findings by Engel & Rodgers (1996) of large and persistent deviations from the LOP both between countries and within countries. While research has been carried out on price dispersion in Africa, there is very little empirical investigation into the effects of a new currency system on price dispersion. This paper will examine how price dispersion evolves in the aftermath of introducing a new currency and the end of hyperinflation.

2.3 Theoretical framework on price dispersion

2.3.1 The Law of One Price: Basic Framework

To provide a framework for our analysis, we follow Engel and Rodgers (1996) by using a Cobb-Douglas production function. Product prices sold by retailers in location *j* are considered to be a function of both traded and non-traded inputs:

$$P_{i,j} = \beta_{i,j}\alpha_{i,j}\left(w_{i,j}\right)^{\gamma_i}(q_{i,j})^{1-\gamma_i} \tag{2.1}$$

Where γ_i is the share of non-traded services in the final output. The price of non-traded services is represented by $w_{i,j}$ and the price of traded intermediate input is represented by $q_{i,j}$, and both are determined by competitive markets. Total factor productivity is measured by $\alpha_{i,j}$ and the mark-up over costs $\beta_{i,j}$ is inversely related to the elasticity of demand. The price of the traded intermediate input $q_{i,j}$ may vary across locations if there are costs involved in the transportation of the tradable goods. Locations which are also further apart tend to have different cost structures (Engel & Rogers, 1996).

Therefore, in the absence of arbitrage, buyers faced with a choice to purchase similar products in two different locations will purchase that product from a market which has a lower price subject to transportation costs. With buyers having perfect information, in the long run the prices in two different locations will equalise subject to transaction (including transport) costs. This is termed the Law of One Price (LOP). According to LOP, identical products sold in different locations *i* and *j* should cost the same price in the absence of transaction costs. In a simple specification:

$$P_i = P_j + \tau(x_1, x_2, \ldots\ldots, x_{n)}) + \mu_j \tag{2.2}$$

The above equation implies that price in location *i* should equal price in location *j* in the absence of τ(.) including transaction costs and mark-up in location *j* (μ_j). The above equation also implies that if there is perfect information and the markets are exactly the same, the difference price between location *i* and *j* are transaction costs. However, in the real world with imperfect information, the markets differ and the difference between the two locations will be transaction costs and other location-specific factors.

The measurement of LOP deviations within this framework will be the standard deviation of log price differences in product prices as in Engel and Rodgers (1996) and Parsley and Wei (2001). The insight here is that price dispersion is a linear combination of differences in non-traded and traded input prices, as well as the production share of the non-traded share in the final output. Price dispersion is also influenced by other factors such as market structure and taste and preferences (Knetter & Slaughter, 2001). However, in this paper, we do not examine these factors.

The LOP is built up under perfect information and if the mechanisms work, there can be trade. However, if there is imperfect information, there is uncertainty amongst traders. Trade only occurs above the threshold of uncertainty. Within a country this uncertainty comes from inflation and a lack of information about prices, and between countries uncertainty comes from exchange rate volatility. Taking the above equation, the uncertainty component is within P_j and therefore we have the following:

$$P_j = P^- + \delta \tag{2.3}$$

Where δ is the uncertainty which captures uncertainty. The larger the variance of this uncertainty the more price dispersion we anticipate. Substituting equation 2 into equation 1 gives us the following specification:

$$P_i = (P^- + \delta) + \tau(x_1, x_2, \ldots\ldots, x_{n)}) + \mu_j \tag{2.4}$$

In this specification, we control for τ(.) with distance and then market conditions μ_j with city and product dummies. In our framework, the variance is measured by the time trend in Zimbabwe to proxy for improving price signals. On the international market, this uncertainty comes through exchange rate volatility which distorts price signals and thus discourages trade.

2.4 Empirical literature review

The empirical literature on price dispersion can be divided into three areas – studies which analysed both within and between country dispersion; studies which analysed only within and between country price dispersion in the Eurozone, and within and between country price dispersion in Africa.

2.4.1 Within and Between Country Price Dispersion

Empirical literature for within and between country price dispersion has received widespread attention in recent years. Engel & Rodgers (1996) initiated this empirical work. They examine the nature of deviations from the LOP using CPI data for U.S. and Canadian cities for 14 categories of consumer prices. The study finds that distance between cities explains a substantial amount of variation in the prices of comparable goods in different cities. In addition, they show that the variation is much higher for two cities located in different countries than for cities in the same country.

Parsley & Wei (2001) exploit a panel dataset of prices of 27 traded goods across 96 cities in the US and Japan. They find that crossing the U.S.-Japan border is equivalent to adding as much as 43 trillion miles to cross country volatility of prices. Like Engel & Rodgers (1996), they also find that distance and exchange rate volatility collectively explain a substantial portion of international price dispersion. Crucini *et al.* (2003) analyse study deviations from the LOP using retail prices of 220 individual goods, across 122 cities, located in 79 countries in the Eurozone. They find that there is greater price dispersion internationally than intra-nationally.

Baba (2007) analyses the price difference between Japan and Korea using goods-level consumer price data. They find that the national border has a larger effect on price dispersion in both time series volatility and cross-sectional difference analysis. The study categorises goods by their perishability in order to analyse price dispersion. They find that price dispersion depends on the characteristics of goods since absolute purchasing power parity is applied to a greater extent for durable goods.

For within country price dispersion, there are a number of studies which use panel data sets to measure price dispersion. These studies include Parsley & Wei (1996); Wei & Fan, (2002); Ceglowski (2003); and Blomberg & Engel (2012). This literature examines price dispersion within the borders of a country. Parsley & Wei (1996) use a panel of 51 prices, from 48 cities in the U.S. to provide an upper bound estimate of the rate of convergence to purchasing power parity. The study uses panel unit root analysis to assess speed of convergence of prices. They find that convergence occurs faster for larger price differences. In addition, they conclude that the rates of convergence are slower for cities which are further away from each other.

Wei & Fan, (2002) examine the LOP for China using the same methodology as Parsley & Wei (1996)'s study. They find strong evidence supporting long-run convergence to LOP in China. In their comparison with developed markets, they also find that both pattern and speed of convergence are highly comparable to developed markets. Engel & Rodgers (1999) use disaggregated consumer prices data to determine why there is variability in prices of similar goods across US cities. They, however, use price indexes in their analysis, and find that distance between cities constitutes a significant proportion of variation in prices between a pair of cities. In addition, they find that price stickiness also plays an important role in price dispersion. Like Engel & Rodgers (1999), Cecchetti, Mark, & Sonora (2002) use price indices to examine price convergence for major U.S. cities and find that relative price levels among cities revert at a very slow rate.

2.4.2 Within and between country price dispersion in the Eurozone

The Eurozone is a good example of an area where several countries opted to introduce a common currency. Since the introduction of the Euro in 1999, several studies have attempted to measure the degree of price dispersion within and between countries in the Eurozone (see Engel & Rodgers (2004); Reiff & Rumler (2014); Goldberg & Verboven (2005); Allington *et al.* (2005); Cavallo *et al.* (2014); Dvir & Strasser (2014)). The general consensus in these studies is that price dispersion is lower for countries in a currency union than those outside of a currency union.

Engel & Rodgers (2004) used a detailed dataset of prices of consumer goods in European cities from 1990 to 2003 to investigate whether the introduction of the Euro increased integration of consumer markets. Comparing these results to the results from the U.S. and Canada, they find no evidence of prices converging between countries after the introduction of the Euro. On the contrary, they find that there has been significant reduction in price dispersion before the introduction of the Euro (in the 1990s). However, their assessment was still in the early days of the introduction of the Euro.

In a study of the European car market, Goldberg & Verboven (2005) found strong evidence of convergence towards both absolute and relative versions of the LOP between European cities. Similar results were reported by Allington *et al.* (2005), robustly suggesting that the Euro had a significant integrating effect. Reiff & Rumler (2014) concur with these findings, arguing that price dispersion in the Eurozone has declined since the inception of the monetary union. Another important implication drawn from the study by Reiff & Rumler (2014) is that between country price dispersion is larger than within country price dispersion, even after controlling for product heterogeneity. They argue that cities which are close to each other tend to have prices which move closely together.

Overall, there is strong evidence that price dispersion is lower for countries in the Eurozone than for countries outside the Eurozone. The entry of Latvia into the Eurozone in January 2014 provides an opportunity to investigate this further. Cavallo *et al*. (2014) shows that soon after Latvia's entry into the Eurozone, price dispersion immediately dropped with the percentage of prices nearly identical to those in Germany increasing from six percent to 89 percent.

2.4.3 Within and Between Country Price Dispersion in Africa

Empirical literature on price dispersion in Africa remains limited due to lack of disaggregated data at the consumer price level. A few studies have attempted to measure the extent of price dispersion within and between African countries (see Edwards & Rankin (2012); Versailles (2012); Brenton *et al.* (2014); Nchake (2013); Balchin *et al.* (2015); Mudenda (2016). Edwards & Rankin (2012) investigate price dispersion for over 200 products in 13 African cities. They show that price dispersion at the retail level amongst the sample of African cities declined, with much of the decline concentrated on North African cities in the 1990s. These results are similar to those found in Europe and the U.S.

Brenton *et al.* (2014) used monthly consumer prices for 150 towns in 13 cities in Central and Eastern Africa for three food staples: maize, rice and sorghum, and demonstrated that markets are more integrated within than between countries. Similar results are reported by Nchake (2013) for Southern African Customs Union (SACU) countries, indicating that mean price differences between countries (0.43) are larger than within the same country (0.225). Balchin *et al.*, (2015) concur with the findings, showing that price dispersion is higher between Southern Africa Development Community (SADC) countries than within those individual countries.

Furthermore, these studies show that countries which are members of the same regional trade agreements have substantially thinner borders with other members (Brenton *et al.* (2014) and Balchin *et al.* (2015) report similar results for the SACU countries, with Nchake *et al.* (2015) reporting that the border effect in the SACU region declined substantially between 2004 and 2008.

Versailles (2012) studied border effects using consumer price data for four East African Community (EAC) member states. The study shows that the border effect, as measured by the coefficient of the border dummy in the sample countries, is smaller compared to that reported in literature by Engel & Rodgers (1996). The paper also shows that the advent of a customs union in the East African Community in 2005 improved market integration as shown by the reduced border effect between Kenya and Uganda.

Mudenda (2016) investigated the relationship between tariff reforms and internal product market integration in Zambia, a low-income country. The results from this study indicate wide product variation and imperfect transmission of changes in tariffs to domestic prices. Importantly, the study shows that pass through of tariffs to consumer prices in Zambia is strongly related to the tradability of products. Balchin *et al.* (2015) for SADC countries and Versailles (2012) for the EAC have similar findings, arguing that there is high price dispersion between countries for food products. For developed countries, Engel (1999) and Crucini (2003) show that in theory, LOP deviations should be larger for less tradable goods and for goods that use more non-tradable inputs in production.

To conclude, existing studies in Africa on price dispersion have focussed more on stable macroeconomic environments, and some studies are limited to agricultural or a narrow range of products. The only study which included Zimbabwe in the analysis was Edwards & Rankin (2012); however, the analysis was based on volatile price data, prior to the introduction of a new currency system in Zimbabwe. This study intends to fill in this research gap, by using disaggregated data after the introduction of a new currency system to measure price dispersion within and between Zimbabwe and South Africa.

2.5 Methodology and data

2.5.1 Data description

This paper utilises disaggregated retail price data collected at the provincial level in Zimbabwe and South Africa. Raw data is drawn from monthly retail prices used in the computation of the Consumer Price Index for the period February 2009 to August 2014 (a 68 month period). Each individual price record corresponds to a uniquely defined product sold at a particular province, at a given point in time. This allows us to track the price of each individual product item overtime within the same retail outlet. Within each individual price record, there is the following information – date (month and year); retail outlet (represented by a unique number, which means that we are not able to identify a specific outlet by name, (although we are able to track it overtime); product (with, in some cases, brand names); province; unique codes and the price of the item. Table 2.1 presents the products used in this paper.

Table 2.1: Price records by product category

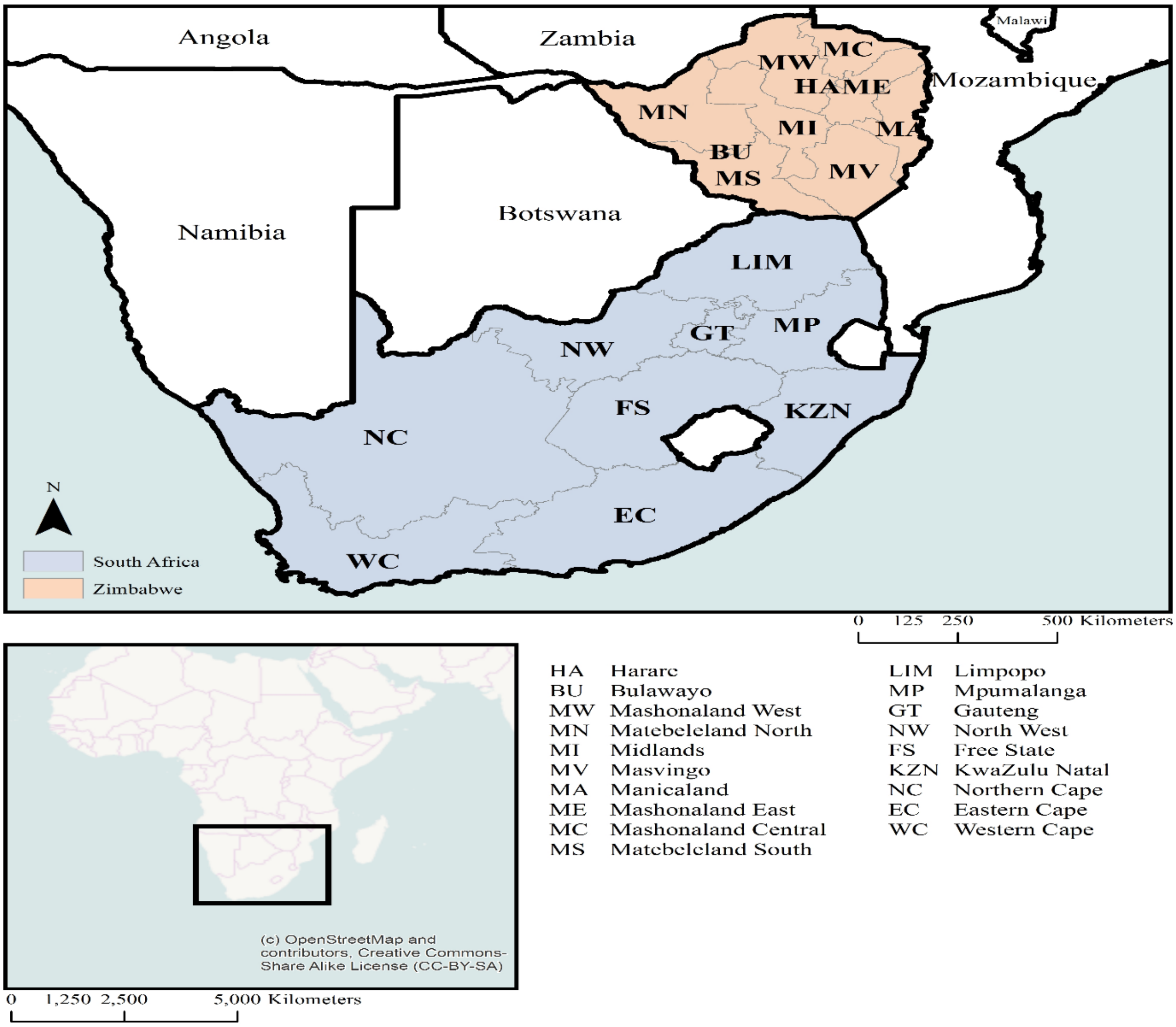
Product Category	Number of price records	Percent	Number of product items	Percent	Number of Price Records	Percent	Number of Product Items	Percent
	Zimbabwe				South Africa			
Food	415 944	38.37	117	23.78	94 155	41.45	209	27.50
Non-Alcoholic Beverages	56 310	5.19	14	2.85	14 133	6.22	25	3.29
Alcoholic Beverages, Tobacco and Narcotics	53 268	3.86	17	3.46	7 393	3.25	13	1.71
Clothing and Footwear	124 273	8.85	69	14.02	37 631	16.56	74	9.74
Housing, Water, Electricity, Gas & Other Fuels	28 214	2.6	22	4.47	6 232	2.74	17	2.24
Furniture, Equipment & Household Operations	153 243	1.77	63	12.80	26 604	11.71	57	7.50
Medical Care & Health Expenses	45 400	4.19	27	5.49	6 509	2.87	14	1.84
Transport	56 112	5.18	39	7.93	5 662	2.49	19	2.50
Communication	9 845	0.91	16	3.25	699	0.31	1	0.13
Recreation & Entertainment	19 908	1.84	57	11.59	17 477	7.69	39	5.13
Other Goods & Services	121 537	1.55	51	10.37	10 681	4.70	292	38.42
Total	1 084 054	100	492	100	227 176	100	760	100

Table 2.1 (above) shows a breakdown of price records by product category. There are 1,084,054 price records for the 68 month period, with 492 product items. Product items are disaggregated into food (117 products); Clothing (56); Recreation and Entertainment (57); Household Operations (51) and other products. Food products constitute the greater number of price records, making up close to 50 percent of price records, although constituting only 23.78 percent of total products.

For South Africa, there are 227,176 price records with 760 product items. As with the Zimstat dataset, food products (41.45 percent) constitute close to 50 percent of all price records. Communication (0.31 percent) contains the least number of price records.

Since we do not have the specific location of the retailer, the geometric mean of price records, across retailers, is used to aggregate to the provincial levels. The geometric mean for each provincial capital is then used to calculate price dispersion across city pairs. The geographical map of provinces in Zimbabwe and South Africa is shown in Figure 2.1.

Figure 2.1: Geographical map of provinces in Zimbabwe and South Africa



Our main aim in the study is to measure price dispersion in retail product prices within Zimbabwe and between Zimbabwe and South Africa. To do this, we match products which are uniquely defined in order to compare similar products across these two markets. The final dataset, constructed by matching similar products, consists of monthly product prices for 88 narrowly defined products spanning the period February 2009 to August 2014. Table 2.2 presents the matched products.

Table 2.2: List of matched goods

Rice	Cereals	Cheese	Spinach
White Bread	Beef	Ice Cream	Cabbage
Brown Bread	Pork	Sour Milk	Tomatoes
Biscuits	Chicken	Eggs	Pumpkins
Spaghetti	Boerewors	Margarine	Cucumber
Macaroni	Pork Sausage	Peanut Butter	Onions
Cake	Bacon	Bananas	Carrots
Flour	Fresh Milk	Dried Fruits	Backed Beans
Chutney	Condensed Milk	Peanuts	Tinned Peas
Mealie Meal	Yoghurt	Lettuce	Potato Crisps
Men's Casual Trousers	Teapot	Instant Coffee	Toilet Paper
Boy’s Shorts	Washing Powder	Fizzy Drink Can	Sanitary Pads
Boy’s Shirts	Pain Killers	Fizzy Drink Bottle	Skin Lotion
Men's Sports Shoes	Cough Syrup	Brandy	Toothpaste
Paint	Diesel	Whisky	White Sugar
Bedroom Suite	Colour TV	Red Wine	Brown Sugar
Floor Tiles	DVD Player	White Wine	Chocolate Bar
Refrigerator	Blank CD	Cigarettes	Sweets
Vinegar	Salt	Pencil	Freezer
Chutney	Baking Powder	Men's Underwear	Tennis Balls
Tomato Sauce	Microwave	Chutney	Men's Jeans

The final sample covers a diverse range of products including perishables, semi-perishables, durable and non-durable goods. All 88 matched products are tradable, and most of these products may have been imported from South Africa. In addition, products which are not directly imported share similar characteristics which makes it easier to measure the extent of product market integration between the two countries. However, it is worth noting that some of the products are not perfectly homogeneous because of their variable branding and quality.

2.6 Empirical model specification

We calculate price dispersion as the mean absolute price deviation between city pairs. Although Engel & Rogers (1996) use the standard deviation of log price differences, we use the mean absolute deviation between city pairs in our analysis as it has been used widely in related empirical literature which makes comparisons easier; see Balchin *et al* (2015); Edwards & Rankin (2012a). Price dispersion is calculated for each city pair implying that LOP deviations between cities are calculated relative to each city pair. Price dispersion is calculated as:

$$Q_{ij,t} = \ln\left(\frac{P_{i,t}}{P_{j,t}}\right) \quad (2.5)$$

Where $Q_{ij,t}$is the price dispersion – the relative ratio of prices, $P_{i,t}$, is the price in city *i* at time *t* and $P_{j,t}$ is the price in city *j* at time *t*. The mean absolute price deviation (price dispersion) is defined as the mean absolute deviation of log prices between provinces overtime shown as $|\ln(\frac{P_{i,t}}{P_{j,t}})|$.

To evaluate price dispersion, we first create city and time dummies. City dummies give average price dispersion over the time period. Since our data comes monthly, the interaction between city and time dummies gives price dispersion for each time period. City dummies control for local market conditions (including seasonality) represented by μ_i in the theoretical framework. We control for these market conditions in our empirical specification. To capture the uncertainty of price signals within Zimbabwe, we create a within-country dummy ('Zimbabwe dummy') which takes the value of 'one' if city pairs are in Zimbabwe, and 'zero' if city pairs are between Zimbabwe and South Africa, or in South Africa. In addition, we create the between-country dummy ('Zimbabwe-South Africa dummy') which takes the value of 'one' if city pairs are Zimbabwe and South Africa, and 'zero' if city pairs are in Zimbabwe or South Africa only. Our empirical specification is as follows:

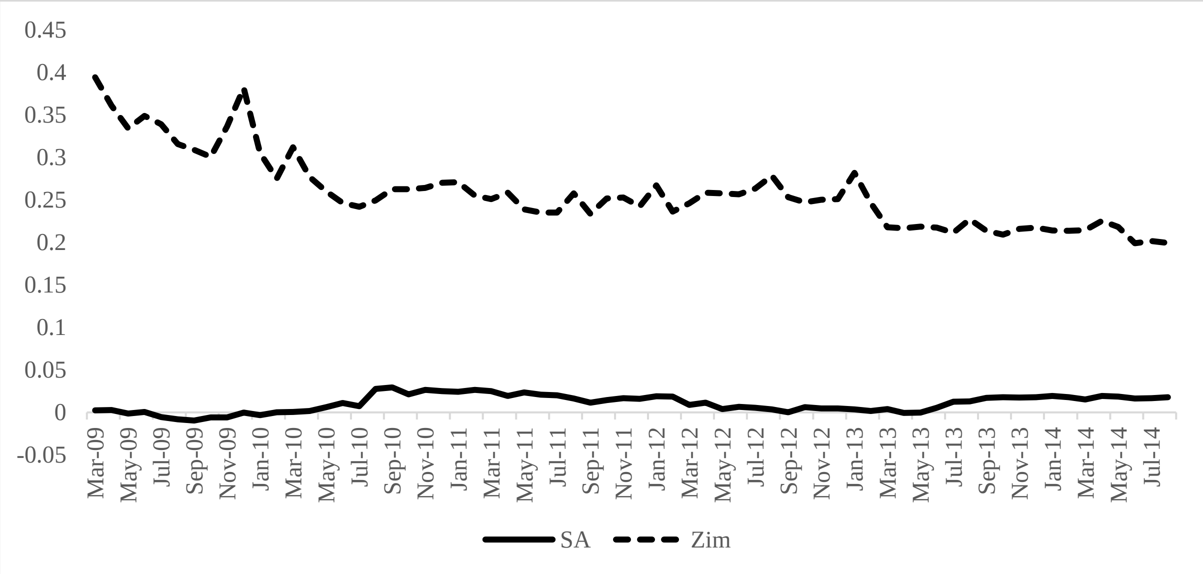
$$Q_{ij,t} = \delta + \beta_1 d_{i,j} + \beta_2 b_{i,j} e_{i,j} + \beta_3 w_{i,j} \gamma_t + \gamma_t + \mu_{i,j} + \varepsilon_{ij,t} \quad (2.6)$$

Where $d_{i,j}$ is the log of distance between city pairs *i* and *j*. We posit a positive relationship between price dispersion and distance. $b_{i,j}$ is a dummy variable for city pairs *i* and *j* are located in different countries. The dummy takes the value of 'one' if city pairs are located between Zimbabwe and South Africa, and 'zero' when city pairs are located within the country. $e_{i,j}$ is the exchange rate volatility which captures uncertainty between countries as shown in the theoretical framework. The interaction between the dummy variable $b_{i,j}$ and exchange rate volatility gives us the border effect. We expect the coefficient to be positive as we hypothesised that areas which are farther apart tend to have less similar cost structures. In addition, literature in pricing to market (Knetter & Slaughter, 2001) emphasises that market conditions (mark-ups) may be different across locations and vary with exchange rates. We also include $w_{i,j}$, a dummy variable, which takes the value of 'one' if city pairs *i* and *j* are in Zimbabwe, and takes 'zero' if city pairs *i* and *j* are between Zimbabwe-South Africa or in South Africa. γ_t is the time trend, and the interaction between $w_{i,j}$ and γ_t captures the uncertainty in Zimbabwe, that is price signals after hyperinflation. γ_t controls for time fixed effects and $\mu_{i,j}$ captures city and products fixed effects. The regression error term is denoted by $\varepsilon_{ij,t}$.

2.7 Price dispersion for Zimbabwe and South Africa

In this section, we focus on the matched products, all of which are traded goods. As described in our construction of the dataset, the matched products have similar characteristics and allow us to compare within and between country price dispersion. In our matching process, we attempt to limit product variations in individual goods. Price dispersion is calculated for each city pair within and between the two countries. The sample produces 171 city pairs[4]. $P_{i,k,t}$ is the price of commodity k in city i at time t, and $P_{j,k,t}$ is the price of commodity k in city j at time t. Price dispersion is therefore defined as the mean absolute deviation of log prices between city pairs shown as $|\ln(\frac{P_{i,k,t}}{P_{j,k,t}})|$. Figure 2.2 plots price dispersion within each of the two comparisons (within Zimbabwe and within South Africa) from February 2009 to August 2014.

Figure 2.2: Price Dispersion for Zimbabwe and South Africa



We report results for a pooled regression of all the 88 matched products overtime with product fixed effects. Price dispersion for Zimbabwe falls sharply for the first 18 months after the introduction of a new currency system and then remains fairly stable for the remaining period, whilst price dispersion for South Africa is fairly stable throughout the period. Our results also reveal that volatility in prices is slightly higher for cities in Zimbabwe than cities in South Africa. This leads us to our next question – did prices within Zimbabwe converge faster given what was happening to the South African prices, and if so, what were the mechanisms through which the prices adjusted?

[4] 171 city pairs were based on the following calculation $\frac{n(n+1)}{2}$ where n is the total number of cities in the sample, 10 from Zimbabwe and 9 from South Africa.

2.7.1 Within and Between Country Price Dispersion

Figure 2.2 shows that price differences between Zimbabwe and South Africa narrow with time. The evidence in the previous subsection show that price dispersion has a downward trend. This downward trend can come from within the country (improving price signals) or from the international market through exchange rate volatility (we already built this into the theoretical framework). In section 2.8, we investigate these factors explicitly and see how each of them impact our variable of interest: price dispersion.

We begin by replicating the analysis of the border effect by Engel and Rogers (1996) and Parsley and Wei (2001). To achieve this, we create a within-country dummy variable which captures domestic variation in prices, and a between-country dummy variable which captures the border effect. In the empirical specification, $w_{j,k}$ captures within-country variation, which takes the value of 'one' if city pairs are within Zimbabwe, and takes 'zero' if city pairs are between Zimbabwe and South Africa, or in South Africa. We include $b_{j,k}$, which captures between-country variation, a dummy variable for whether city pairs *i* and *j* are located in different countries. The dummy takes the value of 'one' if city pairs are located between Zimbabwe and South Africa, and 'zero' when city pairs are located within the country. We interact both of the dummy variables with the time trend to get the price difference at each point in time, after controlling for product and city dummies. Specifically, we regress the price dispersion $Q_{ij,t}$ on the within Zimbabwe dummy and the border dummy variable.

$$Q_{ij,t} = \delta + \beta_1 w_{i,j} + \beta_2 w_{i,j}\gamma_t + \beta_3 b_{i,j} + \beta_4 b_{i,j}\gamma_t + \beta_5 w_{i,j}\gamma_t^2 + \beta_6 b_{i,j}\gamma_t^2 + \gamma_t + \gamma_t^2 + \mu_{i,j} + \varepsilon_{ij,t} \quad (2.7)$$

Where $w_{i,j}$ is a within-Zimbabwe dummy, $b_{i,j}$ is a between-country dummy and γ_t is the time trend and γ_t^2 is the trend squared. $\mu_{ij,}$ captures the within-city pairs variation and within-product variation. $\beta_1$interacts the Zimbabwe dummy and the trend (Zimbabwe *x* trend); β_2 interacts the border dummy and the trend (Border *x* trend); $\beta_3$interacts the Zimbabwe dummy and the trend squared (Zimbabwe x trend squared); β_4 interacts the border dummy and the trend squared (Border *x* trend squared) . Table 2.3 presents estimates of a pooled regression, results of the interaction between the trend and the square of the trend with the Zimbabwe dummy, as well as the border dummy with heteroscedasticity-consistent standard errors below the estimates.

Table 2.3: Explaining within-country and between-country variation in prices with product fixed effects

VARIABLES	(1)	(2)
Zimbabwe	0.167***	0.198***
	(0.00624)	(0.00662)
Trend	0.00000579***	0.0000241***
	(0.0000012)	(0.00000467)
Zimbabwe *x* Trend	-0.00000667***	-0.000156***
	(0.00000164)	(0.00000665)
Trend Squared		-0.0000000915***
		(0.00000000226)
Trend *x* Border	-0.0000292***	0.000000043***
	(0.00000145)	(0.00000000316)
Border	0.302***	0.326***
	(0.00655)	(0.00681)
Zimbabwe *x* Trend Squared		-0.000100***
		(0.00000576)
Border *x* Trend Squared		0.0000000346***
		(0.00000000276)
Constant	0.178***	0.172***
	(0.00445)	(0.00469)
City Effects	Yes	Yes
Observations	742,474	742,474
R-squared	0.157	0.158
Number of Matched Commodity	88	88
N	742474	742474

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Since the trend is daily, we transform the coefficient by multiplying by 365 days to understand the increase/decrease in prices per year

Column 1 presents results from a linear trend. Both variables (Zimbabwe dummy, trend and the interaction between the Zimbabwe dummy and the trend) in the first specification are statistically significant. The negative coefficient of the interaction between the Zimbabwe dummy and the trend implies that prices in Zimbabwe have been declining over time by 0.24 percent per year[5]. We do the same analysis for the border effect. The negative coefficient of the interaction of trend and border also shows that prices between Zimbabwe and South Africa have been declining by 0.10 percent per year. From our coefficient estimates, prices within Zimbabwe converged faster, relative to South African prices, than prices between Zimbabwe and South Africa. This can be shown by plotting the coefficients of the regression.

In order to get a clear picture of the fall in price dispersion within Zimbabwe and between Zimbabwe and South Africa, we also interact the within-Zimbabwe dummy with a quadratic

[5] Figure 3 plots the fall in price dispersion in Zimbabwe yearly, the fall in the border effect and price dispersion in South Africa

function of the square of trend variable. The results are shown in equation 2 of Table 3. We use the trend and the trend squared variable to examine how prices have been falling overtime in Zimbabwe. We repeat the same analysis for the border effect and plot both the linear and quadratic functions to show how prices have been falling overtime in Zimbabwe. Figure 2.3 presents price dispersion over time.

Figure 2.3: Price dispersion over time

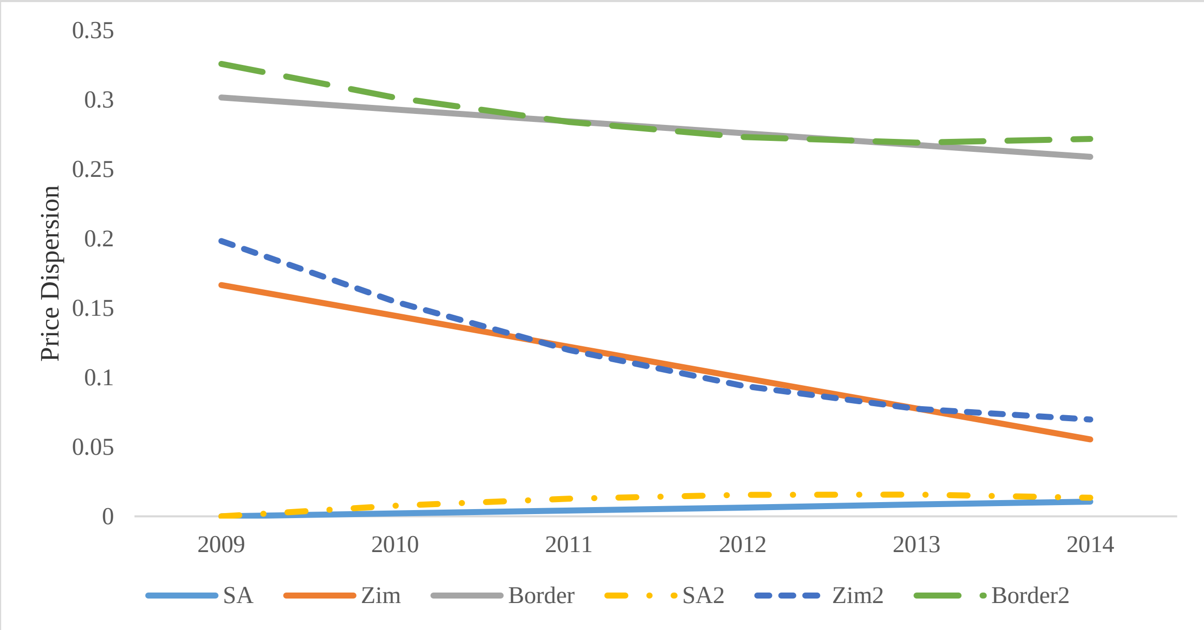


Figure 2.3 presents the results which concur with our findings that price dispersion has been falling over time both within Zimbabwe and between Zimbabwe and South Africa. The dotted lines show the quadratic of the trend. Price dispersion initially falls rapidly immediately after the introduction of a new currency system and then gradually falls at a decreasing rate as the country moves further away from the date on which the new currency system was introduced. Price differences for South Africa have been gradually increasing over time as shown by the yellow dotted line.

Our results are similar to Parsley and Wei (2001). For Japan and the U.S., the study shows a statistically significant trend decline in relative price variability both within and between the two countries. For Zimbabwe, the coefficient of interaction of the trend and the border dummy is negative, and the within-Zimbabwe dummy is steeper (Table 2.3), implying that price became more integrated within Zimbabwe than between Zimbabwe and South Africa[6].

[6] Although circumstances may differ making comparisons potentially misleading, price dispersion, as measured by the mean absolute deviation, averaged 0.34 and 0.28 between 2004 and 2008 for South Africa-Botswana and South Africa-Lesotho respectively Nchake *et al.*, (2017)

2.8 The role of exchange rate volatility

In our theoretical framework, we argue that uncertainty in the domestic market comes from inflation, and uncertainty on the international market comes from exchange rate volatility. This uncertainty causes the domestic prices of goods to deviate from the foreign prices. The larger this uncertainty, the more price dispersion we anticipate. Empirical literature on pricing to market argues that cities that fall across national borders may have huge price differences due to mark up and changes in the exchange rate (Engel & Rogers, 1996). Parsley and Wei (2001) show that exchange rate volatility is positively related to cross-country price dispersion for the U.S. and Canada. This uncertainty, when applied to developing countries, can be huge due to the high volatility of currencies.

In this paper, we assess the impact of exchange rate volatility on both within and between country price dispersion. Exchange rate volatility is defined as the standard deviation of the log of changes in exchange rates. We obtain daily exchange rates from the South African Reserve Bank (SARB) and calculate the standard deviations for each month[7]. We lag the standard deviation of exchange rates over a twelve (12) month period and regress it against the price dispersion. Specifically, we estimate the following specification:

$$Q_{ij,t} = \delta + \beta_1 w_{i,j} + \beta_2 w_{i,j}\gamma_t + \beta_3 b_{i,j} + \beta_4 b_{i,j}\gamma_t + \beta_5 w_{i,j} e_{ij,t-1} + \beta_6 b_{i,j} e_{ij,t-1} + \gamma_t + e_{ij,t-1} + \gamma_t e_{ij,t-1} + \mu_{i,j} + \varepsilon_{ij,t} \quad (2.8)$$

We run four different equations to assess the impact of exchange rate volatility on both within-country and between-country price dispersion. We present results with the standard deviation of exchange rates lagged only for one month. Specification 2 tests for the impact of the first lag of exchange rate volatility. Specification 3 interacts the within-country and the between-country dummy with exchange rate volatility. This specification gives us the average impact of exchange rate volatility on within and between-country price dispersion. Specification 4 is interesting because it gives the impact of exchange rate volatility on price dispersion at each point in time. We report heteroscedasticity-consistent standard errors in parentheses.

[7] We choose the Rand/US dollar exchange since South African products are denominated in rand and it's easy to convert them to US dollars.

Table 2.4: Exchange rate volatility and price dispersion

VARIABLES	(1)	(2)	(3)	(4)
Zimbabwe	0.167***	0.167***	0.153***	0.117***
	(0.00624)	(0.00624)	(0.00659)	(0.00734)
Trend	0.00000579***	0.00000695***	0.00000517***	0.00000172
	(0.0000012)	(0.0000012)	(0.00000122)	(0.0000026)
Zimbabwe *X* Trend	-0.0000667***	-0.0000671***	-0.000065***	-0.0000313***
	(0.00000164)	(0.00000165)	(0.00000167)	(0.00000358)
Border *X* Trend	-0.0000292***	-0.0000294***	-0.0000271***	-0.00000239
	(0.00000145)	(0.00000145)	(0.00000148)	(0.00000316)
Border	0.302***	0.302***	0.287***	0.261***
	(0.00655)	(0.00655)	(0.00682)	(0.00735)
Exchange Rate Volatility$_{t-1}$		0.0464***	-0.0251**	-0.0466***
		(0.00485)	(0.00991)	(0.0174)
Zimbabwe *X* Average Exchange Rate Volatility$_{t-1}$			0.0882***	0.342***
			(0.0137)	(0.0259)
Border *X* Average Exchange Rate Volatility$_{t-1}$			0.0970***	0.270***
			(0.0121)	(0.0218)
Exchange Rate Volatility$_{t-1}$ *X* Trend				0.0000242
				(0.0000161)
Zimbabwe *X* Exchange Rate Volatility$_{t-1}$				-0.000247***
				(0.0000267)
Border *X* Exchange Rate Volatility$_{t-1}$				-0.000177***
				(0.0000197)
Constant	0.178***	0.171***	0.182***	0.185***
	(0.00445)	(0.00452)	(0.00473)	(0.00521)
City Effects	Yes	Yes	Yes	Yes
Observations	742,474	742,474	742,474	742,474
R-squared	0.157	0.158	0.158	0.158
Number of Joint Commodity	88	88	88	88
N	742474	742474	742474	742474

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Regression results indicate that higher exchange rate volatility leads to higher price dispersion. Specification 2 controls for exchange rate volatility and the coefficient sign is positive and statistically significant. This is similar to the results from earlier work by Parsley and Wei (2001) for the U.S. and Canada. Specification 3 further strengthens our results with the impact being stronger for between-country price dispersion than within-country. More importantly, the coefficient of the border dummy declines from 0.302 percentage points to 0.287 percentage points if we interact exchange rate volatility with the within and between -country dummy. Specification 4 is more interesting as it gives the impact of exchange rate volatility at each point in time. We find that the impact of exchange rate volatility on within-country price dispersion has fallen with time (for a year, the impact fell by approximately 0.09 percentage points). However, the impact for between-country price dispersion is lower than that of within-Zimbabwe price dispersion. In general, exchange rate volatility has an important impact on price dispersion, although the impact is greater within-Zimbabwe than between Zimbabwe and South Africa[8]. Also note that the coefficient of the border effect reduces when we control for exchange rate volatility.

2.9 Role of trade in price dispersion

The analysis thus far shows that the border effect has been changing and falling over time. In our analysis, we attributed part of the fall to uncertainty (domestic market conditions on the local markets and exchange rate volatility on the international market). We show that exchange rate volatility has a significant, positive effect on price dispersion within and between countries. However, it does not fully account for the border effect. Empirical literature spearheaded by Paul Krugman (1991) suggests that much of the pattern of international trade can be explained by geographical considerations (distance), which brings us to the role of trade in price dispersion.

To investigate the role of trade in price dispersion, we first specifically control for trade in the specific product. Our objective is to isolate how much of the price dispersion can be attributed to trade. Trade data is obtained at the product level, downloaded from the World Integrated Trade System (WITS) of the World Bank. We used the lagged value total imports of Zimbabwe from South Africa for the matched commodities at the product level[9].

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[8] The argument is that, since Zimbabwe is a net importer, with the bulk of the imports from South Africa, an uncertainty on the international market (exchange rate volatility) has a direct effect on prices within Zimbabwe. If the exchange rate is volatile, firms are not sure of what the actual price is, so they increase prices to hedge for that uncertainty. On the contrary, if the exchange rate is stable, firms are certain of the actual price on the international market and there is stability on the local market

[9] Imports are downloaded from the World Integrated Trade System (WITS) website. Since some products have ambiguous definitions, we narrow down our set of products to 32. Consequently, since our price data comes monthly, we take the price of June for each year as our reference price for that particular year.

Table 2.5: Price Dispersion and Trade

VARIABLES	(1)	(2)	(3)
Zimbabwe	0.119***	0.119***	0.128***
	(0.0274)	(0.0275)	(0.0274)
Imports		-0.00000039***	0.000000912***
		(0.000000148)	(0.000000186)
Zimbabwe X Imports			-0.00000079***
			(0.000000187)
Border	0.334***	0.334***	0.355***
	(0.0286)	(0.0287)	(0.0287)
Border X Imports			-0.00000219***
			(0.00000016)
Year 2010	-0.0673***	-0.0654***	-0.0647***
	(0.00552)	(0.00558)	(0.00556)
Year 2011	-0.0499***	-0.0484***	-0.0477***
	(0.00558)	(0.00562)	(0.00560)
Year 2012	-0.0398***	-0.0391***	-0.0385***
	(0.00554)	(0.00560)	(0.00558)
Year 2013	-0.0500***	-0.0492***	-0.0491***
	(0.00540)	(0.00543)	(0.00541)
Year 2014	-0.0648***	-0.0632***	-0.0629***
	(0.00542)	(0.00547)	(0.00545)
Constant	0.178***	0.181***	0.168***
	(0.0203)	(0.0203)	(0.0203)
Observations	27,088	26,949	26,949
R-squared	0.205	0.206	0.212
Number of Matched Commodity	32	32	32
N	27088	26949	26949

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.5 presents the role of trade on price dispersion within and between countries with heteroscedasticity-consistent standard errors reported in parenthesis. The results after controlling for imports are reported in Specification 2. We show that imports are significant and negatively related to price dispersion. This means that the more imports from South Africa into Zimbabwe, the lower the prices are dispersed within and between countries. The coefficient of the border dummy is positive and significant.

Regression results when we interact the within country and border dummy are reported in Specification 3 of Table 2.5. This specification is interesting because it allows us to split the impact of imports on price dispersion. For both within- and between-country price dispersion, the coefficients are significant and negative implying that higher import entails lower price dispersion relative to South African prices. We control for yearly dummies in both specifications and our results are virtually unchanged. There was a huge impact in price dispersion in 2010 but the yearly dummies remain fairly constant throughout the study period. Our only explanation with regards to the pooled regression is that trade explains some of the variation in prices but does not change the yearly dummies by very much. Time variation, as captured by year fixed-effects, explains much of the observed price dispersion between Zimbabwe and South Africa. This indicates that time-varying factors, such as economic growth rates, may be important in explaining the border effect.

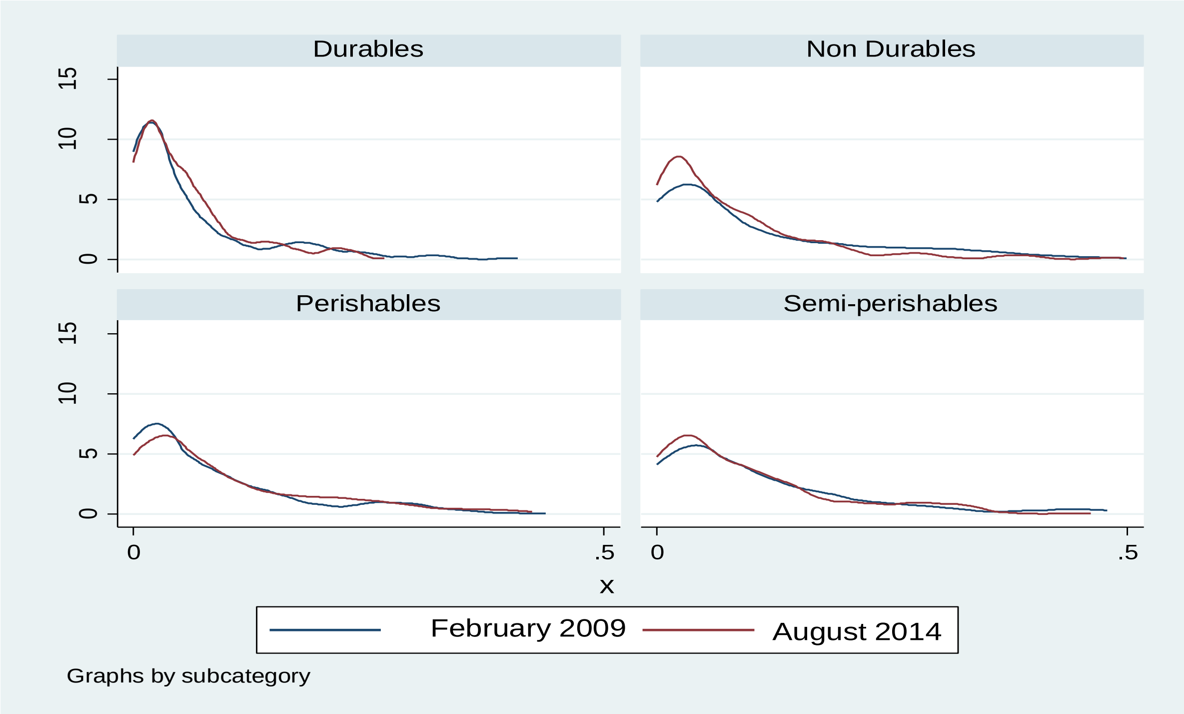
2.10 Comparison of price dispersion across products

The above analysis focused on price dispersion computed as averages for a pooled set of products. Our next step is to do the same analysis at the product level. It is important to note that price dispersion at the product level allows us to unpack important differences across different product categories. Engel (1999) show that deviations from the LOP are larger for less tradable goods and goods that use more non-tradable inputs in the production process. Firstly, we analyse price dispersion across different product categories by classifying them according to different product categories. We follow the same approach used by Baba (2007) to categorise products based on their perishability. Baba (2007) argues that perishability of products stimulate arbitrage because of higher storage and transaction costs. Following this classification, products are classified into four groups – perishables; semi-perishables; non-durable; durable goods[10]. Price dispersion is then calculated at the category level across all city pairs.

Figure 2.4 plots kernel density estimates of price dispersion across different product categories. We show that perishables have a lot of variation in prices as compared to different product categories as shown by flatter tails of the curves. Durable goods, on the contrary have steeper tails showing less price variation.

[10] Baba (2007) classified perishables as those products within 5 days of expiration; semi-perishables as products within 3 months of expiration; non-durables as those food and household products which last more than 3 months; and durables as durable household products. This approach is used to classify products in our data.

Figure 2.4: Price dispersion across different product categories



The concept behind higher price variations for perishable products is that one needs to be sure that they are going to trade at a different location. This uncertainty pushes up prices, together with high transport and storage costs, leading to more price dispersion. In our theoretical framework, the higher this uncertainty, the more the price dispersion. This implies that, the tradability of products also matters for the integration of a country's product markets. Perishable products push the variance of uncertainty up, as in our theoretical framework thereby leading to more price volatility.

Table 2.6 further corroborates our findings that the tradability of products matter. We classify the tradability of products by perishability in this paper, following Baba (2007). The coefficient of the interaction of trend variables with the Zimbabwe dummy and the border effect (which are both linear in this case) are negative and statistically significant for all product categories. The coefficients on the border dummy and the within-Zimbabwe dummy are also statistically significant and positive.

Table 2.6: Border effect across different categories

VARIABLES	(1) Perishables	(2) Semi-perishables	(3) Non-Durables	(4) Durables
Zimbabwe	0.322***	0.0498***	0.137***	0.200***
	(0.0116)	(0.0167)	(0.00984)	(0.0177)
Trend	0.0000261***	0.000000808	0.00000581***	-0.00002***
	(0.00000229)	(0.00000313)	(0.00000189)	(0.00000315)
Zimbabwe *x* Trend	-0.000088***	-0.0000795***	-0.0000534***	-0.00008***
	(0.00000304)	(0.00000434)	(0.00000257)	(0.0000049)
Border	0.373***	0.265***	0.345***	0.235***
	(0.0123)	(0.0175)	(0.0103)	(0.0191)
Border *x* Trend	-0.000044***	-0.00000588	-0.000041***	0.0000323***
	(0.00000272)	(0.00000380)	(0.00000229)	(0.00000398)
City Effects	Yes	Yes	Yes	Yes
Constant	0.0727***	0.252***	0.153***	0.299***
	(0.00856)	(0.0119)	(0.00700)	(0.0118)
Observations	174,258	115,553	301,204	109,834
R-squared	0.188	0.184	0.187	0.122
Number of Joint Commodity	20	14	34	13
N	174258	115553	301204	109834

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.6 shows that price dispersion fell over time within Zimbabwe, than between Zimbabwe and South Africa. The largest coefficient of the interaction of trend and Zimbabwe dummy is on perishable products (0.32 percent) and the smallest is on non-durable products (0.19 percent)[11]. For the border effect, the negative coefficient is high on perishable products (0.15 percent) compared to other product categories (non-durables: 0.14 percent, semi-perishables: 0.02 percent and durables: 0.12 percent). Versailles (2012) and Balchin (2015) supports this argument and reports relatively high levels of price dispersion for perishable products for within and between countries in the East African Community and SADC region respectively. Balchin *et al.* (2015) argue that these products are subject to fast deterioration and high transportation costs making them less tradable.

[11] Note that the coefficients above are in days. To get the yearly percentage fall, we multiply by 365 days.

2.11 Conclusion

This paper examines how the introduction of a new currency system, after a period of high inflation, affects product market integration within a country. We show that price dispersion dropped sharply for the first 18 months after the introduction of a new currency system. Little convergence occurs thereafter, indicating closer product market integration within Zimbabwe. Furthermore, our results suggest that prices in Zimbabwe converged towards South African prices for the period under study.

We assess the impact of exchange rate volatility on both within- and between-country price dispersion. Our results indicate that higher exchange rate volatility leads to higher price dispersion. We argue that exchange rate volatility has an important impact on price dispersion but does not fully explain the border effect, having a greater impact within Zimbabwe prices than across borders.

We extend our analysis by assessing the role of trade in price dispersion with the objective of isolating how much of price dispersion is attributed to trade. We show that trade (proxied by the lagged value of imports) has a significant and negative effect on price dispersion. The higher the imports, the lower the prices are dispersed within and between countries. When we control for yearly dummies in both our specifications, we find that there is a huge bump in the beginning of the study period but it then remains fairly constant, indicating that there is something hidden in yearly dummies that explains price dispersion.

We next examine price dispersion for different product categories. We find strong evidence that the tradability of products matter. Retail prices differ most for perishable and non-durable products due to the uncertainty which comes with selling these products. Overall, we find strong evidence that introducing a new, stable currency (the currency effect) improves price signals and leads to product market integration within and between countries.

3 CHAPTER 3

What price-level data tells us about consumer price rigidity in Zimbabwe: Evidence from new data

3.1 Introduction

Sometimes countries adopt new currencies which are not their own as a medium of exchange[12]. The reasons for this vary, but many countries pick established currencies as a response to a macroeconomic crisis. Zimbabwe is an example of this. In January 2009 it adopted a new currency after experiencing a decade of hyperinflation and economic crisis. The change in currency may have positive effects on inflation – for example Zimbabwean inflation dropped to -3.4 percent by March 2009, from approximately 231 million percent in July 2008, but there are often other challenges that come with it, such as a loss of monetary policy control. A less obvious challenge has to do with the stickiness of prices. In most cases the adopted currency is 'strong' in value but less fine in terms of denominations (the face value of the currency). Kramarenko, Engstrom, & Verdie (2010) argued that Zimbabwe's new multicurrency system came with a number of challenges for prices as the shortage of change posed difficulties for retailers. In addition to this, the 'coarseness' of the new currency denominations means that prices are likely to be more sticky as retailers have limited scope to change prices as a response to smallish economic shocks, especially for lower priced products. This matters because it introduces another source of rigidity into the economy, and can have distributional effects if it impacts certain groups of consumers more than others (for example lower income groups who may disproportionally buy goods with low face-values). This type of challenge has, to date, been overlooked in the literature.

One way to investigate this price stickiness and its implications to the economy is to examine the pricing, and price-setting behaviour of firms, using the product-level data used in the computation of the country's consumer price index. The study of pricing and price-setting behaviour of firms at a disaggregated level is an important part of economic theory and is the starting point of micro-founded macro models. Baudry *et al.* (2007) argue that the response of output, inflation and employment to an economic shock is highly dependent on the flexibility of prices. A number of theories on price stickiness have been developed (see Taylor, (1980) and Calvo, (1983)), but their assessment on flexibility of prices has been limited due to a lack

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[12] The most prominent example is when more than 12 European countries adopted the Euro, by creating a single market and eliminating all differences in the units of account

of information, particularly disaggregated data at the consumer price level. Historically, most micro-studies which used disaggregated data concentrated on specific products or markets (see Cecchetti *et al*. (2002) on magazine prices, Lach & Tsiddon, (1992) on food product prices).

Recently, there has been a renewed interest in the study of pricing and price-setting behaviour of firms at a disaggregated level, largely driven by the increasing availability of rich, micro price data sets Klenow & Malin (2010). The body of evidence based on this type of data has grown over the past decade and has allowed researchers to re-evaluate theoretical pricing models and to assess the role of price stickiness in generating persistent responses of output to monetary shocks Elberg (2014). Studies of micro price data sets used to compute the Consumer Price Index (CPI) have been used in a number of countries to study price dynamics at a micro level, including the U.S.; Bils & Klenow (2004); Klenow & Malin (2010); Spain (Álvarez & Hernando, 2006); Italy (Fabiani *et al*. 2006); France (Baudry *et al.*, 2007); South Africa (Creamer *et al.*, 2012); Sierra Leone (Kovanen, 2006); and Lesotho (Mamello Amelia Nchake et al., 2014a).

The common finding in these studies is that large heterogeneity in the pricing and price setting behaviour exists, which is often contradictory to the macro-economic theory of price setting. Very little of this type of work has been done for low income countries with segmented markets particularly in Africa[13]. To our knowledge, our study is the first to investigate the pricing and price-setting behaviour for low income countries that adopt a new currency as a medium of exchange in Africa. The primary focus of this study is the unique dataset of monthly product prices obtained from the National Incomes and Prices Commission in Zimbabwe.

In this study, we address ‘stylised facts’ of price setting for Zimbabwe and compare them to South Africa, Lesotho and Sierra Leone. Firstly, we investigate whether prices become more flexible or rigid in Zimbabwe after the introduction of the multi-currency system, and compare it to South Africa, Lesotho, and Sierra Leone. We posit prices to be rigid as compared to Lesotho and Sierra Leone as both are countries classified as low income countries by the World Bank Indicators. Secondly, we investigate the magnitude of price changes and explore how prices adjusted to the multi-currency system over time. We also expect price changes to be bigger on average as compared to Lesotho and Sierra Leone due to the lack of small denominations to use as change and other problems associated with denominations in the Zimbabwean context. In addition, we would expect some adjustment process as we move

[13] Product market price-based studies in Africa have been done only for South Africa (Creamer *et al.*, 2012) and Lesotho (Nchake *et al.*, 2014) and Sierra Leone (Kovanen, 2006).

further away from the date when the multicurrency system was adopted. We show that, prices are sticky at lower denominations, with retailers on average changing their prices after every 3.9 months. Moreover, we also show that more than 75 percent of products do not change prices from the previous period. When prices do change, they are big on average although small price changes are also common.

3.2 Background and context of study

In January 2009 Zimbabwe adopted a multicurrency system dominated by the U.S. dollar after a period of hyperinflation and severe economic crisis. Although official statistics, last released by the Zimbabwe National Statistics Agency (Zimstat), indicated that month-on-month inflation reached 231 million percent by July 2008, the International Monetary Fund estimated the hyperinflation rate to be 489 billion percent as of September 2008 (IMF Country Report, 2009). In an attempt to restore the credibility of the financial system, the government of Zimbabwe introduced a multicurrency system, with prices of domestic products quoted in U.S. dollars, although South African Rand, Botswana Pula, British Pound and the Euro were also accepted as a medium of exchange. However, when transacting, these other parallel currencies were directly converted to U.S. dollars at point of sale machines.

Following this, month-on-month inflation declined sharply, to -3.4 percent by March 2009, and prices of commodities began to stabilise (Hanke & Kwok, 2009). Domestic pricing was mitigated by lower prices, particularly from South Africa (Piffaretti, 2011). Even though the multicurrency system was introduced in January 2009, this process did not happen overnight. Prior to the policy change, most firms had already started transacting in U.S. dollars as far back as 2007. By December 2008 more than 1000 shops were licenced by the government to trade in foreign currency. Other traders who were not licenced began to sell their products in foreign currency illegally, without licences. The situation became untenable for those who trading in Zimbabwe dollars as they constantly needed to go to the parallel market to convert their money into foreign currency. The Zimbabwe dollar began to be rejected by the public as the medium of exchange (Hanke & Kwok, 2009) and this led to de facto dollarisation. The government was left with only one option: to adopt the U.S. dollar as the medium of exchange. In January 2009, the government released a government gazette, giving legal tender to the use of the U.S. dollar as medium of exchange, thereby completing dollarisation.

The introduction of the U.S. dollar as the medium of exchange brought its own challenges, particularly with the currency's denomination as at the time the lowest denomination was one dollar (USD1). This meant that products costing less than USD1, such as sweets, were used as change. This introduced some form of price stickiness, which plays an important role in macro-economic theory.

Internationally little attention has been devoted to the price dynamics at a micro level after a country gives away its seignorage and adopts a foreign currency as a medium of exchange. Although Pesantes (2005) analysed how Ecuador adjusted after it dollarised in 1999 using CPI data, this study differs in that it provides a more detailed analysis of price setting behaviour of firms after the adoption of a new currency. In addition, the dynamics and circumstances leading to the implementation of dollarisation in Ecuador are quite different from the Zimbabwean perspective.

This chapter is structured as follows: Section 3.4 outlines the current literature; Section 3.6 details the methodology and data used; Section 3.8 analyses the pricing stylised facts for Zimbabwe, comparing them to South Africa, Lesotho and Sierra Leone and Section 3.9 provides the conclusion.

3.3 Literature review

3.3.1 Introduction

Theoretical models of pricing and pricing behaviour can be used to explain nominal rigidities and price stickiness. Two types of models are dominant in the literature: time-dependant and state-dependant pricing models. The following section describes these two groups of models, highlighting their notable differences and discusses their relevance in the context of developing countries. In addition, related empirical evidence on price-setting behaviour is analysed.

3.4 Theoretical evidence of price setting

3.4.1 Time-dependant pricing models

Time-dependant pricing models argue that the timing of individual price changes are exogenous to the firm. The firm only determines the size of adjustment. Taylor (1980) and Calvo (1983) are well known proponents of time-dependant pricing models. In these models a firm sets its price every *n*th period (Taylor, 1980) or randomly (Calvo, 1983), with a constant hazard function since price is kept fixed for certain period of time.

In Taylor (1980)'s model, firms set prices of goods knowing exactly how long the price spell will last before they decide to change the price. Prices are kept unchanged for a fixed period of time, and all firms in the industry know when to change their prices. The main weakness of this pricing model is that it ignores the concept of heterogeneity of different firms and cannot be applied to extreme changes in economic conditions. This type of model is more applicable to regulated prices (such as social service delivery, mostly in the education and health sectors) in developing countries.

Like Taylor (1980), Calvo (1983) uses staggered contracts, but in contrast, the model assumes that there is a constant probability that firms can set a new price, however, they do not know how long the price spell will last. Firms' prices have random durations, such that the number of periods the price is fixed may not be predicted precisely. The firm faces a probability distribution over possible price spell durations and, unlike in the Taylor (1980) model where all completed price spells have the same length, there will be at any time a distribution of completed price spell lengths. The major weakness of the Calvo (1983) pricing model is that it cannot respond to extreme changes in economic conditions such as high inflationary environments because of its assumption of constant price changes.

Empirical evidence, such as Golosov & Lucas, (2007) suggests that the assumption of constant price changes in time dependant pricing models is false. Golosov & Lucas, (2007) argue that the assumption of constant repricing cannot fit the fact that repricing is more frequent in high inflationary environments. Time-dependant pricing models assume that the frequency of price changes is exogenously given and that a shock that raises the desired prices does not affect the duration of price spells, but only raises the magnitude of price increases (Calvo, 1983). These models ignore the fact that there is heterogeneity among different firms and that firms react differently to shocks that affect the economy. This means that firms are not allowed to change their price even if the costs of not changing that price exceed the benefits.

3.4.2 State-dependant pricing models

In state-dependant pricing models, the decision to change prices is endogenous and based on changes in the market and are not related to the passage of time. Firms only change their prices when they experience a shock. This means that prices are changed when the benefit of changing a price exceeds the menu cost[14] of changing the price. Firms face different shocks and therefore different costs of changing prices, implying that the hazard function increases. At the start of each period, there is a separate distribution of firms which changed their prices at different periods in the past. If there happens to be a shock in the economy, the benefit of changing prices would be higher for those firms who changed their prices further back in time, as these firms would have accumulated shocks from the last period they changed prices.

The most prominent model of this type is by Dotsey *et al.* (1999), who develop a dynamic stochastic general equilibrium model of state-dependant pricing. In this model, an economy is characterised by monopolistic competition where all firms have the power to set prices, with common technology and common factor markets, implying that marginal costs are the same between firms. The model assumes that the fixed adjustment costs of changing prices are random across firms and drawn from a continuous distribution, such that equilibrium involves some but not all firms opting to adjust. Fixed adjustments costs of individual firms are assumed to be independent over time. Therefore, all firms face stochastic price adjustments costs which are independently and identically distributed across firms and across time. Firms evaluating their prices weigh the expected benefit of adjusting their prices against the price adjustment costs realised in the current period. This implies that in equilibrium, not all firms will change their prices, but the decision to change prices will depend on the benefit of changing the price and the current value of the costs of changing that price.

[14] Menu costs are those costs incurred by firms when they change prices.

Dotsey *et al.* (1999) find that the fraction of firms changing prices responds to monetary shocks - a positive monetary shock induces more firms to change their prices, whilst a negative monetary shock induces fewer firms to change prices. This form of state-dependant pricing means that the endogenous bunching of prices speeds up the price adjustment process and dampens short run effects on real output. In addition, in state-dependant pricing models, the frequency of price changes varies with the average inflation rate and the business cycle.

A more recent model on state-dependent pricing models is by Golosov and Lucas (2003), who develop a model of a monetary economy in which individual firms are subject to idiosyncratic productivity shocks as well as general inflation. In this model, firms only change their prices when they incur a real menu cost. The study finds that the average size of the change in the adjusted, individual prices is much larger than the expected inflation between adjustments. This model is different to the one by Dotsey *et al.* (1999) in that it includes idiosyncratic shocks (shocks that affect productivity) in addition to general inflation. The study finds that idiosyncratic shocks are responsible for most of the price changes. In Dotsey *et al.* (1999), idiosyncratic shocks affect an individual firm's menu cost, only influencing firms that will re-price at a specific time. In contrast, in the Golosov and Lucas (2003) model, idiosyncratic shock affects productivity, affecting all firms who re-price.

In conclusion, state-dependant pricing models predict that economic agents base their behaviour on economic shocks and that the timing of price changes is endogenous. This means the average size of price changes is much larger than the expected inflation between adjustments (Golosov & Lucas, 2007). These types of models suggest that two main factors matter for the degree of nominal rigidities: idiosyncratic shocks and the existence of menu costs.

3.5 Empirical evidence of price setting

Empirical research using micro level price data has grown rapidly in recent years mostly due to the availability of disaggregated consumer price data used in the computation of CPI. For example, Bils and Klenow (2004), and Klenow and Kryvstov (2008) analysed pricing behaviour using disaggregated data for the U.S. Evidence for several European countries is also available such as Álvarez & Hernando (2006), Aucremanne *et al*. (2004), and Baudry *et al.* (2007). Recent studies for developing countries include Kovanen (2006) for Sierra Leone, Creamer *et al.* (2008) for South Africa and Nchake *et al.* (2014) for Lesotho. These studies have provided new insights on the price-setting behaviour of firms with a number of common findings across these studies.

These studies generally find that there is substantial heterogeneity both within and across different product categories. For example, Klenow and Malin (2010), who examined the role of price setting in business cycles using both CPI and Producer Price Index (PPI) data for the U.S., find that the frequency of price changes differs widely across goods, with more cyclical goods exhibiting greater price flexibility. Klenow & Kryvtsov (1997) show that there is heterogeneity between regular and posted prices, while studies by Álvarez & Hernando (2006); Aucremanne *et al.* (2004); Baudry *et al.*.(2007); Creamer *et al.* (2012) and Nchake *et al.* (2014) report that there is significant heterogeneity across different product categories.

In addition, empirical literature finds that price changes are relatively infrequent. For developing countries, prices tend to be more flexible compared to developed countries. Creamer *et al.* (2012) find that individual prices in South Africa change more frequently than once per year. Using CPI micro data, the average price duration for South Africa is 5.0 months. Developed countries tend to have a lower frequency of price changes (Álvarez & Hernando (2006); Aucremanne *et al.* (2004); Baudry *et al.* (2007) and Bils & Klenow (2004), compared to developing countries (Nchake *et al.* (2014); Kovanen, 2006) and Gouvea, 2007).

In addition, most studies which have used micro price datasets find that on average price changes are relatively large, although many small price changes occur. Creamer *et al.* (2012) show that South African micro price data reveal relatively large magnitudes of price changes. This is also the case in other developing countries (Gouvea, 2007, and Nchake *et al.* (2014a), and for developed countries (Klenow & Kryvtsov, (2008), and Nakamura & Steinsson, (2008).

In the U.S. the variance in monthly inflation is explained by fluctuations in the average size of price changes rather than the frequency of price changes in each month. This means that pricing behaviour in the U.S. is consistent with the assumptions of time-dependant pricing models Klenow & Kryvtsov (2008). A similar study for Lesotho by Nchake *et al.* (2014a) finds consistent results.

A number of studies have examined the price-setting behaviour of European firms (Álvarez & Hernando, 2006 for Portugal; Aucremanne *et al.*, 2004 for Belguim; and Baudry *et al.*, 2007 for France). A common finding from these studies is that they find relatively lower frequencies of price changes and longer price duration spells. In addition, there is marked heterogeneity across product categories and prices do not change more often but when they do, they do so by a large amount. Overall, there is also evidence of both time-dependant and state-dependant pricing models across these studies.

Recently, there has been a growing number of similar studies for a number of African countries: (Nchake *et al*. (2014) for Lesotho; Kovanen, (2006) for Sierra Leone, Edwards & Rankin (2012) for African cities, and Creamer *et al.* (2012) for South Africa). These use product level data to investigate the price-setting behaviour of retailers. Nchake (2014) examined the price-setting behaviour of firms in Lesotho using disaggregated data used in the computation of the country's CPI. Furthermore, Creamer *et al.* (2012), and Kovanen (2006) analysed price-setting behaviour in South Africa and Sierra Leone respectively using product level data. Results from both studies show that there is heterogeneity in the price-setting behaviour of firms at a disaggregated level across countries, hence the need to conduct country specific studies. This paper adds to this growing literature on African countries by investigating the short-term effects of the multicurrency system on the dynamics of price at a micro level.

There is relatively little literature which analyses price-setting behaviour for countries who adopt a new currency as a medium of exchange. Pesantes (2005) studied price dynamics before and after dollarisation for Ecuador. The paper examined real exchange rates in relative and absolute terms, as well as the CPI before and after the adoption of the U.S. dollar and finds that micro-prices are stationary as a panel, with half-lives of about twelve months. The paper also found that, after the start of dollarisation, price levels became more integrated for eleven Ecuadorian cities.

The only other study we are aware of which uses micro price data to examine price adjustment and currency change is Cavallo *et al.* (2014). The paper examines Latvia, a country which dropped its pegged exchange rate and joined the Eurozone, and uses high frequency goods level data prices of thousands of differentiated goods sold by Zara, the world's largest clothing retailer. This data is scraped from Zara's online retail website and although it covers many differentiated products they are all clothing and footwear products. The study finds that prices converged rapidly between Latvia and the Eurozone countries following Latvia's entry.

Lastly, literature on price adjustment after high inflationary periods is limited. Angeloni *et al.* (2006) examined the price-setting behaviour and inflation persistence before and after the introduction of the Euro in 1999 for six Eurozone countries. The paper argues that the motivation behind joining the Eurozone for most countries was that of monetary stability, as well as moving away from high inflation and exchange rate instability. The study finds no evidence that a Euro changeover in 1999 brought any change in price setting and inflation persistence. Similar results are found by Hoffman (2006) who examined patterns of price-setting behaviour at the retail level in Germany for the period 1998 to 2003 under low rates of inflation.

This paper adds to the growing literature on micro price data sets for low income countries in Africa, albeit in different economic environments. In particular, there is little evidence for countries that adopt a new currency as a medium of exchange and this paper intends to fill this research gap. In addition the nature of both the data and the shock prior to the change in currency for Zimbabwe is quite different to the studies done in Latvia and Ecuador.

3.6 Methodology and data

3.6.1 Data description

The study uses unique data constructed from primary sources of weekly product prices at the retail outlet level. The data is unpublished and was obtained directly from the National Incomes and Pricing Commission (NIPC) in Zimbabwe. The raw data consists of 291 products with 196,199 price records, spanning across 21 supermarkets in the Harare Metropolitan province for the period January 2012 to February 2015 (Table 3.1). NIPC collects prices for approximately 30 percent of the products in the entire CPI basket. Each individual price record has information on the date; retail outlet; product brand and unit. Some of the supermarkets are part of two big retail chains in Zimbabwe. The set of retailers included in this data is largely representative of the Zimbabwean supermarket sector as a whole as supermarkets are highly concentrated in Harare.

Table 3.1 shows a summary of the disaggregated data by major product groupings. There are 291 products in the dataset, with food products constituting 75 percent of all the products. In terms of price records, food products constitute 65 percent of the total price records. Bread and cereals constitute the greatest proportion (19.59 percent) of all the products in the dataset, despite having only 31,272 price records (compared to 34,125 price records by other appliances, articles and products of personal care), followed by oils and fats with 12.03 percent (14,604 price records). Other appliances, articles and products of personal care are overrepresented in the sample relative to their share of total product items. Oils and fats are underrepresented (14,604 price quotes) relative to the number of product items (35) in the dataset. Bread and cereals has a greater proportion of CPI weights (34.02 percent) followed by meat (17.40 percent) with stationery having the least proportion of CPI weights (1.04 percent).

Table 3.1: Price records by major groups

Product class	Price quotes		Product items		Zimstat CPI Weights	CPI Re-weights
	Number	Percent	Number	Percent	Percent	Percent
Food						
Bread and cereals	31 272	15.94	57	19.59	10.29	34.02
Meat	11 422	5.82	24	8.25	5.26	17.40
Milk, cheese and eggs	14 643	7.46	24	8.25	1.86	6.15
Oil and Fats	14 604	7.44	35	12.03	2.30	7.60
Vegetables	16 299	8.31	27	9.28	1.88	6.21
Sugar, jam, honey, chocolate and confectionery	4 896	2.50	15	5.15	2.48	8.20
Other food products	10 835	5.52	8	2.75	0.39	1.29
Coffee, tea and cocoa	8 335	4.25	7	2.41	0.22	0.73
Mineral waters, soft drinks, fruit and vegetable juices	12 880	6.56	19	6.53	0.72	2.38
Beer	2 038	1.04	1	0.34	0.72	2.37
Non-food products						
Household maintenance	29 310	14.94	34	11.68	2.60	8.60
Stationery	5 540	2.82	6	2.06	0.32	1.04
Other appliances, articles and products for personal care	34 125	17.39	34	11.68	1.21	4.00
Total	**196 199**	**100**	**291**	**100**	**30.24**	**100**

3.6.2 Specific Data Issues and Weighting

Raw data is collected by the NIPC on a weekly basis and comes in Excel files. Since there are some missing weeks in the data, data is converted into monthly price data with the middle of the month[15] price as the reference price for that particular month. In case of a missing price during the middle of the month, the closest price to the range (middle of the month) is used as the reference price for that particular month. Products with less than 100 observations are dropped from the final dataset as they provide little variation and are potentially problematic when calculating monthly frequencies.

To compute the aggregate measure of the frequency and size of price changes, CPI weights from Zimbabwe National Statistics are used. Since the NIPC data does not constitute all the products in the CPI basket, it is necessary to reweight. The procedure to calculate aggregate statistics is to set the weight for each individual observation equal to the weight of the CPI category, and then divide it by the number of observations in that category. For each product line and category, it is necessary to calculate a new CPI weight. The new CPI reweights are then multiplied by each product line and summed up to obtain the aggregate frequency and size of price changes.

[15] In this case, the middle of the month is that price between the 12th and the 18th of each month.

3.7 Methodological framework

3.7.1 Frequency of Price Changes

Generally, there are two ways to analyse the periodicity – the frequency of price changes approach and the duration approach. This paper uses the frequency of price changes approach based on the type of data available for this study. The frequency of price changes is an indirect method of estimating the duration of price spells[16]. Álvarez & Hernando (2006) define the frequency of price changes as the percentage of non-zero price change observations over the total number of observations. An advantage of using the frequency of price changes approach is that it uses all the statistical information available and is less affected by selection bias. In addition, Baudry *et al.* (2007) argues that the frequency of price changes does not require a long time series of data as the measure is less sensitive to specific events. For example, a certain month can be ignored if it is characterised by an exceptional event (according to Baudry *et al.*, 2007, one can ignore a specific month characterised by say, an increase in value added tax). This applies to the NIPC dataset used for this paper, as there are two months where data was not collected at all.

Furthermore, Baudry *et al.* (2007) argues that, assuming homogeneity and stationarity[17] in the data set, the inverse of frequency of price changes converges to the mean duration. The mean duration can be used to estimate the average duration of price spells, that is, it gives the precise monthly interval for which prices change. Under stationarity and homogeneity assumptions, the frequency of price changes gives an indirect estimate of the duration of price spells.

Following Creamer *et al.* (2012), the frequency of price changes is defined as the percentage of all non-zero price changes over the total number of observation. To calculate the frequency of price changes, the paper specifies an indicator variable which takes the following form:

$$I_{ijk,t} = \begin{Bmatrix} 1 \; if \; p_{ijk,t} \neq p_{ijk,t-1} \\ 0 \; if \; p_{ijk,t} = p_{ijk,t-1} \end{Bmatrix} \qquad (3.1)$$

[16] The duration of price spells is calculated as the inverse of the frequency of price changes.

[17] In this instance, we assume that the data generating process is stationary if the sequence of consecutive points follows the same distribution as any other sequence. In addition, we assume that the process is homogeneous if the transition probability between two given prices at any two periods depends on the difference between those two times. I follow work by Baudry *etal* (2007), who assumes that the data generating process of retail price data follows a stochastic process. Therefore, using that assumption, we can indirectly estimate the duration of price spells by calculating the inverse of the frequency of price changes

Where $p_{ik,t}$ is the log price of product *k* in store *i* and time *t*. The indicator variable is then used to calculate the frequency of price changes. More specifically, the frequency of price changes to be estimated will be as follows:

$$Freq_{ijk} = (\frac{1}{T_{ijk}}) \sum_{t=2}^{T_{ijk}} I_{ijk,t} \tag{3.2}$$

Where T_{ijk} is the total monthly observations of the price p_{ijkt}. The study assumes that $I_{ijkt} = 1\ if\ p_{ijkt} \neq p_{ijkt-1}$ and 0 if $p_{ijkt} = p_{ijkt-1}$. After calculating the product specific measure of frequency, the average frequency is then calculated across outlets, with the weighted average frequency finally computed across a sample of products using recalculated weights based on the Zimbabwe National Statistics.

3.7.2 Measurement of the direction of price change

The measure of price increases and decreases is calculated in the following ways:

$$I_{ijk,t}^{+} = \begin{Bmatrix} 1\ if\ p_{ijk,t} > p_{ik,t-1} \\ 0\ otherwise \end{Bmatrix} \tag{3.3}$$

$$I_{ijk,t}^{-} = \begin{Bmatrix} 1\ if\ p_{ijk,t} < p_{ik,t-1} \\ 0\ otherwise \end{Bmatrix} \tag{3.4}$$

This indicator variable is then used to calculate the average frequency of price increases and decreases within and across product categories.

3.7.3 Size of price changes

The size of price changes captures the intensive margin, whereas the frequency of price changes captures the extensive margin. In this paper the size of price changes at the store/product level is calculated as the month-on-month log differences in prices such that $p_{ijkt} \neq p_{ijkt-1}$. For each price line, the average of the absolute values for each are taken for each of the log price differences over the period. The average monthly magnitude of price changes following Creamer *et al.* (2012) is calculated as follows:

$$M = \left| \frac{\sum_{i=1}^{N} (ln\, p_{it} - ln\, p_{it-1})}{N} \right| \tag{3.5}$$

Where $\ln p_{it} - \ln p_{it-1} > 0$ (for the magnitude of price increases) and $\ln p_{it} - \ln p_{it-1} < 0$ (for the magnitude of price decreases). *p* is the magnitude of the price of a specific item, and *N* is the number of observations where price magnitude increase (as price changes of 0 are not included in the calculation of average price change magnitudes).

3.8 Pricing stylised facts and Zimbabwe

This section documents stylised facts of micro-pricing behaviour in Zimbabwe. Secondly the section explores in more detail how the behaviour may be different in a country, or period, where a different currency regime is introduced. We do this by comparing the Zimbabwean results against similar countries (Lesotho and Sierra Leone), and by comparing behaviour within Zimbabwe as the multi-currency regime becomes more familiar.

3.8.1 Data Analysis: Distribution and Clustering of Prices

Table 3.2 shows summary statistics of prices in the NIPC dataset by products.

Table 3.2: Summary Statistics

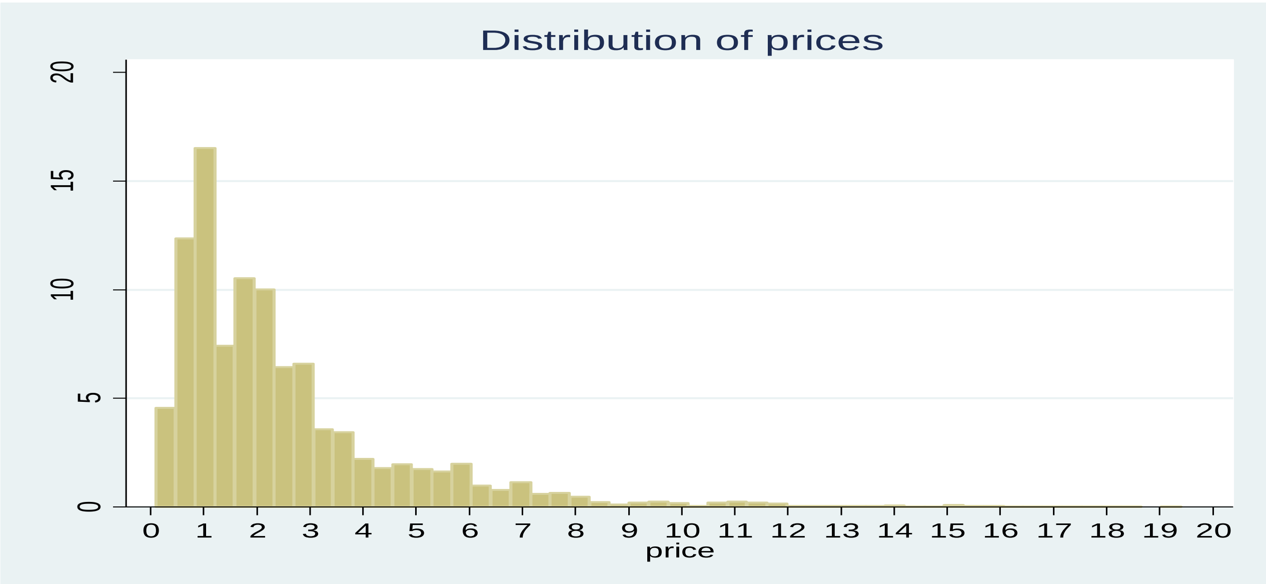
Product	Mean price ($)	Standard deviation	Number of observations	Min	Max	Median
White Bread	0.98	0.06	1212	0.60	1.10	1.00
Flour	2.89	1.24	1791	1.69	6.45	2.25
Super Refined Meal	9.18	3.37	614	5.00	17.15	7.65
Roller Meal	6.62	2.79	1013	2.40	14.00	6.16
Cereals	3.74	1.13	1586	0.95	10.89	3.48
Rice	2.71	2.18	1787	0.85	19.40	2.20
Beef	7.73	2.15	1511	4.30	13.50	6.95
Chicken	6.16	1.82	880	2.17	9.00	6.89
Pork	5.25	0.79	513	3.30	8.50	5.25
Sour Milk	0.75	0.06	660	0.50	0.99	0.75
Fresh Milk	0.82	0.14	585	0.65	1.50	0.79
Sterilised Milk	0.92	0.05	327	0.75	1.00	0.90
Powdered milk	4.16	1.38	1815	1.00	8.80	4.20
Eggs	5.55	0.41	363	4.40	6.90	5.65
Peanut Butter	1.83	0.21	585	1.30	2.69	1.88
Cooking Oil	3.42	0.98	1437	1.40	5.52	3.80
Margarine	3.39	2.71	1687	0.70	11.80	2.65
Cabbage	0.92	0.18	267	0.49	1.45	0.95
Lettuce	0.85	0.15	101	0.50	1.20	0.90
Onions	1.49	0.43	249	0.69	3.60	1.45
Tomatoes	1.30	0.39	269	0.60	2.45	1.26
Baked Beans	1.30	0.39	1119	0.65	2.60	1.20
Peas	2.05	0.68	347	0.79	3.30	2.15
Chips	1.80	0.50	1034	0.20	2.73	1.99
Tomato Sauce	1.88	0.94	633	0.85	5.50	1.40
White Sugar	2.17	0.22	291	1.80	2.70	2.20
Brown Sugar	2.03	0.20	303	1.65	2.40	2.00
Jam	2.32	0.66	642	0.90	4.65	2.10
Salt	0.66	0.23	1624	0.25	1.20	0.52
Soups	0.48	0.08	1143	0.29	0.75	0.49
Tea	2.86	0.96	2142	1.02	5.20	2.60
Mineral Water	0.55	0.23	739	0.30	2.55	0.50
Soft Drinks	0.76	0.29	997	0.40	1.70	0.80
Fruit Squash	2.87	0.33	1548	1.70	3.80	2.90
Beer	1.23	0.42	515	0.65	2.20	1.10
Washing Soaps	1.59	0.24	1062	0.99	2.10	1.59
Washing Powder	2.84	1.56	2353	0.70	9.65	2.30
Detergents	1.68	0.79	1976	0.43	4.25	1.70
Matches	0.57	0.14	431	0.25	1.00	0.55
Candles	1.87	0.25	561	1.00	2.30	1.90
Shoe Polish	1.46	0.56	911	0.70	2.80	1.20
Floor Polish	4.71	2.54	1138	1.30	10.20	3.65
Exercise Books	0.54	0.40	1152	0.10	2.65	0.45
Pen	0.21	0.15	266	0.12	1.98	0.20
Bathing Soap	0.95	0.25	2118	0.46	1.80	0.95

Toilet paper	1.13	0.41	440	0.26	2.20	1.20
Skin cream	2.72	0.88	1494	1.00	5.85	2.50
Petroleum Jelly	1.53	0.66	1974	0.65	3.95	1.37
Toothpaste	1.05	0.28	950	0.45	1.80	1.05
Sanitary pads	1.32	0.44	866	0.70	2.99	1.10

The highest variation is in super refined mealie-meal, with a standard deviation of 3.37, minimum price of $5.00 and a maximum price of $17.15, followed by roller meal and margarine with standard deviation of 2.79 and 2.71 respectively. An explanation for this variation is that these products are sold in different quantities (say mealie-meal ranges from 1kg to 20kg). The lowest variation is in white bread and sour milk with a standard deviation of 0.06.

Prices are clustered around one US dollar, with products priced at one dollar appearing most in the dataset (Figure 3.1). The price distribution is skewed to the right, showing that prices are concentrated on lower denominations.

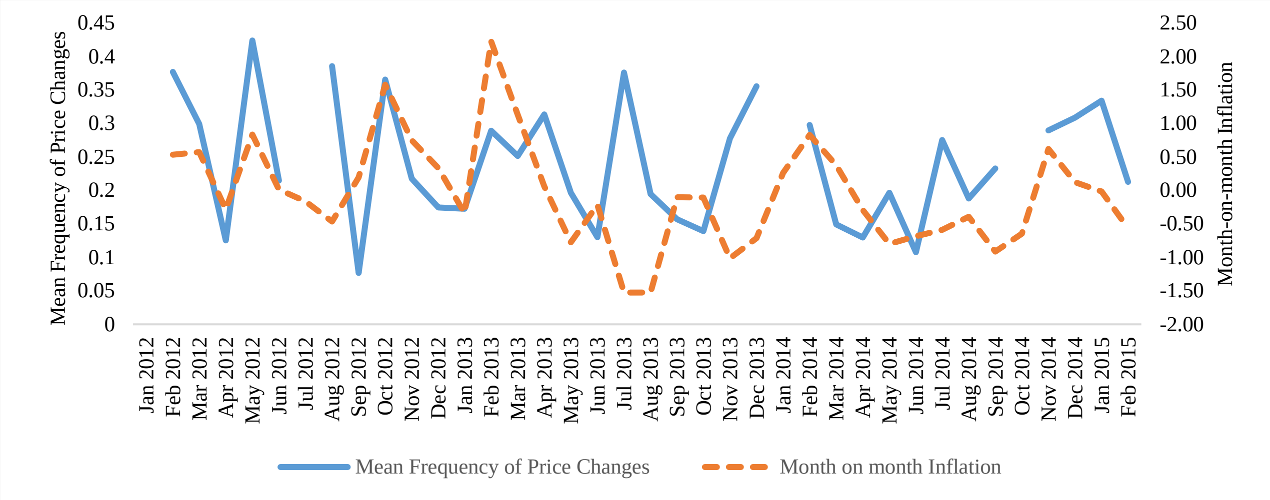
Figure 3.1: Distribution and Clustering of Prices



3.8.2 Frequency of price changes

We use the frequency of price changes to investigate whether prices became more flexible or rigid after the introduction of the multicurrency system in January 2009. The frequency of price changes is an indirect measure of the average duration of price spells. Assuming stationarity and homogeneity of the data, the inverse of the frequency of price changes indirectly estimates the average mean duration of price spells.

Figure 3.2: Frequency of price changes per month and month-on-month inflation



Note: The month-on-month inflation rate was calculated for the products only in the dataset using the magnitude of price changes and CPI reweights.

Figure 3.2 plots the frequency of price changes and the inflation rate. The varying frequency of price changes co-moves with month-on-month inflation. The data shows varying frequency of price changes with the highest change occurring in May 2012 (42.41 percent) and the lowest frequency of 7.7 percent occurring in September 2012.

Over the period from January 2012 to February 2015, the average monthly frequency of price changes is 23.6 percent (unweighted). This means that for each month, an average of 23.6 percent of prices changes across all product categories with an implied duration of 4.24 months (Table 3.3). After reweighting, the average monthly frequency of price changes increases to 25.32 percent with an implied monthly duration of 3.91 months.

Table 3.3: Average frequency of price changes across all products

	Aggregate	Increases	Decreases
Mean Frequency of price changes (Unweighted)	0.24	0.114	0.123
Mean frequency of price changes (Weighted)	0.25	0.128	0.125

Zimbabwe's weighted average frequency of price changes (25.32 percent) is close to that of the U.S. (24.8 percent) but significantly lower Lesotho (37 percent) and Sierra Leone (51 percent). We use the inverse of the frequency of price changes to investigate the duration of price spells to answer our main question. This means that on average, retailers change their prices every 3.91 months compared to Lesotho (2.7months) and Sierra Leone (2.0 months). Of the African countries for which figures exist, South Africa has the lowest frequency of price changes (17 percent)[18]. When compared to developed countries, particularly in the Eurozone, Zimbabwe has a significantly higher frequency of price changes as evidenced by the results for Spain (15 percent), France (18.9 percent), Belgium (17 percent) and Eurozone (15 percent) (Table 3.4)

Table 3.4: Comparison of the frequency of price changes across countries

	Frequency of price changes (%)	Mean Implied Duration
Zimbabwe (2012-2015)	25.3	3.9
Lesotho (2002-2009)	37.1	2.7
South Africa (2002-2007)	17.1	5.8
Sierra Leone (1998-2003)	51	2.0
United States (1998-2003)	24.8	4.0
Spain (1993-2001)	15	6.7
France (1994-2003)	18.9	5.3

Although it seems that the frequency of price changes in Zimbabwe is towards the middle of the distribution of countries, these results need to be interpreted with caution since samples, periods and methodologies do differ across countries.

3.8.3 Heterogeneity in the frequency of price changes

The data shows that there is significant heterogeneity in the frequency of price changes across different product categories, with prices of perishable products, mainly vegetables, changing more frequently than the prices of other products in the dataset (Table 3.5). This is a common finding across countries (Nchake *et al.* (2014b), Creamer *et al.* (2012) and Klenow & Malin 2010).

[18] Note that South Africa is not classified as a low income country, but as an upper middle income country according to the World Bank

Table 3.5: Average frequency of price changes by product categories

Product category	Weighted			Unweighted		
	Frequency of price changes	Frequency of price increases	Frequency of price decreases	Frequency of price changes	Frequency of price increases	Frequency of price decreases
Food						
Bread and cereals	0.227	0.117	0.109	0.256	0.123	0.133
Meat	0.328	0.160	0.168	0.292	0.138	0.154
Milk, cheese and eggs	0.234	0.129	0.105	0.222	0.114	0.108
Oils and fats	0.271	0.131	0.141	0.233	0.114	0.120
Vegetables	0.349	0.159	0.190	0.247	0.115	0.132
Sugar, jam, honey, and confectionery	0.215	0.099	0.116	0.164	0.074	0.090
Other food products	0.161	0.085	0.076	0.188	0.096	0.092
Coffee, tea and cocoa	0.204	0.098	0.105	0.204	0.098	0.105
Mineral waters, soft drinks, fruit juices	0.199	0.087	0.111	0.181	0.081	0.100
Beer	0.289	0.151	0.138	0.289	0.151	0.138
Non Food Products						
Household maintenance	0.247	0.127	0.120	0.276	0.134	0.142
Stationery	0.122	0.044	0.078	0.157	0.068	0.090
Personal care	0.236	0.113	0.123	0.234	0.112	0.122

Vegetables exhibit the highest frequency of prices changes, with 35 percent of vegetable prices changing each month, followed by meat with 33 percent of prices changing each month (Table 3.5). Klenow & Malin (2010) find similar results and argue that prices of perishable products are more unstable and change more frequently due to storage costs. In Zimbabwe, another possible reason is shelf life and discontinuing to avoid spoiling. This causes prices to fluctuate as retailers prefer to pass these costs onto consumers more quickly to avoid selling below marginal cost. In addition, the supply of perishable foods is more likely to be affected by variable weather patterns (Nchake *et al.*, 2014). Stationery recorded the lowest frequency of price changes throughout the whole period, with 12 percent of stationery changing each month. High frequencies for perishable (food) products are also found in Lesotho (Nchake *et al.*, 2014)and South Africa (Creamer *et al.*, 2012).

3.8.4 Frequency of price increases and decreases

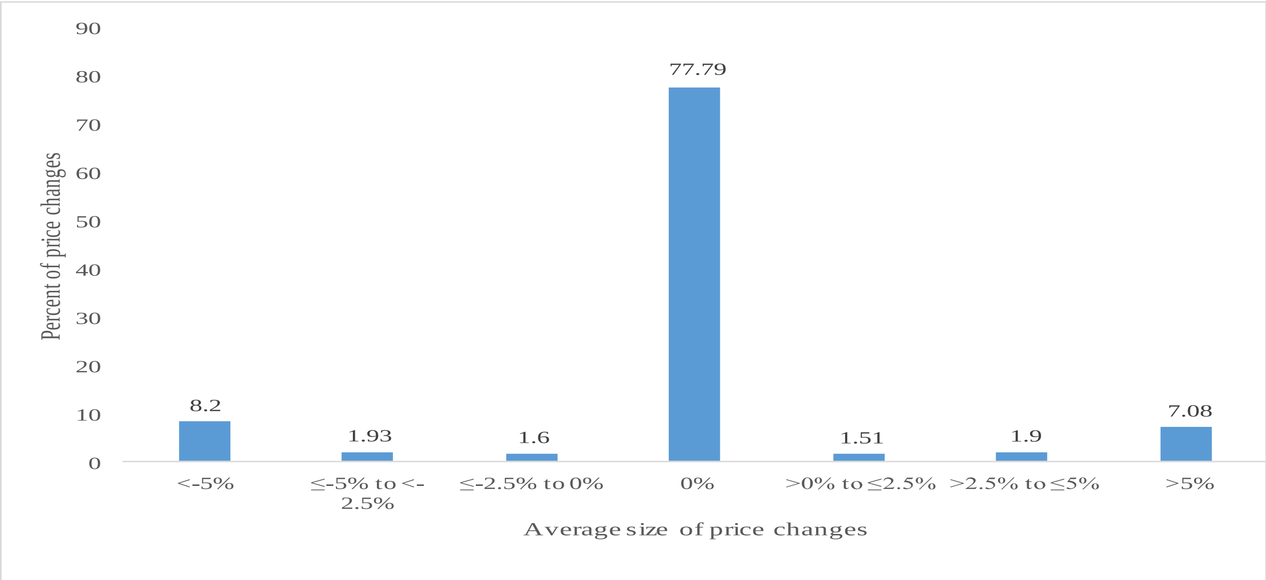
The aggregate frequency of price changes is the summation of the frequency of price increases and the frequency of price decreases. The disaggregation of the frequency of price changes is important, particularly when they display offsetting movements in response to the aggregate shocks in the economy (Nchake *et al.*, 2014). Table 3.5 shows the weighted and unweighted average frequency of price increases and price decreases across major product categories.

There is significant heterogeneity in the frequency of price increases and decreases across product categories. Using CPI reweights, vegetables exhibited the highest frequency of price decreases of 19 percent, followed by meat with a frequency of price decreases of 17 percent. The unweighted data shows that household maintenance had the highest frequency of price increases and decreases. Table 3.5 shows that household maintenance has the second highest total number of price records (29,310) after bread and cereals (31,272). Stationery recorded the lowest frequency of price decreases of 8 percent, reflecting sticky prices. The highest frequency of price increases can be found in beer (15 percent), with other food products recording the lowest frequency of price increases of 8 percent. It can also be seen that products with the highest frequency of price decreases also displayed the highest frequency of price increases (see vegetables and meat).

3.8.5 Size or magnitude of price changes

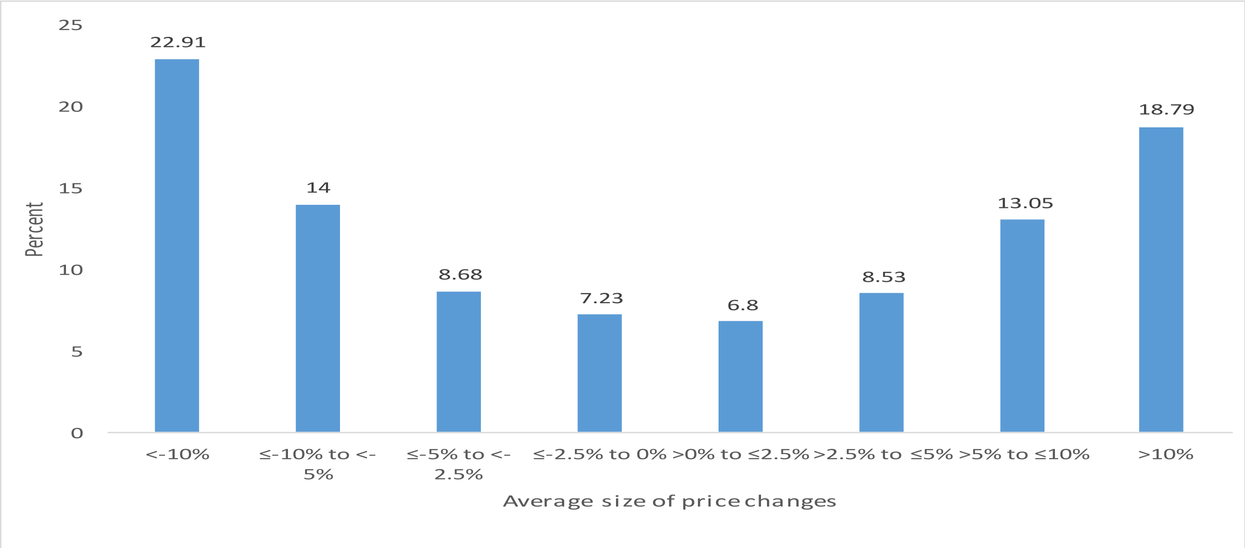
We investigate the magnitude of price changes and explore how prices adjusted over time to the multicurrency system. The size of price changes captures the intensive margin of inflation, while the frequency of price changes captures the extensive margin (how often price changes). The general finding, which is common in literature, is that price changes are infrequent, with more than 50 percent of prices not changing from one period to another. Figure 3.3 shows the distribution of the magnitude of price changes for Zimbabwe.

Figure 3.3: Histogram of magnitude of price changes



77.79 percent of products do not change prices from the previous period (Figure 3.3). Although price changes are rare, when prices do change, they are, on average, big price changes as shown in Figure 3.3. In absolute terms, 15.28 percent of the price changes are bigger than five percent, although smaller price changes also occur. Figure 3.4 shows the distribution of price changes after taking into account only non-zero price changes. Over half (68.75 percent) of all absolute price changes are greater than five percent indicating that when price changes do occur, they are relatively large.

Figure 3.4: Distribution of average size of price changes



Klenow and Kryvtsov (2008) find that absolute price changes for the U.S. are large, averaging ten percent. The existence of large price changes and small price changes might also be rationalised by a wide range of menu costs across items and time as in the Dotsey *et al.* (1999) model of state-dependant pricing behaviour. In the model, the small and large price changes are reflective of small and large menu costs respectively. The large absolute price changes are also reflective of idiosyncratic shocks unique to a particular firm (marginal costs, desired mark-ups) which vary from firm to firm.

There is also substantial heterogeneity in the magnitude of price changes across different product categories. Table 3.6 decomposes the size of price changes by product category, size of price increases, and the size of price decreases. The weighted average size of price increases is 6.85 percent, while the weighted average size of price decreases is -7.25 percent. The largest magnitude of price changes can be found in vegetables, which tend to increase by 20.6 percent and decrease by 19.3 percent. The smallest magnitude of price changes can be found in oils and fats, which tend to increase by five percent and decrease by six percent.

Table 3.6: Average size of price increases and decreases, conditional on a price change, by product category

Product category	Weighted			Unweighted		
	Size of price changes	Size of price increases	Size of price decreases	Size of price changes	Size of price increases	Size of price decreases
Food						
Bread and cereals	-0.005	0.068	-0.071	-0.001	0.076	-0.081
Meat	-0.006	0.102	-0.112	-0.002	0.102	-0.106
Milk, cheese and eggs	0.002	0.083	-0.090	-0.001	0.090	-0.103
Oils and fats	-0.005	0.055	-0.060	-0.001	0.079	-0.080
Vegetables	-0.011	0.206	-0.193	-0.002	0.190	-0.183
Sugar, jam, honey, and confectionery	-0.007	0.069	-0.071	-0.002	0.091	-0.097
Other food products	-0.001	0.119	-0.134	-0.001	0.134	-0.152
Coffee, tea and cocoa	0.005	0.161	-0.141	0.001	0.161	-0.141
Mineral waters, soft drinks, fruit juices	-0.021	0.128	-0.122	-0.003	0.076	-0.091
Beer	0.002	0.149	-0.159	0.000	0.149	-0.159
Non-Food Products						
Household maintenance	-0.009	0.089	-0.108	-0.003	0.115	-0.133
Stationery	-0.032	0.222	-0.163	-0.001	0.284	-0.223
Personal care	-0.010	0.132	-0.139	-0.003	0.130	-0.143

Like for other countries, the magnitude of price decreases is generally lower than the magnitude of increases in Zimbabwe, possibly due to the fact that Zimbabwe was experiencing negative inflation during this period. This is generally argued to show downward nominal price rigidity. Baudry *et al.* (2007) show that, for France, the size of price decreases are more frequent in the economy with 40 percent of observed prices as decreases, suggesting the absence of downward nominal price rigidity. However, although the size of price decreases are more frequent than price increases, prices seem to fall as often as they increase across all product categories. Klenow & Kryvtsov (2008) show that, for the U.S., both large and small price changes are common for both price increases and decreases. Similar results are found for developing countries (see Nchake *et al* (2014); Kovanen (2006)). The weighted size of price changes across all product categories is -0.61 percent, which tallies with the prevailing inflation rates in Zimbabwe.

3.8.6 Effects of time trend on the frequency of price changes

A key question is how the pricing behaviour of Zimbabwean retailers has changed over time as the economy becomes more used to the multicurrency system. To do this, we regress the variable of interest against a time trend and monthly dummies. The estimated specification is:

$$fr_{it} = \alpha_{it} + \beta_1 trend_t + \beta_2 trend_t^2 + \varepsilon_{it} + \sum_{i=1}^{12} \gamma_i month_i \qquad (3.6)$$

Where fr_{it} is the weighted frequency of price changes, $trend_t$ captures the time trend and $month_i$ are monthly dummies from January to December.

Figure 3.5: Frequency of price changes with monthly dummies

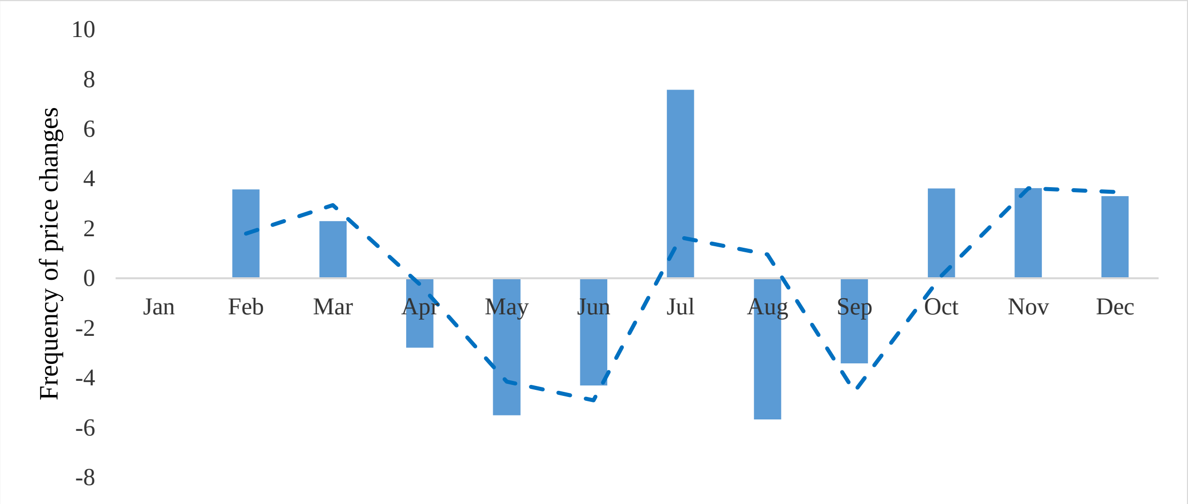
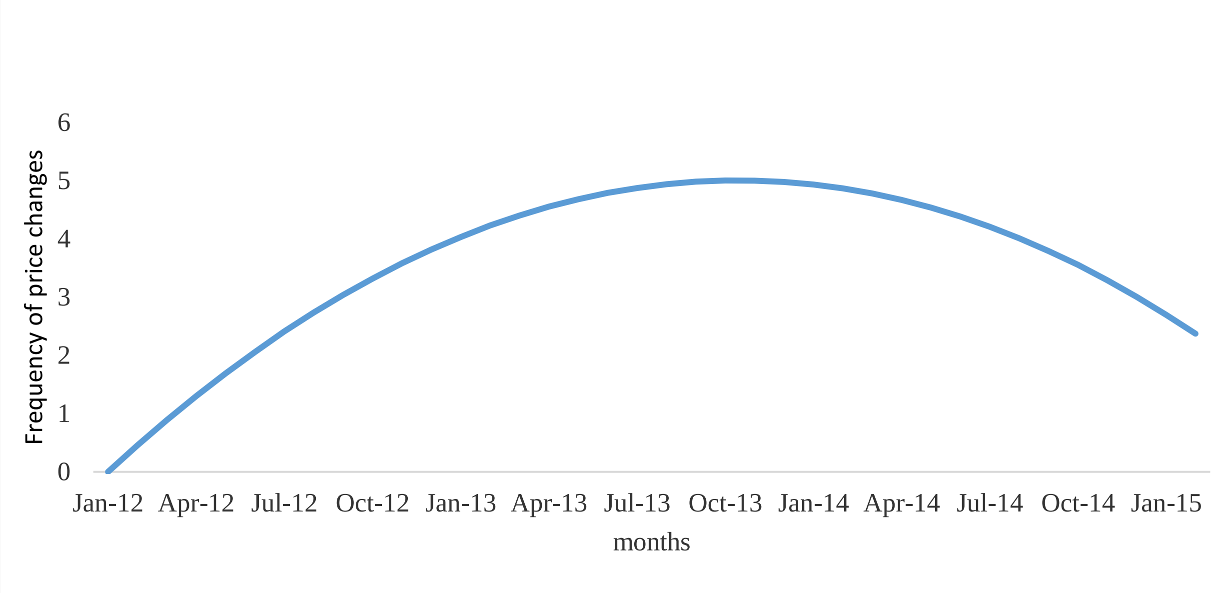


Figure 3.5 plots the frequency of price changes with monthly dummies. The frequency of price changes is high at the beginning of the year, in February, before they start falling down to reach their lowest in May. There is a sharp jump in July, and are also positive (relative to January) towards the end of the year.

Figure 3.6: Frequency of price changes and time



The coefficient estimates on the time trend show that the frequency of price changes increases at a decreasing rate. Figure 3.6 shows the frequency of price changes with time trend. The frequency of price changes peaks in October 2013, 22 months after the start of our sample (January 2012). The change in frequencies with time is relatively small compared to the monthly changes – the difference in the frequency of price changes between the start of the period and the peak, is less than the average monthly difference in July (relative to January). Thus, although the estimates suggest that there is a trend, which might be associated with adjustment to the multi-currency regime, this is relatively small.

3.8.7 The frequency and size of price changes: Time series evidence

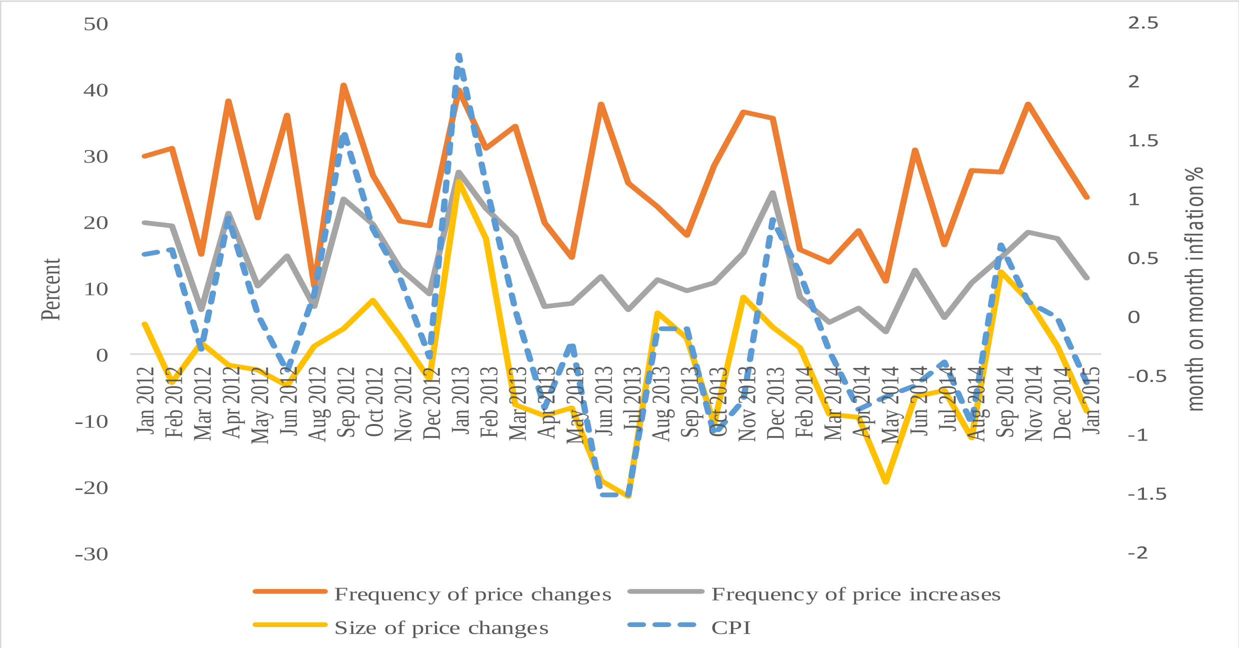
The relationship between the frequency and size of price changes with inflation is of paramount importance particularly in analysing theoretical models in pricing behaviour. If price movements reflect market forces, then knowing the relationship between price changes and inflation may have implications on business cycles and the transmission into monetary policy (Kackmeister, 2005). Klenow & Kryvtsov (2008), Baudry *et al.* (2007), Creamer *et al.* (2012) and Nchake *et al.* (2014) all analyse the relationship between the frequency and size of price changes from a time series perspective.

With staggered contracts in time dependant pricing models, the variation in inflation is explained by the size of price changes, and the frequency of price changes is assumed to be constant overtime. This assumption seems plausible for the U.S. as the average size of price adjustment accounted for 95 percent of the variance of inflation (Klenow & Kryvtsov, 2008). Nchake *et al.* (2014) also find a close association between the size of price changes and inflation for Lesotho, with the frequency of price changes less closely associated with inflation.

However, in contrast, Creamer *et al.* (2012) find a strong relationship between the frequency of price changes and inflation for South Africa.

Figure 3.7 shows how the frequency and size of price changes with month-on-month inflation. Month-on-month inflation, only calculated for the products in the dataset, seems to co-move with both the frequency and size of the price changes. In addition, the frequency of the price increases and decreases also display a strong relationship with CPI month-on-month inflation. Creamer and Rankin (2008) also find a strong relationship between the frequency of price changes and CPI inflation for South Africa. However, Klenow & Malin (2010), find a close association between inflation and the size of price changes, and that the frequency of price changes is weakly correlated with inflation.

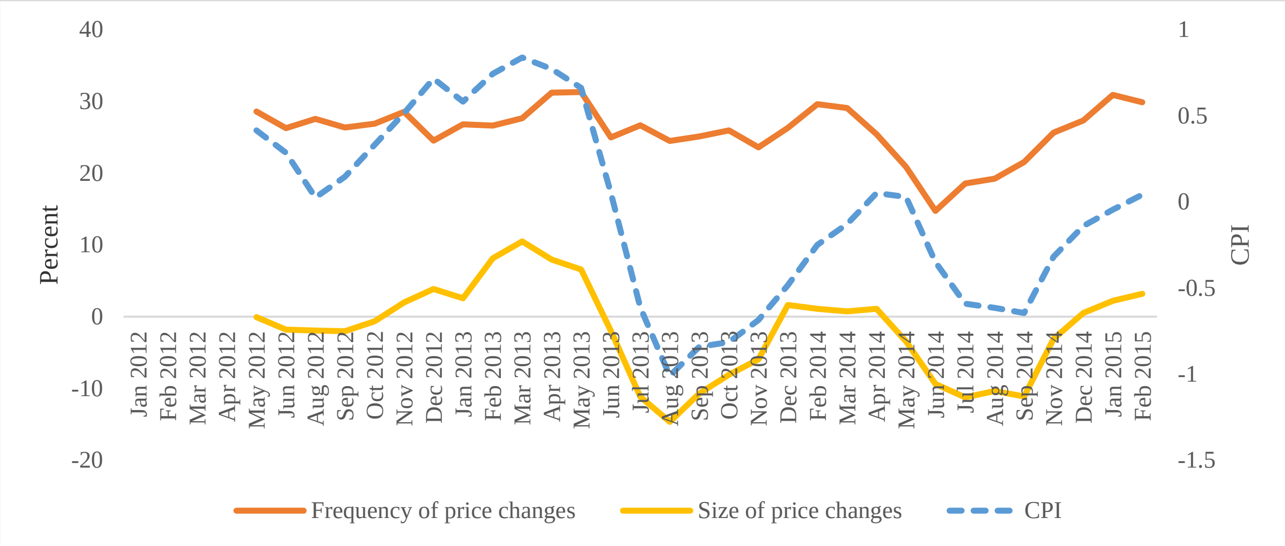
Figure 3.7: Frequency and size of price changes with month-on-month inflation (weighted)



Note: The month-on-month inflation is restricted only to products in the sample

To analyse the relationship more closely, we smooth out the data by calculating four month moving averages. We chose four month moving averages because the duration of price spells is 3.9 months. Nchake *et al.* (2014) used similar moving averages for Lesotho. Figure 3.8 plots the moving averages for the CPI (month-on-month inflation), frequency of price changes, and the size of price changes.

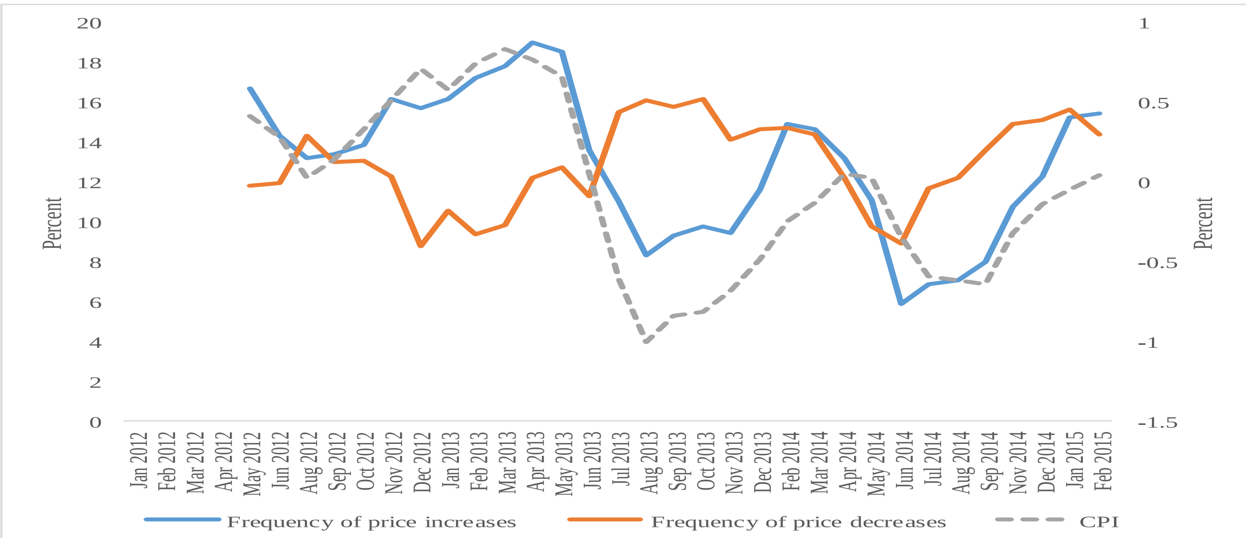
Figure 3.8: Four month moving averages for CPI, frequency and size of price changes



The figure shows that changes in the size of price changes are more volatile and more closely correlated with the inflation rate than the frequency of price changes. These results are similar to Klenow and Kryvtsov (2008) for the U.S., and Nchake *et al.* (2014) for Lesotho, and suggest that the level of inflation are driven by the size of price changes. We investigate this by running regressions in the next section.

The relationship between the frequency of price changes and inflation may be weak because of offsetting movements between the frequency of price increases and decreases (Gagnon, 2009). Figure 3.9 plots the four month moving averages between inflation, frequency of price increases and the frequency of price decreases.

Figure 3.9: Four month moving averages of inflation, frequency of price increases and frequency of price decreases



There is strong co-movement between the frequency of price increases and inflation, but a weaker relationship between the frequency of price decreases and inflation. Due to offsetting movements (prices increasing as much as they are decreasing), the frequency of price changes therefore exhibits a weaker relationship with the inflation rate. This corresponds to what Nchake *et al.* (2014) found for Lesotho.

Regression results suggest that both the frequencies and magnitudes are correlated with CPI but that the magnitude of price changes has a stronger relationship. Both positive and negative frequencies and magnitudes are related to the CPI. The frequency of price increases has a stronger relationship with CPI changes compared to the frequency of price decreases. For magnitudes, the positive and negative changes have similar (but opposite signed) relationships with CPI.

Table 3.7: Time series moments for price changes

Variable	**Mean** %	**Std dev** %	**Corr with cpi**	**Regression on cpi** Coef	Std. Err
Cpi	-0.03	0.79			
fre	25.32	9.93	0.3	0.024**	0.01
dp	-0.66	2.28	0.8	0.276***	0.04
fr^{+}	12.83	6.62	0.71	0.085 ***	0.01
fr^{-}	12.49	5.51	-0.31	-0.04**	0.02
dp^{+}	6.85	1.66	0.38	0.174***	0.01
dp^{-}	-7.25	1.42	-0.3	-0.176***	0.02

*Note: *** significant at 5 percent **significant at 10 percent*

Data covers the period January 2012 to February 2015 obtained from the NIPC. The entries are means, standard deviations and correlations across time, of the monthly values of each variable relative to inflation. The last two columns are OLS regressions and standard errors of each variable individually on inflation, with the monthly variables across time weighted using 2013 CPI weights obtained from Zimstats.

$Cpi = inflation$

$fre = frequency\ of\ price\ changes$

$dp = size\ of\ price\ changes$

$fr^{+} = frequency\ of\ price\ increases$

$fr^{-} = frequency\ of\ price\ decreases$

$dp^{+} = size\ of\ price\ increases$

$dp^{-} = size\ of\ price\ decreases$

Klenow and Kryvtsov (2008) show that the coefficient of variation for the average size of price changes is much higher for the U.S., confirming that the variance in inflation is explained by the size of price changes. Nchake *et al.* (2014), confirms this stylised fact for Lesotho, a developing country like Zimbabwe. This is also confirmed in Figure 3.9, where the size of price changes strongly co-moves with inflation, with the frequency of price changes relatively more stable. However, Creamer *et al.* (2012) find a close association between the frequency of price changes and inflation for South Africa.

The level of inflation can be decomposed into the frequency of price increases and decreases, and size of increases and decreases. Klenow and Kryvtsov (2008) decompose the inflation into frequency and size of price changes in the following way:

$$fr_{ijkt} \triangleq \sum w_{ijkt} I_{ijkt} \triangleq \sum \sum w_{ijkt}\, I_{ijkt}^{+} + \sum \sum w_{ijkt}\, I_{ijkt}^{-} \qquad (3.7)$$

Where I_{ijkt}^{+} is the frequency of price increases indicator that is 1 if $p_{ijkt} > p_{ijkt-1}$ or 0 otherwise. Similarly I_{ijkt}^{-} is the frequency of price decreases that is 1 if $p_{ijkt} < p_{ijkt-1}$ or 0 otherwise. Likewise, the weighted average size of price increases and decreases will be as follows:

$$dp = \frac{fr^{+}}{fr_t} \cdot \frac{\sum_i \sum_t w_{it} I_{it}^{+} (p_{ijkt} - p_{ijkt-1})}{\sum_i \sum_t w_{it} I_{it}^{+}} - \frac{fr^{-}}{fr_t} \cdot \frac{\sum_i \sum_t w_{it} I_{it}^{-} |p_{ijkt} - p_{ijkt-1}|}{\sum_i \sum_t w_{it} I_{it}^{-}} \qquad (3.8)$$

Where the first part of the right-hand side is the size of price increases, and the second part is size of price decreases. Taking both equations, it can be noted that inflation is the sum of terms involving price increases and decreases. To summarise, the specification of inflation will be as follows:

$$\pi_t = fr^{+} . dp^{+} - fr^{-} . dp^{-} \qquad (3.9)$$

Table 3.7 shows that frequency of price increases are common (12.83) compared to the frequency of price decreases (12.49), and that the frequency of price increases is highly correlated with inflation (0.71). The size of price increases and decreases are also modestly correlated with inflation (0.38 and -0.30, respectively). We also run separate regressions of both the frequency of price increases and frequency of price decreases together with the size of price increases and decreases on inflation. A one percentage point increase in inflation is associated with a 0.08(-0.04) percentage point change in the frequency of price increase (decreases). Likewise a one percentage point increase in inflation is associated with 0.17(-0.18) percentage point change in size of price increases (decreases). The coefficients are statistically significant at ten percent, however, with the size of price increases and decreases more closely tied with inflation than with the frequency of price increases and decreases.

3.8.8 The duration of price changes and hazard functions

Micro price data allows for further investigation into the duration of price spells and how the probability of price changes differs over the price spell. A price spell is an episode with a fixed price, whilst the price spell duration is just the time between two price changes. The shape of the hazard function shows the probability of the price changing conditional on the time the price remained unchanged from the last price change. The hazard of a price change is merely defined as the conditional probability that a price will change given the time it has survived since the last price change[19]. If prices are more likely to be changed the longer they have remained unchanged, then it represents an upward sloping hazard function. Constant hazard functions arise if firms have a fixed probability of changing prices (as in Calvo, 1983).

At an aggregated level, the shape of the hazard function across the Zimbabwean sample is downward sloping for the first 20 months, and then eventually rises again (Figure 3.10).

[19] According to Nchake et al. (2014),"a hazard rate $h(\tau)$ is expressed as the probability that a price (p_t) will change after τ periods conditional on it having remained constant in the previous $\tau - 1$ periods, that is $h(\tau) = \Pr\{p_{t+\tau} \neq p_{t+\tau-1} | p_{t+\tau-1} = p_{t+\tau-2} = \ldots = p_t$"

Figure 3.10: Hazard function

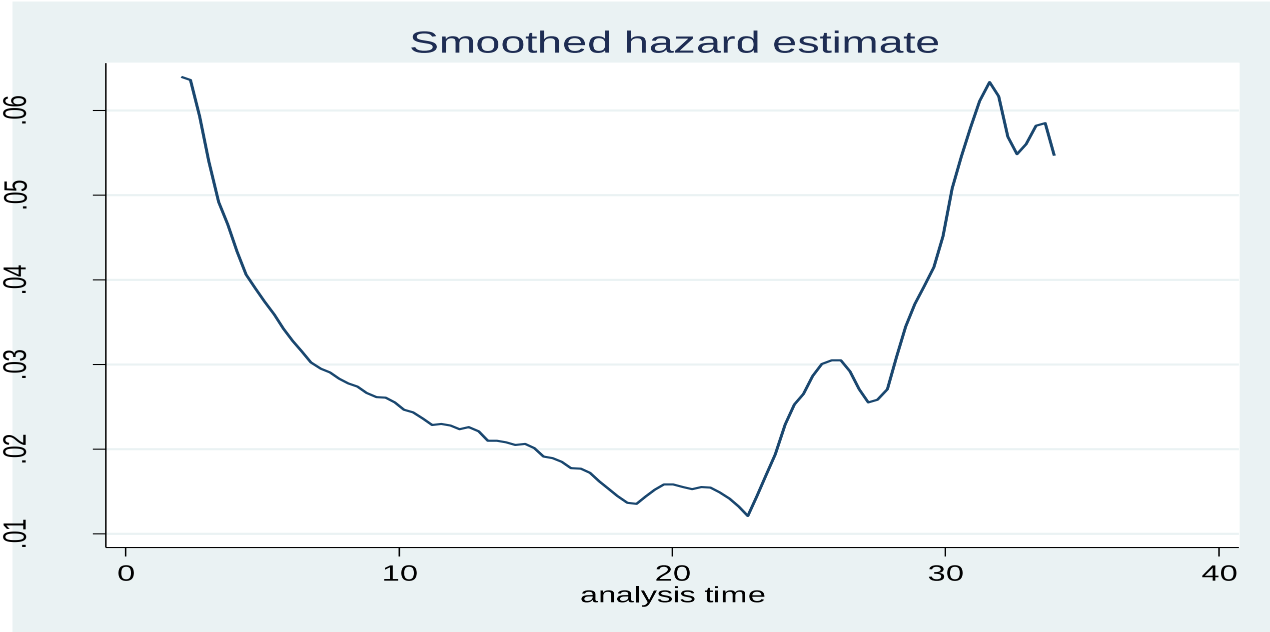
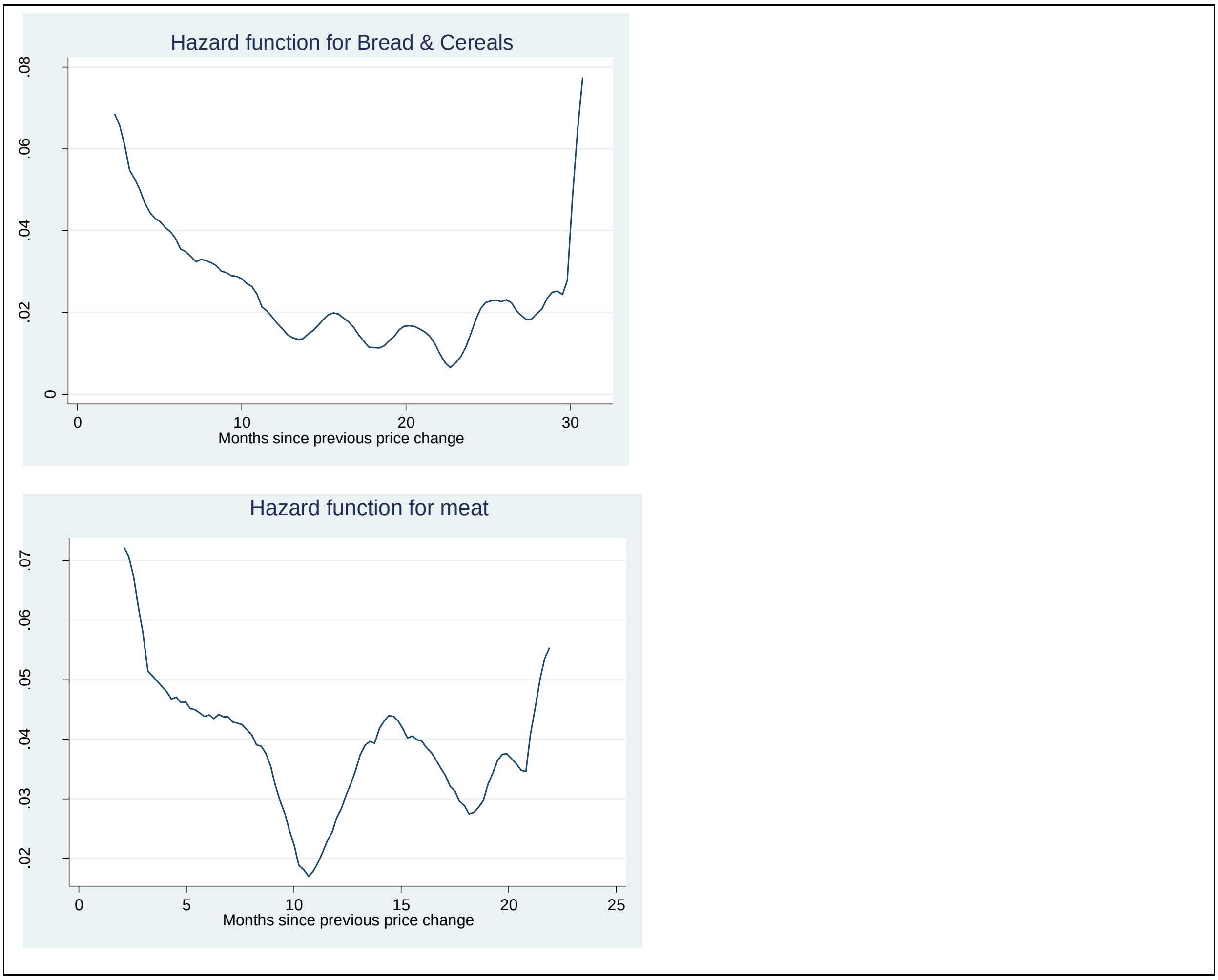
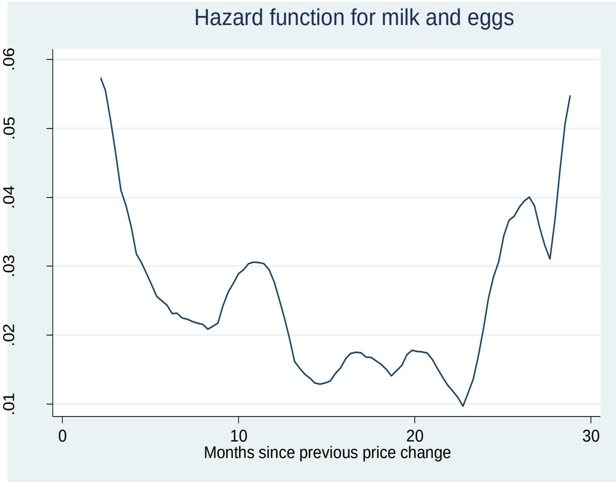
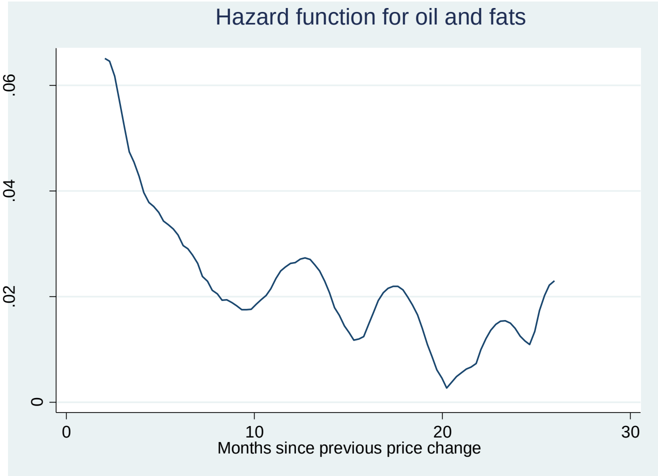
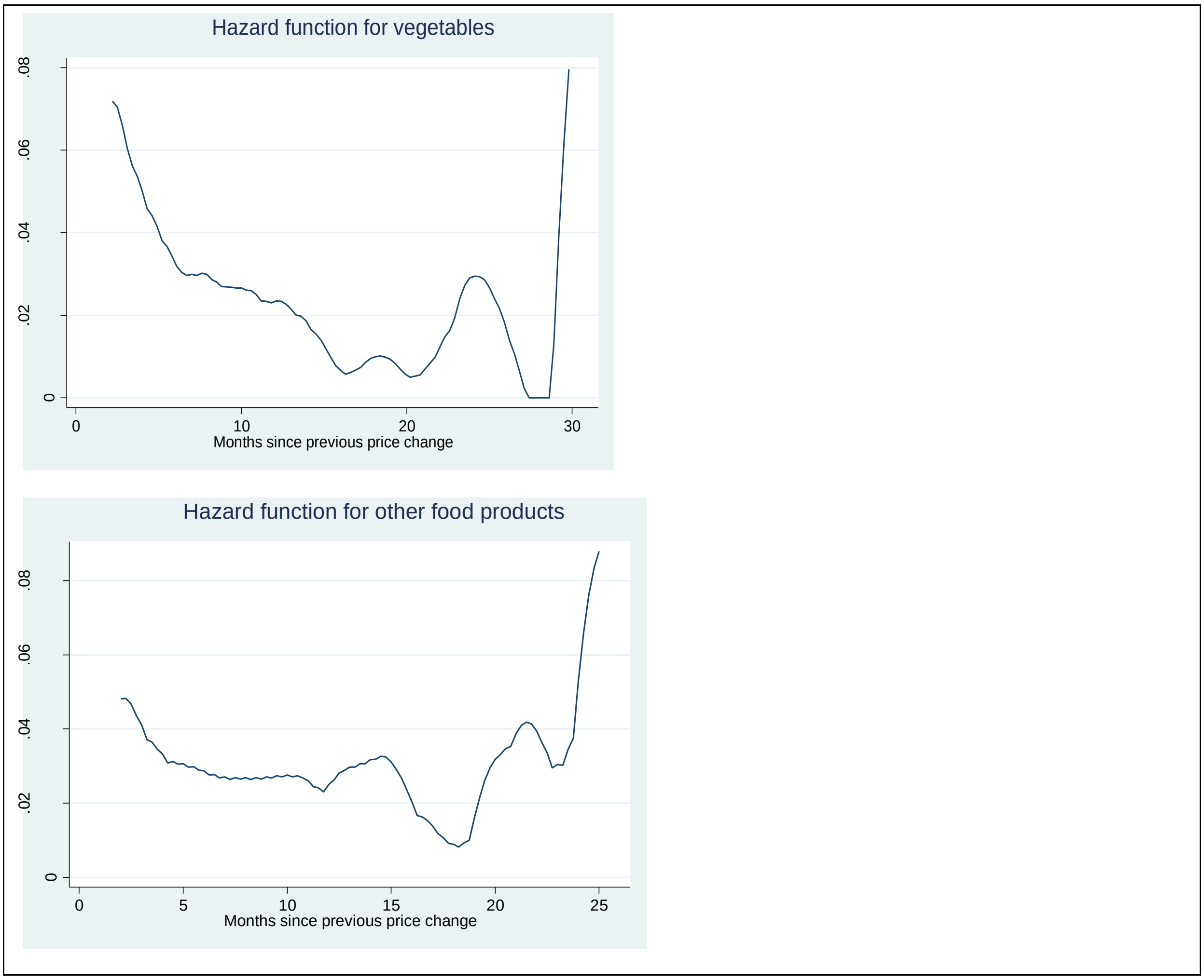


Figure 3.11: Hazard functions for food products



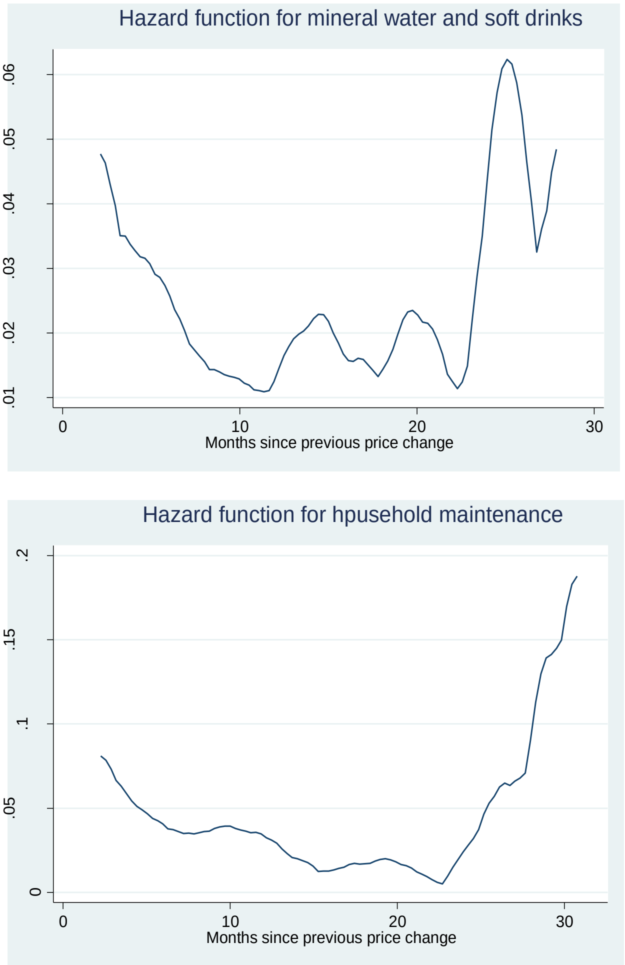

Hazard function for milk and eggs
.01
.02
.03
.04
.05
.06
0
10
20
30
Months since previous price change

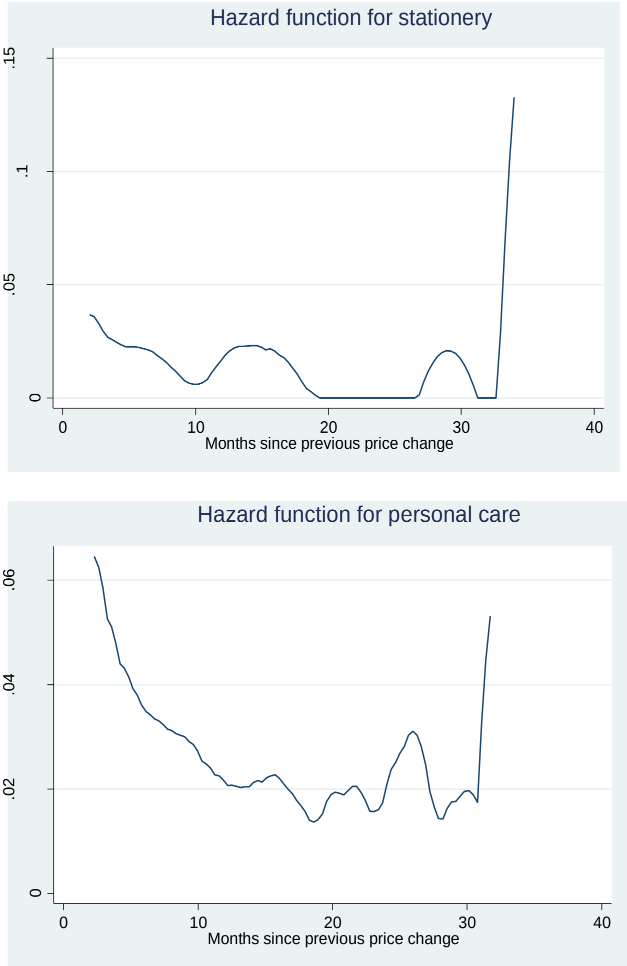

Hazard function for oil and fats
0
.02
.04
.06
0
10
20
30
Months since previous price change



Hazard functions by product category are shown in both Figure 3.11 and Figure 3.12. These hazard functions are initially downward sloping for food products, but rise after about 20 months. The pattern for non-food products is similar to food. This is in contrast to Nchake *et al.* (2014), who finds upward sloping hazard functions for Lesotho, and Creamer *et al.* (2012) for South Africa. The fact that the probability of price changes differs with the length of each time spell provides evidence for state-dependant pricing models.

Figure 3.12: Hazard functions for non-food products





3.8.9 Evidence of heterogeneous price dynamics: Variance decompositions

The data allows us to decompose the frequency of price changes into: variation within a given store, variation across stores for a given product, and lastly, the idiosyncratic shock for a particular product and store. To estimate this, this paper uses a variance components model using the nested random effects model[20]. The model specification is as follows:

$$f_{i,k} = \beta + \varphi_i + \varphi_k + \varepsilon_{ik} \qquad (3.10)$$

Where $f_{i,k}$ is the frequency of price changes for a unique product k, sold in store i; β is a constant term and φ_i is the fraction of variation common to a particular store; φ_k is the variation common across stores for a given product; and ε_{ik} is an idiosyncratic shock to a given store and product, and aims to pick up the remaining variation in the frequency of price changes. The random components $(\varphi_i; \varphi_k \; and \; \varepsilon_{ik})$ are assumed to be identically, independently and normally

[20] The nested random effects model assumes that products are nested within stores.

distributed with zero mean and variance. The model is estimated using maximum likelihood[21]. Table 3.8 reports this decomposition estimated separately for the years 2012, 2013 and 2014.

Table 3.8: Variance decomposition of the frequency of price changes

	Store	**Product**	**Store-Product**
2012	16.51	60.53	22.96
2013	23.44	55.34	21.22
2014	24.80	54.29	20.92

The first column shows the fraction of variation common to a particular store for all products (φ_i), with the second column showing fraction of variation common to all stores selling a particular product (φ_k), and the last column gives the residual variation common to a particular product and store (ε_{ik}). Across all years the fraction of variation common to all stores selling a particular product accounts for most of the total variation of the frequency of price changes. Store and store-by-product variation account for an almost similar amount of variation[22].

These results are similar to Nakamura *et al*. (2011) who report the largest variation being from stores selling a particular product in the U.S.. However, Elberg (2014) finds that variation common to all stores selling a particular barcode only accounted for 25 percent of the variation in the frequencies of posted price adjustments in Chile. However, Elberg (2014) did include the proportion of variation attributable to common movements across retail chains.

Table 3.9 further decomposes the variance by product category. This confirms the aggregate results – product level variation is the largest source of price variance. The results across product categories are similar, although within-store variation in the meat category is substantially higher than for other product categories.

Table 3.9: Variance decomposition by product category

	Store	**Product**	**Store-Product**
Bread & cereals	19.38	58.52	22.11
Meat	35.74	45.76	18.50
Milk, cheese & eggs	26.76	52.91	20.33
Oils and fats	19.85	58.35	21.80
Vegetables	21.37	57.10	21.53
Household maintenance	19.65	58.14	22.20

[21] Nakamura (2011) used the same specification using the U.S. CPI level data.

[22] We have to note that retailers who were given licences to trade in forex could have benefited more soon after the transition, since they were more used to trading in foreign currency and the challenges that come with it.

3.9 Conclusions

In January 2009 Zimbabwe adopted a multicurrency system after a period of hyperinflation. This paper presents new evidence of price-setting behaviour for a period after this change and compares these results to similar studies in other countries. The results fit with the 'stylised facts' emerging about the micro aspects of price adjustment.

We find evidence that prices are stickier in Zimbabwe, with retailers changing their prices on average every 3.9 months, compared to Lesotho (2.7 months) and Sierra Leone (2.0 months). There is significant heterogeneity in the frequency of price changes across different product categories, with prices of perishable products changing more frequently than prices of other products in the dataset. These results fit well with international literature, where there is substantial heterogeneity in price-setting behaviour across products and outlets (Nchake *et al.* 2014; Creamer *et al.* (2012); Klenow & Kryvtsov (2008); Nakamura and Steinson, (2008); Klenow & Malin, 2010).

There is evidence of some adjustment process, as Zimbabwe moved further away from the date the multicurrency system was introduced. Using monthly dummies, we regressed the frequency of price changes with the time trend, to see how prices have adjusted after the introduction of the multicurrency system. The coefficient estimates suggest that there is a trend (which might be associated with adjustment to the multicurrency regime), although they are relatively small compared to the monthly variation in the frequency of price changes.

In addition, we investigate the magnitude of price changes and explore the price-setting behaviour of firms over time, after the introduction of the multicurrency system. We find that more than 77.79 percent of the products in the dataset do not change prices from the previous period. Over half (68.75 percent) of all absolute price changes are greater than five percent indicating that when price changes do occur, they are relatively large.

Furthermore, the paper also analyses the dynamics of price changes over time. We find that the level of inflation is driven by the size of price changes, rather than the frequency of price changes. Using four month moving averages to plot inflation, frequency and the size of price changes, we find evidence to suggest that level of inflation is strongly correlated with the size of price changes, rather than with the frequency of price changes. This also corresponds with international literature (Klenow & Kryvtsov, (2008); Nakamura & Steinsson, (2008)).

We decompose the frequency of price changes into variation within a given store, variation across stores for a given product, and lastly the idiosyncratic shock for a particular product and store. Interestingly, across all years, the fraction of variation common to all stores selling a particular product accounts for most of the total variation of the frequency of price changes. Store and store-by-product variation accounts for a similar amount of variation. This gives an indication that retailer characteristics are an important determinant with which firms change their prices.

Overall, price-setting behaviour in Zimbabwe fits with the stylised facts identified by Klenow and Malin (2010). In the Zimbabwean context, the lower frequency of price changes may be due to the new currency effect, but also to lower inflation rates as shown by the magnitude of price changes. There is scope for further research in this area as it is essential to explore the synchronicity in the price-setting behaviour within and across retailer outlets. In addition, the sample in this paper only covered goods, excluding services. Further research that includes services is therefore necessary.

4 CHAPTER 4

The face value of a currency as a source of price stickiness

4.1 Introduction

In January 2009, the Zimbabwean government dollarised to end hyperinflation. This introduced U.S. dollar notes, but not coins, as the medium of exchange. The smallest denomination note was a $1, which meant that there was no 'official' medium of exchange which could be used as change for products not priced in round numbers. Instead, products priced at less than $1, such as sweets and pens, were used as change. Zimbabwe is classed, according World Bank country indicators, as a low income country, as, in 2011 approximately one-fifth of its population lived below the $1.90 poverty line. As a result a large number of products are priced at low levels, and were affected by dollarisation. Furthermore, given that low income people spend relatively more on lower-priced products, they were disproportionally affected by this change.

In order to overcome the problem of providing change, bond coins were introduced into the market by the Central Bank in December 2014, and a 50c coin released on 1 March 2015, allowing for smaller denominations of currency to circulate[23]. When the new currency system was adopted, with $1 being the smallest denomination, a lower bound was placed on the prices that retailers could charge for relatively cheaper products[24]. This introduced a source of price stickiness as it was difficult, particularly for lower value products, to change prices by relatively small amounts. For example a loaf of bread, if initially priced at $1 dollar could only increase in price by doubling its price to $2. Given this, it was highly likely that prices were sticky at the lower denominations, for example, Chapter 3 shows that the frequency of price changes was lower compared to countries like Lesotho and Sierra Leone.

The introduction of bond coins provides an opportunity for us to examine this unusual source of price stickiness, by analysing the heterogeneous responses by firms to the introduction of bond coins. Although sources of price stickiness is widely discussed in the academic literature (Bils & Klenow, 2004), very little of this investigate the 'face value' of the medium of exchange as a source of price stickiness. Understanding the choice of denomination as a source of price stickiness is important in contexts where countries choose different currencies, such as Zimbabwe, particularly where a country is transitioning from a period of high inflation as some price stickiness may be positive and useful for arresting price increases. In addition, it also

[23] Smaller denominations started circulating on December 2014 which then culminated in the introduction of the 50c in March 2015

[24] It is important to note at this stage that most transactions in Zimbabwe were in cash during this period.

brings forth with the current debate of using digital currencies, such as Bitcoin, and whether they can be used in cases like these. However, as we argue in this paper there are also costs for getting the choice of denomination wrong resulting in an asymmetric distribution across the population.

In this paper, we use a difference in differences, time-regression discontinuity design, as well as an interrupted time series design to assess the impact of the introduction of bond coins on price stickiness for lower-priced products. Specifically, we explore the difference in the initial price as an intensity of treatment. We argue that products with higher prices have a low intensity of treatment since coins make a relatively small difference to price stickiness, but products with lower prices have a high intensity. Furthermore, we implement a time-regression discontinuity design to document any short-run, discontinuous changes in prices around the time bond coins were introduced (March 2015). Our main objective is to compare the distribution of consumer prices before and after the introduction of bond coins to see whether the institutional change affected price stickiness and pricing behaviour of firms at a disaggregated level.

Empirical literature on this type of price stickiness is limited and mainly assesses the price-setting behaviour of firms. Much of the literature examines price stickiness caused by the unwillingness of firms to pay costs related to setting, implementing and advertising new prices. In New Keynesian models, menu costs are often cited as a microeconomic foundation of price stickiness. However, Eife (2009), using data from the Euro changeover, argues that the unwillingness of firms to change prices is caused by factors other than menu costs. In this study, we interrogate the reason why firms are unwilling to change prices in a new currency system.

Other areas in the academic literature examine how convenient pricing results in price stickiness – whereby firms sometimes choose certain prices because they facilitate rapid, easy-to-make transactions. Knotek (2005) shows that, for newspaper prices in the U.S., convenience is an essential component of price setting. However, the study restricts its analysis to certain products in which charging convenient prices is advantageous to both consumers and firms. In this study, we show that firms do practice convenient pricing, in cases where it is advantageous for both firms and consumers due to lack of change. Furthermore, we show that the denomination of the currency is important as it allows firms to reprice (in this case downwards), which benefits the low income earners who disproportionately purchase lower price products.

In the context of developing countries, there is relatively limited literature on price stickiness using disaggregated data across different regimes. Benedict *et al.* (2014) uses a dataset of micro prices to show pricing patterns across different regimes (including after dollarisation) in

Ecuador. They show that firms repriced at a much higher rate during the crisis period, compared to a more stable and dollarised regime. Furthermore, they argue that pricing patterns are related to the firms' cost structure and that traded products are more likely to reprice across different regimes. In this paper, we only concentrate on traded products, so the issue of firms' cost structure is irrelevant. The idea in this paper is to evaluate the pricing patterns of traded products as a result of adopting a stronger currency which is less fine in terms of denominations.

This paper contributes to the existing body of literature in two ways. Firstly, we examine the impact of the introduction of bond coins on price flexibility in Zimbabwe using non-experimental designs. We argue that these methodologies can also be used in the context of pricing behaviour and price stickiness of commodities. Using the time-regression discontinuity design and the interrupted time series design, we show that the introduction of bond coins in Zimbabwe led to a downward shift in prices, and that prices became more flexible as retailers gained the scope to change prices.

Secondly, we investigate the importance of the denomination of a currency and estimate how much the choice of a 'too big' denomination cost consumers. We use results from the regression discontinuity design and the 2013 CPI weights from Zimbabwe National Statistics Agency (Zimstat). We show that, after the introduction of bond coins, inflation was 0.06 percentage points lower, meaning that consumers were paying less than the period before bond coins were introduced.

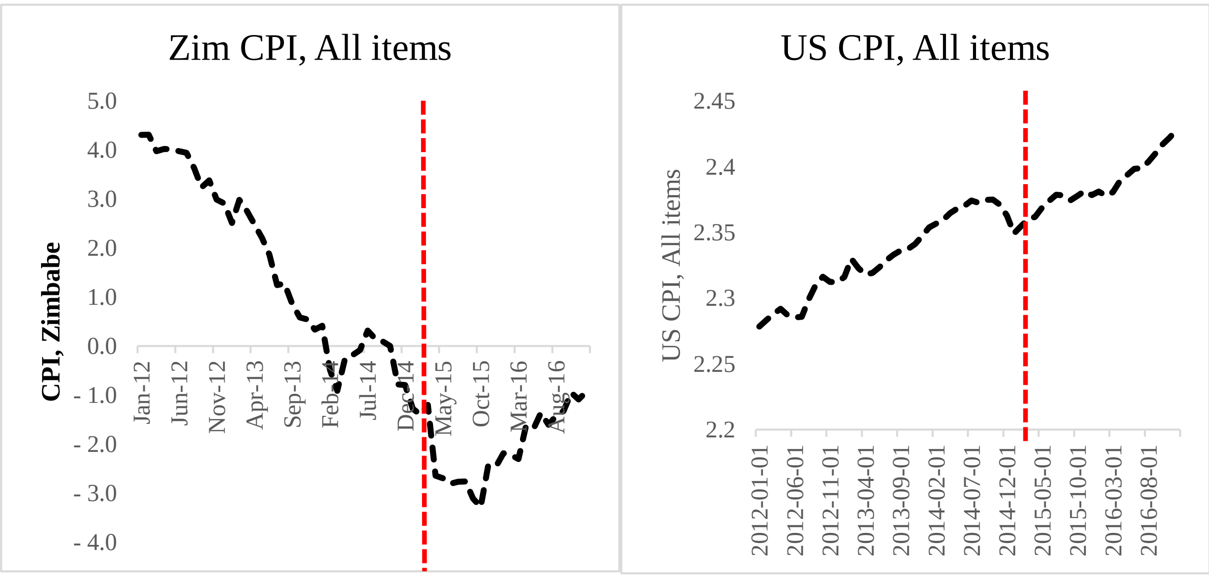
The rest of the paper is structured as follows. Section 2 discusses the background and context of study, including the models of price setting and currency denomination. Section 3 discusses these models, while Section 4 describes the data. Section 5 outlines the methodology, Section 6 analysis the results and Section 7 estimates the cost of wrong denomination. Finally, Section 8 concludes the paper.

4.2 Background and context of study

In January 2009 Zimbabwe, after a decade of hyperinflation and economic crisis, adopted a new currency system dominated by the U.S. dollar. By March 2009 inflation had dropped to -3.02 percent (Zimstat) and the prices of basic commodities started to stabilise. Although there was price stability in the economy, the use of the U.S. dollar as a reference currency came with its own challenges, especially as the lowest denomination was the $1 dollar bill. Retailers had limited scope for setting prices more finely as they had no 'official' low denomination medium of exchange, using lower cost items such as pens and sweets as change instead. Money could not perform its medium of exchange role at these lower levels, which increased transaction costs, and it can be argued that this is the primary role of money.

Lack of price flexibility for lower priced products is likely to have the largest negative effect on those who consume relatively more of these low denomination products, such as the low income earners. This lack of change meant that they were forced to accept sweets and other small products as change, and were not able to freely save for future consumption. The government of Zimbabwe, through its central bank introduced bond coins in March 2015 with the intention of solving the change problem.

Figure 4.1: Annual inflation, January 2012 to December 2016



When the bond coins were introduced, annual inflation in Zimbabwe was already declining compared to that of the United States (Figure 4.1). There was a further decline in inflation (a downward 'jump') when bond coins were introduced in March 2015. The downward trend in annual inflation continued and reached its lowest in October 2015 (-3.29 percent), before it started rising again in November 2016. The introduction of bond coins came with mixed reactions from both consumers and firms since they thought that the government was trying to bring back the Zimbabwe dollar through other means. For example, a supervisor at one of the OK supermarkets in Zimbabwe said: *"The bond coins have been accepted by the public. So far there have been isolated cases of customers refusing the coins but generally the acceptance is pleasing. For those who do not want the coins we are giving them the rand coins, while some are opting for small items such as sweets"* (Sunday Mail, December 21, 2014).

The introduction of bond coins thus provides a novel natural experiment which can be used to understand the role that the denominations of a currency play in price stickiness.

4.3 Models of price setting and currency denomination

Previous research in this area can be divided into three sections: literature on price stickiness caused by firms' unwillingness to change prices due to menu costs; price stickiness caused by firms pricing conveniently; and stickiness due to firms wanting to facilitate easy to make transactions. We attempt to understand the reasons why firms stick to certain prices and are reluctant to change prices. Lastly, we look into the literature on currency denomination.

4.3.1 Price stickiness due to menu costs

For firms to change nominal prices they need real resources (Golosov & Lucas, (2003). These resources are termed 'menu costs' and are a source of price stickiness. Eife (2009) define menu costs as the physical costs of changing prices and price tags in a firm. These physical costs are the main reason why some firms are reluctant to change prices given the ever-changing demand and supply conditions in the market.

Empirical literature on menu costs is twofold. Firstly literature which measures the size of these menu costs (Levy, Bergen, Dutta, & Venable, 1997), and secondly, literature that studies the price-setting behaviour of firms using time series data.

The main contribution of the literature that focusses on the size on the menu cost is that it provides the actual magnitude of these menu costs, which in turn helps us understand why firms are reluctant to change prices. The major drawback, however, of only measuring the size of menu costs is that it provides insufficient explanations as to why firms are sometimes reluctant to change prices, for example changes in business cycle, external shocks and also information on how long firms hold on to a certain price before they change.

In the second body of literature, researchers use micro data to investigate the period for which firms hold on to a certain prices (it measures the duration of price changes) (Bils & Klenow, 2004); (Nakamura & Steinsson, 2008); (Klenow & Kryvtsvov, 1997); (Mamello Amelia Nchake et al., 2014c). The results from this strand of literature are similar, with prices in the retail sector remaining unchanged on average for 7 to 11 months Eife (2009). Furthermore, Eife (2009) uses data at the euro-changeover to investigate whether menu costs are large enough to explain why firms are reluctant to change prices. Interestingly, at a currency changeover, firms have to reprint their price tags regardless of whether they want to change prices or not. This study shows that the reluctance of firms to adjust prices more frequently appears to be caused by factors other than menu costs.

4.3.2 Convenience pricing and currency denomination

Another area of the academic literature examines how convenient pricing results in price stickiness – when whereby firms choose certain prices because they facilitate rapid, easy-to-make transactions. Knotek (2005) shows that, for newspaper prices in the U.S., convenience is an essential component of these prices. Using empirical data on U.S. firms, the study shows that firms set prices that were more convenient than adjacent prices 61 percent of the time. However, the major drawback of the study is that it restricts its analysis to certain products, such as newspapers or movie tickets, to coincide with the available monetary units, or set prices so that change is not required.

A question which develops from this is whether the denominating currency is important for firms to re-price. Literature on denominating currency is sparse. The bulk of the literature analyses the optimal spacing of denominations (Caianiello, Scarpetta, & Smoncelli, 1982); (Hove & Heyndels, 1996) and (M. Lee, Wallace, & Zhu, 2005). The concept of optimal spacing-currency spacing is based on the 'principle of least effort'. This is achieved with the smallest number of monetary items (bank notes and coins) used in cash payments.

The principle of least effort was introduced by Caianiello *et al.* (1982). They argue that the optimal spacing of currency results in the smallest average numbers of tokens in cash payments. This can be achieved by setting a denomination space in the same factor or by using a common ratio as a geometric sequence. The smaller the spacing factor, the smaller the average numbers of tokens in cash payment, resulting in efficiency. Accordingly, a spacing factor of 2 (1; 2; 4; 8; 18….) is the most efficient in order to avoid one spacing factor.

Hove & Heyndels (1996) develop this concept further and try to find the optimal spacing factor using average frequencies of denomination between spacing factors 2 and 3, using the Cramer's approach[25]. Cramer's approach used computer algorithms to determine the average frequencies

[25] Cramer assumed that public behavior is efficient, that is, each payment requires a minimum number of tokens

of denominations. Hove & Heyndels (1996) used the same approach to determine average frequencies of denominations to show that a spacing factor of 2 outperforms a spacing factor of 3 according to the principle of least effort. However, the study argues that the spacing factor for denominations must not be too low as it makes it harder for the public to recognise different coins and notes for transaction purposes. Lowering the spacing factor reduces the number of average units needed in a transaction, resulting in smaller numbers of notes and coins in circulation. Adding a new note will carry a fixed cost to issuance.

For the case of Zimbabwe, it can be seen that denominations in U.S. dollars included a series of binary decimal triplets (1; 2; 5; 10; 20; 50; 100) for the bank notes only. However, there were no coins when the new currency system was introduced, which did not fulfil the principle of least effort and efficiency of currency system. Therefore, there were no currency denominations which could facilitate cash payments with a high circulation system, resulting in price stickiness.

4.4 Data description

In order to investigate the influence of the introduction of bond coins on price stickiness we use highly disaggregated data at the retailer level from January 2012 to December 2016, collected by the National Incomes and Pricing Commission (NIPC) in its retail price surveys. NIPC collects weekly data from all retail outlets within the Harare Metropolitan Province. Although the data is collected weekly, there are missing weeks/values in the dataset. In order to address this, we convert that data into monthly retail prices by taking the middle of the month price (prices which fall between the 11^{th} and 18^{th} of that particular month) as the reference price for that particular month. If in the reference period we do not find a price, we take the price closest to the reference period/date range. In total, our data consists of 291 products with 286 563 price records.

As the NIPC only publishes price data for food and other basic commodities, (it does not publish prices for durable goods or services because they are not homogeneous overtime), our selected set of products is relatively small, covering approximately 30 percent of the CPI basket. This dataset, however suits our analysis well since it covers the types of products which have lower denominated prices. Table 4.1 describes the data before and after the bond coins were introduced.

Table 4.1: Data description before and after March 2015

	Before March 2015				After March 2015				
Product class	**Price quotes**		**Product items**		**Price quotes**		**Product items**		**Zimstat CPI Weights**
	Number	**Percent**	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**	**Percent**
Food									
Bread & cereals	31 272	15.96	57	19.66	15407	16.99	35	16.20	10.29
Meat	11 422	5.83	24	8.28	3713	4.10	20	9.26	5.26
Milk, cheese and eggs	14 643	7.48	24	8.28	7153	7.89	18	8.33	1.86
Oil and Fats	14 604	7.46	35	12.07	6821	7.52	21	9.72	2.3
Vegetables	15 992	8.16	26	8.97	7433	8.20	23	10.65	1.88
Sugar, jam, honey, chocolate and confectionery	4 896	2.50	15	5.17	3047	3.36	11	5.09	2.48
Other food products	10 835	5.53	8	2.76	4722	5.21	7	3.24	0.39
Coffee, tea and cocoa	8 335	4.25	7	2.41	4227	4.66	5	2.31	0.22
Mineral waters, soft drinks, fruit and vegetable juices	12 880	6.58	19	6.55	5980	6.60	15	6.94	0.72
Beer	2 038	1.04	1	0.34	1140	1.26	1	0.46	0.72
Non-food products		0.00		0.00				0.00	
Household maintenance	29 310	14.96	34	11.72	13288	14.66	24	11.11	2.6
Stationery	5 540	2.83	6	2.07	2726	3.01	6	2.78	0.32
Other appliances, articles and products for personal care	34 125	17.42	34	11.72	15014	16.56	30	13.89	1.21
Total	**195 892**	**100**	**290**	**100**	**90671**	**100**	**216**	**100**	**30.24**

Food products constitute a greater proportion of products in our dataset. Our sample declines from 195 892 price records before bond coins were introduced to 90 671 after bond coins were introduced. The number of products decreases from 290 before the introduction of coins to 216 products after the coins were introduced. We match these products with the consumer basket in Zimbabwe to assess their weights by Zimstat. The products in this dataset constitute approximately 30 percent of the consumer basket. Within that, bread and cereals (10.29 percent) is the highest followed by meat (5.26 percent) and then sugar, jam and confectionary (2.48 percent).

4.5 Methodology

To assess the impact of the introduction of bond coins on price flexibility in Zimbabwe we use two empirical approaches, both of which exploit the introduction of the coins as a treatment and the 'intensity' of this treatment which varies by initial prices. Furthermore, we use the interrupted time series design to estimate whether a change in the slope of the trend occurred after the introduction of bond coins.

Our identification assumptions differ for these three methodologies. The difference-in-differences calculates the averages before and after the introduction of bond coins, using the initial prices as an intensity of treatment. However, we cannot conclusively say bond coins had a positive impact on price flexibility by basing our results only on difference-in-differences as this calculation does not take into account potential underlying price trends in the data. For example, rand coins started circulating earlier in Zimbabwe and there was already a converging trend.

To control for this, we fit a flexible trend for the period just pre and post the introduction of coins. We use time-regression discontinuity to estimate the short-run, discontinuous changes in prices around the date the bond coins were introduced. We calculate averages (termed as ‘local averages’) for the period just before and after the introduction of bond coins, and the difference between the local averages gives us a ‘jump’ which is the impact of the introduction of bond coins. The difference between the difference-in-differences and the time-regression discontinuity is that the later gives us the impact during the transition period[26].

Lastly, we use the interrupted time series design to estimate the slope of the trend before and after the introduction of bond coins. The identification assumption is that if the slope changes by a greater proportion after the introduction of bond coins, then there was an impact. We use a linear trend and calculate the slope before and after coins were introduced. The difference between the interrupted time series and the other non-experimental designs is that it does not calculate the ‘jump’ but rather the slope of the trend. This helps us to eliminate if there were baseline variables within the model which might affect out results. In the next section, we describe the three methodologies in more detail.

4.5.1 Difference-in-differences approach

To estimate the impact of introducing bond coins, we exploit the introduction as a treatment and the ‘intensity’ of this treatment varies by initial prices. We argue that products with higher prices (in this case prices greater than $5) have a low intensity of treatment because introducing coins makes a relatively smaller difference to them, but products with lower prices have a high intensity.

We employ a difference-in-differences design to identify the stickiness of prices before and after the introduction of bond coins in March 2015. Instead of having one control and one

[26] In this instance, we assume that there might be other factors which might impact our results in the difference-in-differences, so a time-regression discontinuity may potentially give us different results.

treatment group, we exploit the difference in the initial price as an intensity of treatment. We regress the monthly frequency of price changes on the difference in the initial price as an intensity of treatment, and a dummy for before and after the intervention. The interaction between the difference in the initial price and the dummy for post intervention gives us the impact as it varies by initial price. Our basic equation is specified as follows:

$$\Delta \ln P_{ij} = \alpha_i + \beta_1 postintervention + \beta_2 initialprice + \beta_3 postintervention \times initial\ price + \delta_j + \lambda_t + \varepsilon_{ijt} \quad (4.1)$$

...where $\beta_1$is a dummy variable which takes the value of 'one' if the date is on, or after, March 2015, and 'zero' otherwise; β_2 is a dummy variable which takes the value of 'zero' if price the previous year is not equal to the price in the current year, and 'one' if price in the previous year is equal to price in the current year. β_3, is the difference-in-differences, using initial prices as an intensity of treatment. The initial price in this context is a measure of the treatment intensity. We hypothesise that lower-priced products are more constrained or sticky compared to higher-priced products. Inclusion of $\delta_j$controls for within-product variation and λ_t controls for time-fixed effects. We also estimate the specification including product fixed effects to control for within product variation[27].

To study the impact of the introduction of bond coins on price stickiness, we estimate the above specification on whether a price changes. This framework will be used to estimate the short-run and long-run impacts of introducing bond coins on the flexibility of prices in Zimbabwe. The expectation is that prices become more flexible after the introduction of the bond coins

4.5.2 Time-regression discontinuity (RD) design

We employ the time-regression discontinuity design to identify the short-run discontinuous change in price stickiness as a result of the policy intervention in March 2015. Specifically, we want to estimate the gain to consumers (how much would have been paid if the bond coins were not introduced, compared to what was actually paid). The identification assumption is that due to price stickiness as a result of the 'coarseness' of the new currency, consumers were paying more than they were supposed to pay if the currency had finer denominations. In particular, we estimate the following specification:

$$lnP_{it} = \beta_0 + \beta_1 postintervention + \beta_3 trend + \beta_3 postintervention * trend + \varepsilon_{it} \quad (4.2)$$

[27] I use fixed effects in all specifications because it captures within product variation. The idea is to assess whether the variation is happening within products if there is something associated with certain types of products

Where lnP_{it} is the log prices; β_1 is a dummy equal to 'one' if time is post introduction of bond coins (post intervention) and 'zero' otherwise; β_3 is the linear time trend. The inclusion of the linear trend variable allows for a linear movement in prices over time. To study the impact of bond coins on prices, we estimate the above with an interaction term between the post intervention and the trend variable (which gives us the effect at each point in time). Given that our outcome is a deterministic function, all prices on or after March 2015 are assigned to the treatment group, whereas prices before March 2015 are assigned to the control group. The impact of the bond coins on price flexibility is given by:

$$\lim_{t \downarrow Mar\ 2015} E(Y_{it}|t_{it} = t) - \lim_{t \uparrow Mar\ 2015} E(Y_{it}|t_{it} = t) \qquad (4.3)$$

Which is the average causal effect of bond coins on price flexibility at the time of the policy intervention (March 2015), where *t* refers to time:

$$\beta_3 = E[Y_{it}(postintervention = 1) - Y_{it}(postintervention = 0)|t_{it} = Mar\ 2015] \qquad (4.4)$$

The expectation is that there is a downward shift in prices soon after the introduction of bond coins in March 2015.

The above specification was used by Fuje (2016) to document any short-run, discontinuous change in price dispersion after the removal of a fossil fuel subsidy in Ethiopia, in October 2008. Other notable studies which have used the regression discontinuity design include Ozier (2011); Pugatch *et al.* (2013); Barrera-Osorio & Raju (2011). Ozier (2011) examines the impact of Kenyan secondary school on schooling, social and labour market outcomes, using a pass on the primary exit exam as a cut-off for entrance into secondary school, while Pugatch *et al*. (2013) uses the required threshold in distance from the main road to analyse the impact of hardship allowance for teachers in the Gambia. Barrera-Osorio & Raju (2011) analyse the impact of subsidies to private schools in Pakistan, using the fact that schools have to achieve a certain average on an achievement test in order to qualify for the subsidy.

4.5.3 Interrupted time series design

For the introduction of bond coins to be considered an effective intervention in Zimbabwe, we expect that the trend in the behaviour of prices to deviate by a greater proportion after their introduction. In order to evaluate this trend, we use an interrupted time series design before and after the introduction of bond coins. As we have more than 38 months in our data before the intervention, the interrupted time series' stringent data requirements are not an issue in this context. We use the following specification to estimate the differences in the trends before and after the intervention:

$$lnP_{it} = \beta_0 + \beta_1 postintervention + \beta_3 trend + \beta_3 postintervention * trend + \varepsilon_{it} \quad (4.5)$$

Where lnP_{it} is the log prices; β_1 is a dummy equal to 'one' if time is post-introduction (or post-intervention) of bond coins and 'zero' otherwise; β_3 is the linear time trend. The inclusion of the linear trend variable allows for a linear movement in prices over time. To study the impact of bond coins on prices, we estimate the above equation with an interaction term between the post-intervention and the trend variable (which gives us the effect at each point in time). The difference between this estimation with the difference-in-differences, and the regression discontinuity is that we calculate the slope of the trend. We posit that, after bond coins were introduced, the slope of the trend changed, becoming steeper as prices became more flexible.

4.6 Results analysis

4.6.1 Descriptive statistics

In this section, we present the distribution and clustering of prices before and after March 2015 when bond coins started circulating in Zimbabwe. Although the coins were officially announced in December 2014, they only started circulating in the system in March 2015[28]. Figure 4.2 presents a histogram on the distribution and clustering of prices for the whole period.

Figure 4.2: Distribution and clustering of prices

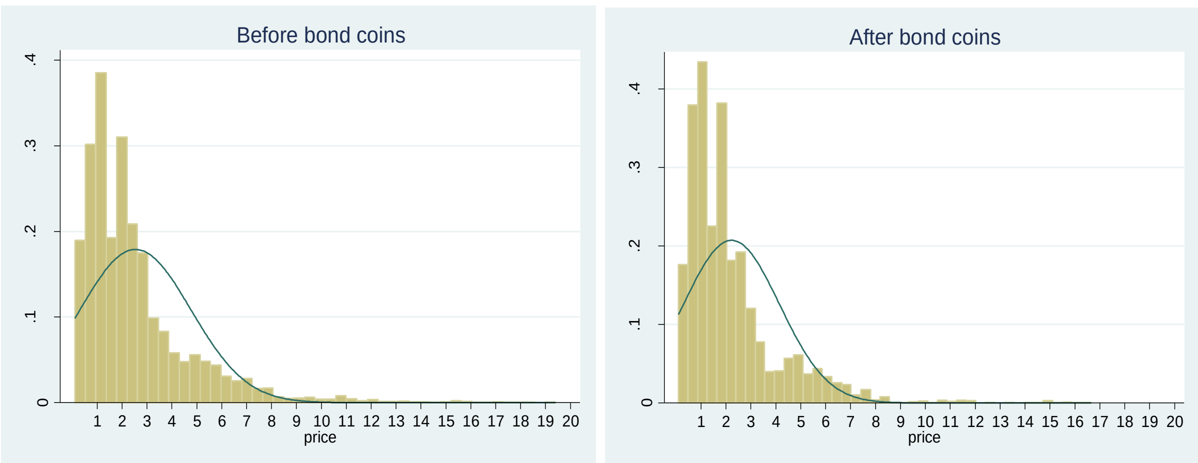


Figure 4.2 shows the distribution and clustering of prices for the whole dataset. Most products are priced below \$3. The fitted line starts declining after \$3, indicating that the majority of

[28] A total of bond coins worth US\$15 million was circulated in the system. It was supported by a US\$50 million extended to Reserve Bank of Zimbabwe by the African Export-Import Bank.

products are clustered below $3. We then break down the distribution of prices into two periods: before March 2015, and after March 2015.

Table 4.2 presents a breakdown of the distribution of prices before and after March 2015. The cumulative percentage of products priced below $2 increased from 54.11 percent before March 2015, to 61.16 percent after March 2015. The table also shows that the majority of products in the dataset are below $5 dollars, making this dataset more applicable to stickiness of prices at lower denominations.

Table 4.2: Distribution of price before and after March 2015

Price($)	Before March 2015 Cumulative %	After March 2015 Cumulative %
0.5	7.94	9.93
1	28.14	32.55
1.5	39.85	44.18
2	54.11	61.16
2.5	65.11	70.62
3	73.97	79.53
3.5	78.73	83.38
4	83	85.81
4.5	85.17	87.61
5	88.14	90.9
>5.00	100	100

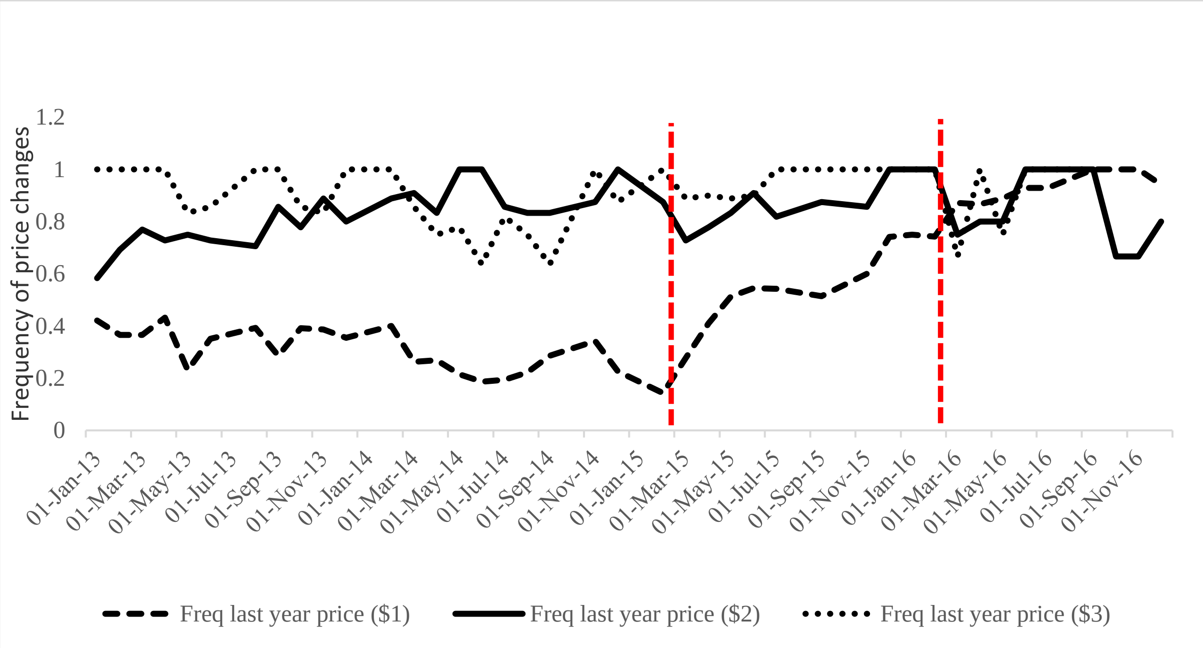
For the rest of our analysis we will concentrate on products valued at $3 or less, as, firstly, they constitute more than 70 percent of the total products in the dataset, and secondly, much of our analysis on price stickiness is for lower-priced products, and selecting the products priced at $3 helps us to get robust results. The next section will assess the frequency of price changes before and after the introduction of bond coins.

4.6.2 Frequency of price changes

The first outcome variable of interest is the frequency of price changes. Álvarez & Hernando (2006) define the frequency of price changes as the proportion of non-zero price changes over the total number of all observations. It gives the value of ‘one’ if there is a price change from one period to another, or ‘zero’ otherwise. The frequency of price changes is commonly used when analysing the flexibility of prices. In this section, we will use the frequency of price changes before and after introduction of bond coins to assess the flexibility of prices.

We calculate the frequency of price changes for products priced at $1, $2 and $3 in the previous year. We posit that bond coins impact the dollar priced category more as coins make a relatively large difference to them. We expect the frequency of price changes to be higher after the introduction of bond coins as retailers have more reason to change prices as a direct result of the availability of change. Figure 4.3 shows the frequency of price changes for the products priced at $1, $2 and $3 in the previous year.

Figure 4.3: Year-on-year frequency of price changes for selected prices



These descriptive statistics show a large change in the frequency of price changes, particularly those initially priced at $1. Prior to the introduction of bond coins, there are different frequencies of price changes for different categories. For the products which were priced at $1 the previous year, the average frequency of price changes was approximately 20%[29], which is considerably lower and stickier compared to Creamer and Rankin (2012)'s 17% for South Africa, and Nchake *et al.* (2013)'s 37% for Lesotho. After the introduction of bond coins, there is a discontinuity, or sharp rise, in the frequency of price changes. It takes approximately one year for the products priced at $1 a year ago to start looking like other categories.

The rise in the frequency of price changes shows flexibility in prices after the introduction of bond coins for products which were valued at $1 the a year ago. For the products valued at $2 the a year ago, there is a once-off change, whereas there is a continuous change in prices for the products valued at $1 a year ago. There is evidence of catch up in the flexibility in prices over time, as products priced at $1 a year ago with other categories ($2 and $3).

[29] The main reason why prices were changing frequently prior to the introduction of bond coins was the rand coins which began circulating in Zimbabwe. There is no literature which details the actual rand coins circulating before March 2015, but from personal knowledge, they were generally scarce".

Figure 4.4: Average prices for products priced at $1 a year ago

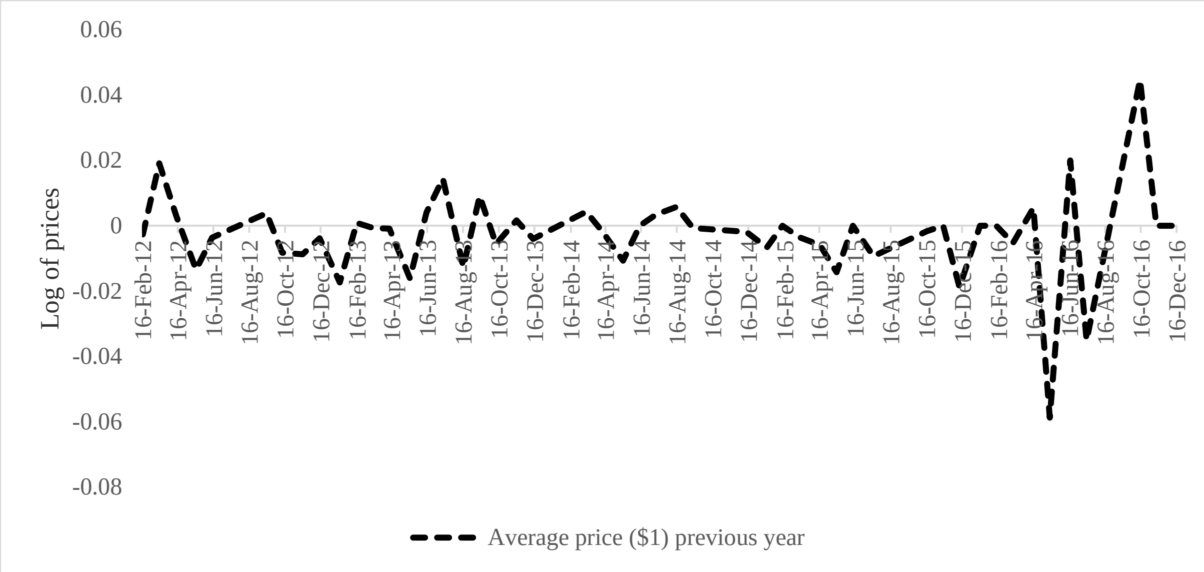


Figure 4.4 plots average prices for products priced at $1 a year ago. variation in prices after March 2016 (after the transition period) for products priced at $1 a year ago This corroborates our earlier findings that there was a catch up in the flexibility of prices a year after bond coins were introduced. Prior to the introduction of coins, prices were pretty stable but one year after the transition period, the variation in price changes increased.

We are also interested to know which of products priced at $1 a year ago were more affected by the introduction of bond coins. Table 4.3 presents the composition of products priced at $1 a year ago.

Table 4.3: Products priced at $1 a year ago

Category	Number of price records	Percent	CPI weight
Bread	1,051	44.16	3.5
Bathing soap	255	10.71	0.21
Chips	112	4.71	0.12
Salt	107	4.5	0.34
Sanitary pads	104	4.37	0.03
Vegetables	104	4.37	1.88
Petroleum jelly	91	3.82	0.33
Shoe polish	73	3.07	0.11
Margarine	65	2.73	0.27
Tinned foods	51	2.14	0.1
Toothpaste	48	2.02	0.17
Beer	43	1.81	0.72
Milk	38	1.6	0.48
Baked beans	37	1.55	0.22
Detergents	34	1.43	0.19
Stationery	34	1.43	0.32
Toiletries	25	1.05	0.18
Soft drinks	20	0.84	0.31
Matches	17	0.71	0.2
Peas	14	0.59	0.03
Washing powder	14	0.59	0.49
Washing soaps	14	0.59	1.64
Mineral water	13	0.55	0.01
Candles	7	0.29	0.3
Tomato sauce	7	0.29	0.24

Bread constitutes the bulk of the products priced at $1 a year ago, with 44.16 percent of the price records, followed by bathing soap (10.71 percent) and chips (4.71 percent). The price records are for a 60 month period, lagged yearly. All these products are basic necessities and constitute 12.40 percent of the consumer basket.

In order to know more about the impact of the introduction of bond coins, we separate the time before and after the policy intervention. For illustrative purposes, we use the price records for bread as it constitutes the greatest proportion of products prices at $1 a year ago We break it down by price record to see the distribution of prices.

Table 4.4: Distribution of prices for bread before and after March 2015

Price	Number of price records	Before March 2015 (%)	Number of price records	After March 2015 (%)
0.6	8	0.66	1	0.2
0.65	0	0	18	3.65
0.7	8	0.66	0	0
0.75	8	0.66	5	1.01
0.79	13	1.07	3	0.61
0.8	20	1.65	36	7.3
0.85	6	0.5	2	0.41
0.89	1	0.08	0	0
0.9	24	1.98	246	49.9
0.95	60	4.95	11	2.23
0.99	6	0.5	1	0.2
1	1,056	87.13	170	34.48
1.1	2	0.17	0	0

Table 4.4 shows the changing patterns in the distribution of bread prices before and after March 2015. Before March 2015, 87.13 percent of bread was priced at $1, and only 1.98 percent priced at $0.90. After March 2015, 34.48 percent was priced at $1, with 49.9 percent at $0.90. This shows that before the introduction of bond coins prices were sticky, because of the lack of change, which meant that retailers had limited scope to change prices. After the introduction of bond coins, there is evidence of flexibility and a downward shift in prices.

In order to get a clear picture of the impact of the intervention, we capture all prices classified into specific price categories. As we have shown in Figure 4.5 (below), there is substantial evidence of the flexibility of prices for the products which were priced at $1 a year ago. In this section we group all the products priced between $0.70 and $1.25; $1.25 and $1.75; and finally $1.75 and $2.25. Figure 4.5 presents the frequency of price changes for these categories.

Figure 4.5: Frequency of price changes for different price categories

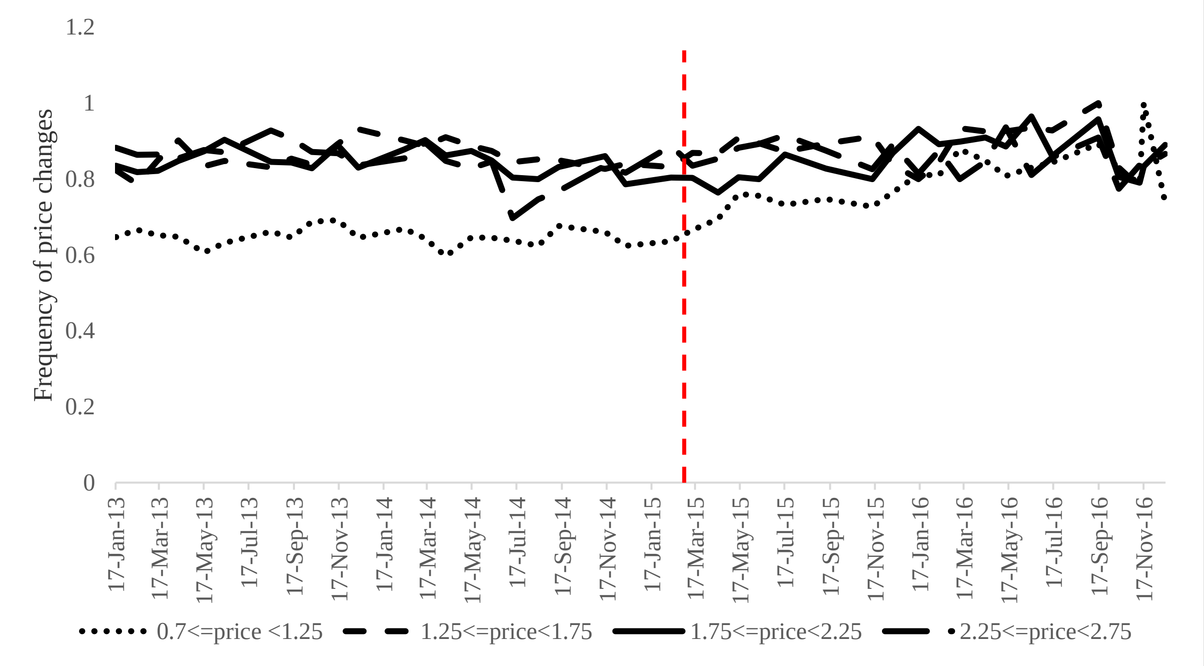


Figure 4.5 illustrates that the first category of prices ($0.70 and $1.25) shows the greatest impact of the introduction of bond coins, as shown by the black dotted line. The line seems to be fairly stable from January 2013 and then starts to rise in March 2015. The trend continues showing flexibility in prices – firms responded with finer denominations in prices. The bold line (prices between $1.75 and 2.25) also starts to pick after March 2015 showing flexibility in prices for that price. A noteworthy result illustrated in Figure 4.5 is that there is more clustering of prices close to the round figures. For example, there is a higher impact on prices within the ranges $0.70 and $1.25 (close to $1), and again $1.75 and $2.25 (close to $2), indicating that firms responded to the bond coins and started having promotional prices and also competing with each other.

4.6.3 Summary of descriptive statistics

The descriptive analysis thus far shows a large change in the frequency of price changes particularly those initially priced at $1. In addition, there is a discontinuity or sharp rise in the frequency of price changes. It takes approximately one year for the products priced at $1 a year ago to start looking like other categories. There is a significant change in the distribution of bread prices (the product that constitutes the greatest proportion of these prices) before and after March 2015. We can conclusively say that there is evidence of a downward shift in prices after the introduction of bond coins in Zimbabwe. The next section examines this downward shift in prices using three different econometric methodologies.

4.6.4 Difference-in-differences results

We estimate the difference-in-differences specification in three different ways using the initial price as an intensity of treatment. Firstly, we estimate the monthly frequency of price changes on the dummy variable (post intervention) and initial prices. In this instance, our dummy variable takes the value of 'one' if the period is on or after 1 March 2015, or 'zero' otherwise. Secondly, we re-estimate the yearly frequency of price changes again with the dummy variable (post intervention). Thirdly, we include another new dummy variable (post transition) in the difference-in-differences specification. The post-transition dummy takes the value of 'one' if the period is after 1 March 2016, and 'zero' otherwise. Specifically, we want to eliminate the transition period (the period immediately after coins were introduced: 1 March 2015 – 1 March 2016). Lastly, we include continuous prices in the difference-in-differences specification for robustness checks). We include time and product dummies in the first specification to control for seasonality and within-product variation. Table 4.5 presents results for the first estimation with post intervention.

Table 4.5: Impact of bond coins on month-on-month frequency of price changes

VARIABLES	(1) Equation 1	(2) Equation 2
Post intervention	0.00516	0.109**
	(0.00395)	(0.0507)
Initial price		-0.441***
		(0.0853)
Initial price X post intervention		-0.00318
		(0.0388)
Constant	0.221***	0.732***
	(0.00262)	(0.123)
Observations	59,605	3,413
R-squared		0.045
Number of unique ids	4,308	609
N	59605	3413

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The sample consists of round numbers and products priced below $3. We control for product fixed effects to capture within product variation.

Our variable of interest is the shift (jump) in prices after bond coins were introduced, given by the interaction between the dummy variable, post intervention and the initial price. We illustrate our results with three categories for initial price ($1; $2; and $3). In specification 1, the post-intervention dummy coefficient (0.00516) is positive, indicating that bond coins had a positive impact on the flexibility of prices. Specification 2 interacts the initial price and post intervention, and we control for monthly dummies and within-product variation. The coefficient is negative (-0.00318) showing that lower initially priced products increased flexibility by relatively more than for higher-priced products. However, the variable is not statistically significant because we are looking at month-on-month, and were unable to pick up the change in the month before and after March 2015.

We estimate the second specification with yearly frequency of price changes and the post-intervention dummy. Table 4.6 presents the results of yearly frequency of price changes and post intervention.

Table 4.6: Impact of bond coins on year-on-year frequency of price changes

VARIABLES	(1) Equation 1	(2) Equation 2
Post intervention	0.0331***	0.491***
	(0.00467)	(0.0505)
Initial price a year ago		0.0673
		(0.0968)
Initial price X post intervention		-0.0832**
		(0.0353)
Constant	0.790***	0.327**
	(0.00601)	(0.139)
Observations	28,064	1,837
R-squared		0.169
Number of unique ids	2,611	347
N	28064	1837

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The sample consists of round numbers and products priced below $3. We control for product fixed effects to capture within product variation.

Specification 1 only estimates the post intervention on frequency of price changes and shows the coefficient is positive and statistically significant. This means the introduction of bond coins increased the year-on-year flexibility of prices by 0.03 percentage points. We interact the dummy variable (post intervention) with initial prices a year ago in specification 2. The interaction, which gives us the jump, is negative and statistically significant. In this specification, we are able to pick the impact since we are assessing year on year changes compared to the month on month changes in Table 4.5. Lower initially priced products increased flexibility by relatively more compared to higher initially priced products.

Thirdly, we include the post-transition dummy (which takes the value of 'one' if period is after 1 March 2016, and 'zero' otherwise. We control for time and product dummies in this specification. Table 4.7 presents the results after we included the post-transition dummy.

Table 4.7: Impact of coins on year-on-year frequency of price change; including post transition period

	(1)	(2)
VARIABLES	Equation 1	Equation 2
Post intervention	0.0186***	0.347***
	(0.00523)	(0.0490)
Post transition	0.0314***	0.830***
	(0.00714)	(0.0801)
Initial price a year ago		0.0555
		(0.0916)
Post Intervention X initial price		-0.0250
		(0.0337)
Post transition X initial price		-0.397***
		(0.0621)
Constant	0.788***	0.330**
	(0.00282)	(0.131)
Observations	28,064	1,837
R-squared	0.002	0.258
Number of unique ids	2,611	347
N	28064	1837

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The sample consists of round numbers and products priced below $3. We control for product fixed effects to capture within product variation.

Specification 1 controls for both post-intervention and post-transition period. Our results show that the impact of bond coins was much stronger after the transition period, that is, price became more flexible after the transition period. Specification 2 interacts both the post-intervention and the post-transition dummy with initial prices. The interaction between the post-transition dummy and initial prices a year ago is positive and statistically significant. After the transition period, price flexibility declined by 0.39 percentage points (in this case the jump).

Lastly, since our initial prices were round figures, we include continuous prices in our analysis for robustness checks and also to increase our sample. We estimate the difference-in-differences specification with both the post-intervention and the post-transition dummy. Table 4.8 presents results after including continuous prices.

Table 4.8: Impact of coins on year-on-year frequency of price changes; including all prices

VARIABLES	(1) Equation 1	(2) Equation 2
Post intervention	0.0186***	0.00452
	(0.00523)	(0.00533)
Post transition	0.0314***	0.0208***
	(0.00714)	(0.00716)
Log of prices		-0.230***
		(0.0178)
Constant	0.788***	0.910***
	(0.00282)	(0.00988)
Observations	28,064	28,064
R-squared	0.002	0.008
Number of unique ids	2,611	2,611
N	28064	28064

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: We control for product fixed effects to capture within product variation.

Table 4.8 presents results when we include all prices in the regression analysis. The coefficient of the log of prices is negative and statistically significant. There was a downward shift in prices (0.23 percentage points) after the introduction of bond coins, substantiating our results from previous specifications.

4.6.5 Time-regression discontinuity results

In this section, we estimate a time-regression discontinuity design. We use the frequency of price changes and the log of prices to illustrate the trend and changes in prices compared to the frequency of prices. First, we regress the frequency of price changes and the log of prices with the trend and the dummy for post intervention. We control for within-product variation and time with dummy variables. The results of the time-regression discontinuity design for a pooled set of products are presented in Table 4.9.

Table 4.9: Results from time-regression discontinuity design against month-on-month frequency of price changes

VARIABLES	(1) Equation 1	(2) Equation 2
Post intervention	0.00436	1.814***
	(0.00458)	(0.386)
Trend		-0.000601***
		(0.000224)
Trend X post intervention		-0.00268***
		(0.000579)
Constant	0.235***	0.624***
	(0.00214)	(0.144)
Observations	59,605	59,605
R-squared	0.000	0.001
Number of unique ids	4,308	4,308
N	59605	59605

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The sample consists of round numbers and products priced below $3. We control for product fixed effects to capture within product variation.

Specification 1 regresses the dummy variable (post intervention) against the month-on-month frequency of price changes. Specification 2 fits a trend variable on the month-on-month frequency of price changes. The interaction between the trend variable and the post intervention is negative and statistically significant. The negative coefficient of the interaction variable changes the slope of the trend to be more negative.

We re-estimate the time-regression discontinuity on year-on-year frequency of price changes. Table 4.10 presents results from this estimation.

Table 4.10: Results for a time-regression discontinuity on year-on-year frequency of price changes

VARIABLES	(1) Equation 1	(2) Equation 2
Post intervention	0.0266***	-3.010***
	(0.00491)	(0.451)
Trend		-0.00177***
		(0.000386)
Trend X post intervention		0.00459***
		(0.000680)
Constant	0.790***	1.936***
	(0.00279)	(0.250)
Observations	28,064	28,064
R-squared	0.001	0.003
Number of unique ids	2,611	2,611
N	28064	28064

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The sample consists of round numbers and products priced below $3. We control for product fixed effects to capture within product variation.

Table 4.10 shows that the trend line ‘kinks’ with the intervention, going from a negative slope of -0.00177 to approximately 0.003. This indicates an increase in flexibility in prices after March 2015. For robustness checks, we repeat the same estimation, but instead of using the year-on-year frequency of price changes, we use log of prices and also categorise our products into products priced at $1 and $2 a year ago. Table 4.11 presents results using log of prices.

Table 4.11: Results from the time-regression discontinuity design against log of prices

VARIABLES	(All products) Equation	(Previous year $1) Equation 2	(Previous year $2) Equation 3
Post intervention	0.672***	0.729*	-0.233
	(0.110)	(0.421)	(1.217)
Trend	-0.00283***	-0.000140	-0.00106
	(6.06e-05)	(0.000139)	(0.000687)
Post bond coin trend	-0.00104***	-0.00111*	0.000371
	(0.000165)	(0.000634)	(0.00183)
Observations	70,964	2,380	652
R-squared	0.105	0.017	0.034
Number of unique ids	4,705	358	160
N	70964	2380	652

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: We control for product fixed effects to capture within product variation.

Specification 1 presents results for a pooled set of products (all price categories). Specification 2 presents regression results for products priced at $1 a year ago while specification 3 represents those products priced at $2 a year ago. We control for seasonality with monthly dummies for both specifications. For a pooled set of products, our explanatory variables are statistically significant at all levels. The negative coefficient of the post bond coin trend variable shows there was a downward shift in prices at the cut-off point when bond coins were introduced. The post bond coin trend is stronger for products priced at $1 (-0.00111) a year ago compared to the products priced $2 a year ago (0.000371). Overall our coefficient estimates are significant and negative for a pooled set of products – there was a downward shift in prices shown by a downward 'jump' in prices around the time bond coins were introduced in Zimbabwe. Our results corroborate our earlier findings with the difference-in-differences estimation.

4.6.6 Interrupted time series design

Results from the difference-in-differences and time-regression discontinuity design indicate that there was a jump in prices after the introduction of coins. In this section, we use the interrupted time series design to pick up the trends before and after the introduction of bond coins. Our variables of interest are the frequency of price changes and the log of prices. The major advantage of using an interrupted time series design is that it picks up discontinuity and immediate effects of a policy intervention. We use the interrupted time series design in this context because it implicitly controls for differences in the 'natural growth rates' and is based on projections on past trends. The impact of bond coins will then be the difference between the deviation from the trend after the intervention and before the intervention. Table 4.12 combines results from the time-regression discontinuity and the interrupted time series on month-on-month frequency of price changes.

Table 4.12: Results from time-regression discontinuity and interrupted time series design on month-on-month frequency of price changes

VARIABLES	(1) Equation 1	(2) Equation 2	(3) Equation 3
Initial price a month ago			-0.308***
			(0.0738)
Trend	-0.000601***	-0.272***	-0.000303
	(0.000224)	(0.0274)	(0.000354)
Trend X initial price			-0.0000435
			(0.000106)
Post intervention	1.814***	-198.1***	0.645
	(0.386)	(39.48)	(2.070)
Post intervention X initial price			0.366
			(1.191)
Trend X post intervention	-0.00268***	0.604***	-0.000949
	(0.000579)	(0.118)	(0.00311)
Post intervention X trend X initial price			-0.000552
			(0.00179)
Trend squared		0.000211***	
		(0.0000213)	
Trend squared X post intervention		-0.000460***	
		(0.0000879)	
Constant	0.624***	87.81***	0.678***
	(0.144)	(8.829)	(0.235)
Observations	59,605	59,605	3,040
R-squared	0.001	0.003	0.026
Number of unique ids	4,308	4,308	552
N	59605	59605	3040

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The sample consists of round numbers and products priced below $3. We control for product fixed effects to capture within product variation.

Specification 1 presents results from the time-regression discontinuity. Specification 2 presents results from the interrupted time series. The interaction between the trend squared variable and the post intervention (-0.000640) is negative and statistically significant. This means that the slope of the trend squared variable became steeper after the introduction of coins. The post-trend variable based on the price a month ago (specification 3) is also negative meaning higher initial prices declined after the introduction of bond coins in Zimbabwe. We re-estimate the same specification using year-on-year frequency of price changes as the variable of interest. Table 4.13 presents the results from this estimation.

Table 4.13: Results from time-regression discontinuity and interrupted time series design on year-on-year frequency of price changes

VARIABLES	(1) Equation 1	(2) Equation 2	(3) Equation 3
Trend	-0.00177***	0.131*	-0.00124
	(0.000386)	(0.0703)	(0.00418)
Trend X initial price			0.000462
			(0.00409)
Post intervention	-3.010***	-163.4***	4.386
	(0.451)	(45.46)	(4.768)
Post intervention X initial price			-4.731
			(4.388)
Trend X post intervention	0.00459***	0.477***	-0.00658
	(0.000680)	(0.137)	(0.00720)
Trend X post intervention X initial price			0.00711
			(0.00663)
Trend squared		-0.000102*	
		(0.0000542)	
Trend squared X post intervention		-0.000348***	
		(0.000103)	
Constant	1.936***	-41.02*	0.464
	(0.250)	(22.78)	(0.544)
Observations	28,064	28,064	808
R-squared	0.003	0.004	0.007
Number of unique ids	2,611	2,611	126
N	28064	28064	808

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The sample consists of round numbers and products priced below $3. We control for product fixed effects to capture within product variation.

Specification 2 presents results for the interrupted time series on year-on-year frequency of price changes. Again, after fitting a flexible trend and interacting it with the post-intervention dummy variable, we find a negative and statistically significant coefficient (-0.000348). The negative quadratic coefficient means that the slope became steeper after the introduction of bond coins. For robustness checks, we re-estimate the interrupted time series design with the log of prices as the variable of interest. Table 4.14 presents the results using log of prices as the variable of interest.

Table 4.14: Results from time-regression discontinuity and interrupted time series design on log of prices

VARIABLES	(1) Equation	(2) Equation 2	(3) Equation 3
Initial price			0.140***
			(0.0250)
Trend	-0.00280***	0.136***	-0.000450**
	(0.00006)	(0.00711)	(0.000195)
Trend X initial price			0.0000397
			(0.0000359)
Post intervention	-0.0687	317.7***	0.570
	(0.166)	(25.38)	(0.935)
Post intervention X initial			0.149
			(0.170)
Trend X post intervention	0.0000583	-0.948***	-0.000843
	(0.000248)	(0.0752)	(0.00139)
Post intervention X trend X initial price			-0.000226
			(0.000253)
Trend squared		-0.000108***	
		(0.00000553)	
Trend squared X post intervention		0.000707***	
		(0.0000557)	
Constant	2.401***	-42.28***	0.502***
	(0.0386)	(2.286)	(0.130)
Observations	63,543	63,543	3,899
R-squared	0.105	0.113	0.098
Number of unique ids	4,672	4,672	769
N	63543	63543	3899

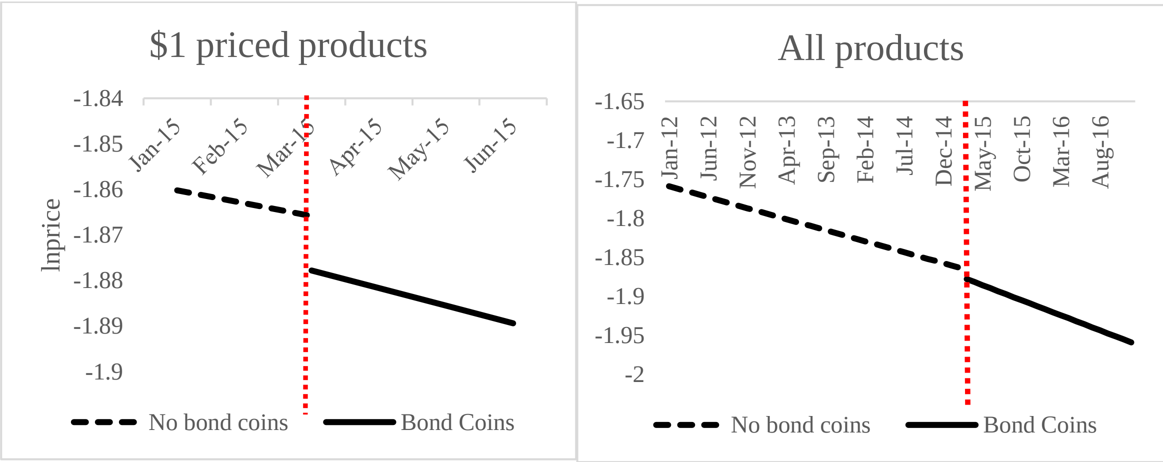
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The sample consists of round numbers and products priced below $3. We control for product fixed effects to capture within product variation.

Specification 1 shows results for the time-regression discontinuity, while specification 2 shows results from the interrupted time series regression with a quadratic trend. In specification 3, we interact the post intervention with the initial price a year ago and also include the trend in the interaction. We are interested in the interaction between the trend variable and post intervention which is negative and statistically significant. This means that the slope of the trend variable was negative after the introduction of bond coins and this corroborates our results from the time-regression discontinuity and the difference-in-differences estimation that the introduction of bond coins in Zimbabwe led to a downward shift in prices.

We plot the results from the interrupted time series firstly for a pooled set of products using results from the estimation, using log of prices as a variable of interest. We also select products which were priced at $1 a year ago, as coins make a relatively large difference to them. We plot the results with the linear trend and present the results in Figure 4.6.

Figure 4.6: Interrupted time series results with linear trend



The first graph in Figure 4.6 plots results for a pooled set of products, while the second graph is only restricted to those products priced at $1 a year ago. The figure on the left-hand side indicates that prices are falling and continue to fall on a slightly faster rate after bond coins were introduced. The figure on the right-hand side shows that prior to the introduction of bond coins these prices were sticky, but once bond coins were introduced, prices start to fall –become less sticky – at a faster rate than the broader sample. Overall, results from the interrupted time series shows changes in the slope of the trend after coins were introduced, indicating a downward shift in prices.

4.7 What does this mean for cost of living?

The results show us that there was a downward shift in prices and price flexibility. We have learnt so far that the frequency of price changes increased dramatically for the $1 priced products with the introduction of bond coins. Prices for the products priced at $1 a year ago fell, while inflation was also on a downward trend. This means that, prior to the introduction of bond coins there was some mispricing due to lack of change, which disproportionately affected those who buy lower-priced products. In this section, we estimate how much the choice of ‘wrong’ denomination cost the consumers particularly on lower-priced products

Since products in the NIPC dataset constitute approximately 30 percent of the CPI basket, we recalculate the CPI weights using the Income and Expenditure Survey which was conducted by the Zimstat in 2013. We use the CPI reweights and results from the time-regression discontinuity to estimate how much the choice of 'wrong' denomination cost consumers[30]. Table 4.15 presents results for each category of product.

Table 4.15: Cost to consumers as a result of wrong denomination using results from the time-regression discontinuity

Product class	**CPI reweights**	**Change in price**	**Weighted cost to consumers**
Bread and cereals	34.02	0.0001	0.0028
Meat	17.4	-0.0022	-0.0382
Milk, cheese and eggs	6.15	-0.0089	-0.0548
Oil and fats	7.6	-0.0002	-0.0016
Vegetables	6.21	-0.0021	-0.0131
Sugar, jam, honey, chocolate and confectionery	8.2	0.0049	0.0404
Other food products	1.29	0.0004	0.0005
Coffee, tea and cocoa	0.73	-0.0030	-0.0022
Mineral waters, soft drinks, fruit and vegetable juices	2.38	0.0034	0.0080
Beer	2.37	-0.0166	-0.0393
Non-food products			
Household maintenance	8.6	0.0033	0.0283
Stationery	1.04	0.0126	0.0131
Other appliances, articles and products for personal care	4	-0.0010	-0.0042
Cost to consumers	100		**-0.0603**

Table 4.15 shows cost to consumers as a result of the wrong denomination by product category. Overall, inflation was 0.06 percentage points lower with the introduction of bond coins. Consumers were paying less after bond coins were introduced than during the period before, where prices were sticky and there was no change. To conclude, the introduction of bond coins in Zimbabwe led to a downward shift in prices and a decrease in the cost of living as a result of a flexibility in prices and availability of change. We show that denominating currency matters, particularly on lower-priced products.

[30] In this instance, we use results from the time-regression discontinuity with the log of prices as the variable of interest, allowing us to evaluate the cost to consumers (in terms of prices) as a result of the wrong denomination.

4.8 Conclusions

This paper seeks to examine the impact of the introduction of bond coins in Zimbabwe on price stickiness of lower-priced products. Using non-experimental designs, we show that the introduction of bond coins led to a downward shift in prices and prices became flexible. Regressing the dummy variable, both month-on-month and year-on-year, on the frequency of price changes, we argue that lower initially priced products increased flexibility after bond coins were introduced, compared to higher initially priced products. In addition, there is a discontinuity or sharp rise in the frequency of price changes after March 2015. It takes approximately a year for products priced at $1 a year ago to catch up with other categories.

Our results are still robust if we estimate the interrupted time series design. If we fit a flexible trend on both month-on-month and year-on-year frequency of price changes, we show that the slope of the trend becomes steeper after the introduction of bond coins. In order to get a clear picture of the impact of the intervention, we capture all prices and classify them into specific price categories. Our results indicate that much of the impact of bond coins was on the first category of prices (between $0.70 and $1.25). We argue that this policy change made a relatively large difference to low-income earners who disproportionately buy lower-priced products.

Furthermore, we use results from the regression discontinuity and the 2013 CPI weights to estimate how much the wrong denomination cost consumers by calculating the change in the cost of living for each product category after the introduction of bond coins. We show that inflation declined by 0.06 percentage points as a result of the introduction of bond coins. Consumers were paying less after bond coins were introduced compared to the period before March 2015 where prices were sticky and there was no change. Again the impact was measurably larger for those products priced at $1 a year ago. Overall, this paper shows that denominating currency is important when a country adopts a different currency which is ‘strong’ in value but less fine in terms of denomination.

5 CHAPTER 5

Conclusions and research implications

5.1 Introduction

In January 2009, Zimbabwe adopted a new currency system as a way to end hyperinflation. This thesis uses a novel dataset of prices at a very disaggregate level to investigate how this new currency system affected market integration within Zimbabwe, the mechanisms of price adjustments, as well as how the choice of the dollar – a 'strong' currency with a high face value – affected price stickiness. Each of these aspects is discussed in a separate chapter: Chapter 2 investigated price dispersion and the new currency system; Chapter 3 price-setting behaviour; and Chapter 4 the 'face value' of the currency and price stickiness.

5.2 Research contributions

This research contributes to the literature on pricing, price dispersion, price stickiness and inflation in at least three ways. The first is the country-specific aspect of how prices behave in the Zimbabwean context and how they adjusted to the change in currency regime. There is strong evidence that prices are stickier in Zimbabwe, with retailers on average changing their prices every 3.9 months compared to Lesotho (2.7 months) and Sierra Leone (2.0 months) where similar, price-based studies have been conducted.

The second is a broader understanding of how prices adjust with a new currency regime and the end of hyperinflation. This research shows that it took 18 months for prices to stabilise with little convergence thereafter. It seems likely that in future other countries will undergo periods of hyperinflation (for example, at the time of writing Venezuelan inflation was measured at 250% according to Reuters) and may change currencies in order to arrest this. Knowing more about how prices adjust is useful in these contexts.

The third, broad contribution is on understanding how the choice of a currencies 'face value' contributes to price stickiness. This is of particular relevance in cases where countries adopt new currencies, such as in Zimbabwe when faced with a crisis, or when joining a currency union like the Eurozone. In both of these examples it is likely that the country is moving from a 'finely' denominated currency to a more 'coarsely' denominated one. As this thesis shows, this introduces stickiness, which can help slow price increases, but can also restrict the adjustment of prices. As this research argues, there are also distributional impacts that are likely to fall on consumers who buy the products where stickiness is largest.

Presumably, the impact of the 'face value' of a medium of exchange will also matter as other 'types' of currency, such as electronic currencies (Bitcoin), develop. In cases like this the costs, such as printing, associated with physical currency will decline, eliminating the 'face value' as a source of price stickiness. The findings from this thesis suggest that prices are likely to be more flexible, *ceteris parabus*, in markets that use electronic currency than in those which require physical money.

In the following sub-sections the key findings of each chapter, and the broader implications thereof, are discussed.

5.3 Summary of findings

5.3.1 Price dispersion and new currency systems

In Chapter 2 the LOP after hyperinflation and its change over the period immediately after the introduction of a new currency system in Zimbabwe, was measured. Data for this study was drawn from the nationally representative disaggregated consumer price data collected by the Zimstat for the period January 2009 to August 2014. The chapter complements this data with nationally representative data from StatsSA for the same period of study.

Using a methodological approach proposed by Parsley & Wei (2001) which has now become standard in this field of this literature, Chapter 2 shows that price dispersion dropped sharply for the first 18 months after the introduction of a new currency system. Little convergence occurs thereafter, indicating closer product market integration within Zimbabwe. The trend variable for both within and between-country price dispersion is negative and statistically significant, however, the interaction with the within-Zimbabwe dummy is much stronger compared to the between-country dispersion, implying that prices became more integrated within Zimbabwe than between Zimbabwe and South Africa. This means that the introduction of the new currency system encouraged price convergence within Zimbabwe, which is suggestive of the important role which prices play in conveying information.

To investigate possible sources of price convergence, the chapter assesses the impact of exchange rate volatility on both within and between-country price dispersion. Results indicate that higher exchange rate volatility leads to higher price dispersion. Chapter 2 argues that exchange rate volatility has an important impact on price dispersion but does not fully explain the border effect, rather having a greater impact within Zimbabwean prices than across borders.

Chapter 2 also examined the role of trade on price dispersion, by isolating how much of price dispersion is attributed to trade. The chapter matched products which share similar characteristics between Zimbabwe and South Africa. Imports from South Africa into Zimbabwe were downloaded from the World Bank's WITS database. The chapter argues that trade (proxied by the lagged value of imports of Zimbabwe from South Africa) has a significant and negative effect on price dispersion. This implies that the higher the imports from South Africa into Zimbabwe, the lower the price dispersion between the two countries will be. Time variation, as captured by yearly fixed effects, explains much of the observed price dispersion suggesting that time varying factors, such as economic growth rates, may be important to explain the border effects.

To this end, Chapter 2 demonstrated that prices took about 18 months to adjust, from the day the new currency system was introduced. When we include the border effect between Zimbabwe and South Africa in the analysis, the study indicates that price convergence was larger within Zimbabwe than between Zimbabwe and South Africa. Trade and exchange rate volatility are important in explaining the convergence in prices between Zimbabwe and South Africa, but time variation remains very important suggesting that there are other important factors not captured in the analysis.

5.3.2 Pricing and price-setting behaviour of firms

Chapter 3 investigated price-setting behaviour, and the change in this behaviour amongst retail firms in Zimbabwe after the introduction of the new currency system. Data is drawn from weekly prices collected by the NIPC within the Harare Metropolitan Province and reweighted with the Zimstat disaggregated CPI weights. This chapter used this data, as well as the calculated frequency, size and probability of price changes, to compare the 'stylised facts' of pricing behaviour in Zimbabwe to similar countries (Lesotho and Sierra Leone). There is strong evidence that prices are stickier in Zimbabwe, with retailers on average changing their prices every 3.9 months compared to Lesotho (2.7 months) and Sierra Leone (2.0 months). There is significant heterogeneity in the frequency of price changes across different product categories, with prices of perishable products changing more frequently than prices of other products. Furthermore, the chapter investigated the magnitude of these price changes showing that more than 77 percent of products did not change prices from the previous month. For the products that did change prices, the size of price changes were relatively large.

A key question that chapter 3 attempted to answer was how pricing behaviour of retailers in Zimbabwe changed as the economy became more used to the new currency system. Regressing the frequency of price changes against the time trend and monthly dummies, the chapter argued that there is substantive evidence of some adjustment process as Zimbabwe moved further away from the date the new currency system was introduced. The frequency of price changes varied with the time trend, however increasing at a decreasing rate. Interestingly, the coefficient estimate suggested that there is a trend (which might be associated with adjustment to the multi-currency regime), although it was relatively small compared to the monthly variation in the frequency of price changes.

In addition, Chapter 3 examined the dynamics of price changes over time. Knowing the relationship between the frequency and size of price changes with inflation is important in analysing theoretical models in pricing behaviour. Kackmeister (2005a) argues that if price movements reflect market forces, then knowing the relationship between price changes and inflation may have implications on business cycles and the transmission into monetary policy. With staggered contracts in time-dependant pricing models, the variation in inflation is explained by the size of price changes, and the frequency of price changes is assumed to be constant over time. In light of this, chapter 3 calculated month-on-month inflation by product using Zimstat 2013 CPI weights. Month-on-month inflation, seemed to co-move with both the frequency and size of price changes. Using four month moving averages, the study that changes in the size of price changes are more volatile and more closely correlated with the inflation rate than the frequency of price changes. Regressing month-on-month inflation against the frequency and size of price changes suggested that both the frequencies and magnitudes are correlated with CPI but the magnitude of price changes has a stronger coefficient compared to the frequency of price changes.

Lastly, chapter 3 decomposed the frequency of price changes into variation within a given store, variation across stores for a given product, and lastly the idiosyncratic shock for a particular product and store. Interestingly, across all years, the fraction of variation which is common to all stores selling a particular product accounted for most of the total variation of the frequency of price changes. This indicates that retailer characteristics are an important determinant of price changes.

5.3.3 The face value of a currency as a source of price stickiness

Chapter 4 focused on the face value of a currency as a source of price stickiness. When the new currency system was introduced, Zimbabwe chose the U.S. dollar as a reference currency, which had a higher face value over the South African Rand. This introduced another source of price stickiness which has not been widely studied. The choice of a high face value currency, with limited low denominations to provide change, and then the later introduction of bond coins introducing smaller denominations, provided a novel natural experiment to understand how the face value of a currency affects price stickiness.

The chapter uses three different econometric techniques – difference-in-differences, time-regression discontinuity and the interrupted time series design; to assess the impact of the introduction of bond coins in March 2015 on price flexibility. Descriptive statistics show a discontinuous, sharp rise in the frequency of price changes in March 2015. It takes approximately one year for products priced at $1 a year ago to look like other categories.

A difference-in-differences estimation was estimated three different ways, using the initial prices as an intensity of treatment. First, the monthly frequency of price changes and secondly yearly frequency of price changes are variables of interest on post intervention. The third specification included the post-transition period with a dummy variable taking the value of 'one' if period is after March 2016. Results from both specifications indicated that the coefficient of the interaction of the post-intervention dummy and initial prices is negative and statistically significant. This means that price flexibility increased by more for lower initially priced products than higher initially priced products.

The chapter also estimates the time-regression discontinuity design to capture any short-run, discontinuous changes in prices flexibility around March 2015. The frequency of price changes and the log of prices were regressed on a post-intervention dummy. Again, the interaction of the trend variable and the post-intervention dummy were negative and statistically significant, indicating a downward shift (jump) in prices around the cut-off period. The results remained robust when we used either frequency of price changes or the log of prices and corroborated with results from the difference-in-differences estimation.

Furthermore, the chapter used the interrupted time series design to pick up trends before and after the introduction of bond coins. The interrupted time series implicitly controls for differences in 'natural growth rates' and is based on projections on past trends. Again, using monthly frequency of price changes, the interaction between the quadratic of the trend variable and post intervention was negative and statistically significant. However, the slope of the trend squared variable became steeper after the introduction of bond coins. Our results remain unchanged when we used the yearly frequency of price changes and the log of prices as variables of interest. The chapter restricted the analysis to lower-priced products (those priced at $1 a year ago and the results showed that the slope becomes much steeper. Overall, results from the interrupted time series design showed changes in the slope of the trend after coins were introduced, indicating a downward shift in prices.

Chapter 4 finally estimated how much the choice of 'wrong' denomination cost the consumers particularly on lower-priced products. The study used results from the time-regression discontinuity design (with the log of prices as the variable of interest). Results indicated that inflation was 0.06 percentage points lower as a result of bond coins, showing that denominating currency matters when a country adopts a 'strong' currency with a higher face value.

5.4 Research implications

The main aim of this research was to contribute to the empirical understanding of market integration after hyperinflation, the dynamics and mechanisms of price adjustments after a new currency system and to understand why denominating a currency with a high face value matters for low-income countries such as Zimbabwe. In this section, we discuss the research implications separately for each chapter.

Chapter 2 measured the dispersion to the LOP within Zimbabwe, extending the analysis to South Africa. The first implication from the main findings is that there is increased domestic market integration within Zimbabwe after the new currency system was introduced. However, crossing the border between Zimbabwe and South Africa adds significantly to price dispersion. Similar results were reported by Parsley and Wei (2001) for the border between U.S. and Japan; Engel and Rodgers (1996) for the U.S.-Canada border and Brenton *et al* (2014) for eastern and central African countries. Our results add to the growing body of literature on market integration in emerging economies.

Secondly, the study argues that exchange rate volatility partly explains why the border between Zimbabwe and South Africa is large. The border effect falls when the study controls for exchange rate volatility. Parsley and Wei (2001) report similar findings for the Japan - U.S. border. The main reason why exchange rate volatility matters for prices is that it brings uncertainty for traders and presumptively, they try to hedge for that uncertainty on the international market by increasing prices. Lower exchange rate volatility is therefore associated with higher price dispersion as traders become more certain that they will make profits and know what prices to sell on the international market.

Chapter 3 adds to the growing body of literature on price-setting behaviour in low-income countries using a unique database of monthly consumer prices by retail outlet. The main implication from this study is that retail outlets do not frequently change prices because of the higher face value of the dollar. In other words, lower initially priced products do not change prices from the previous period (in this case a month). However, if they do change prices, the average size of price change is large.

Furthermore, chapter 3 analyses the dynamic features of price changes. The paper argues that the variance in inflation in Zimbabwe is driven by the size of price changes rather than the frequency of price changes. Similar results are reported in international literature (Klenow and Kryvtsov, (2008); Nakamura and Steinsson (2008); Nchake *et al.* (2014c). The results however contradict Creamer *et al.* (2012) for South Africa who found a positive relationship between the frequency of price changes and inflation. Chapter 3 decomposes the frequency of price changes into variation within products and across stores. Variation across stores accounts for much of the frequency of price changes implying that retailer characteristics are an important determinant of the rate at which firms' change prices from one period to another. Elberg (2014) concurs with the findings that retailer characteristics are an important determinant to the rate to which retailers change prices.

Chapter 4 challenges theoretical standard open economy models that denominating currency matters when a currency adopts a foreign currency which has a high face value but is less fine in terms of denominations. Using a natural experiment – the introduction of coins in Zimbabwe – the study demonstrated that denominating currency does matter for price flexibility when a country adopts a foreign currency with a higher face value. The introduction of bond coins in Zimbabwe brought more flexibility and scope for retailers to change prices, leading to a downward shift in prices.

In addition, chapter 4 estimates how much the choice of the wrong denomination cost consumers. Zimbabwe is a low-income country and according to World Bank indicators, the majority of people live in poverty. Prior to the introduction of bond coins, retailers were forced to price in round numbers, or give sweets or pens and other lower-priced products as change. This affected low-income earners who disproportionately buy these lower-priced products in particular, forced to pay more than the market price as a result. However, the introduction of bond coins provided more scope for retailers to reprice, and the cost of living fell by 0.06 percentage points when coins were introduced.

5.5 Conclusions and suggestions for future research

This dissertation sought to understand market integration after hyperinflation, the mechanisms of price adjustments and the importance of denominating currency after adopting a new currency system. This research is only possible due to access to a novel dataset and this thesis is the first to use this data for research. Chapter 2 contributes to the existing body of literature by measuring within and between country price dispersion in a low-income country, after hyperinflation. In particular, it is the first to measure integration of product markets within a country after a hyperinflationary period. While the border effect has been investigated a lot in literature, this chapter demonstrates that adopting a foreign, stable currency can help reduce price dispersion within a country and between countries. However, uncertainty, proxied by inflation on the domestic market and exchange rate volatility on the international market, only explains a substantial portion of the border effect. Since this study only studies two countries, further research is required by including more countries in the analysis. Furthermore, the paper restricted its analysis to uncertainty, and other factors such as non-tariff barriers and trade restrictions need to be included in the analysis, to determine the impact of each on the border effect.

Chapter 3 adds to the growing body of literature on price-setting behaviour in developing countries. Findings from retail outlets in Zimbabwe confirms stylised facts of price-setting behaviour found in other countries. There is scope for further research as it is essential to explore the synchronicity in the price-setting behaviour within and across retailer outlets. In addition, the sample in this paper covered goods only and excluded services. Further research is therefore necessary to include services in the analysis to determine how price-setting behaviour changes in Zimbabwe.

Finally, Chapter 4 uses a novel natural experiment – the introduction of bond coins in Zimbabwe, to investigate the importance of the face value of a currency as a source of price stickiness. This study is the first to investigate the stickiness of prices caused by the face value of a currency. Results show that the introduction of coins in March 2016 led to the downward shift in prices as retailers had more score to reprice. However, this study only examined approximately two years after intervention date. Further research is essential to examine the long-term effects of coins. Another interesting angle is to assess the impact of bond notes introduced by Zimbabwe on 28 November 2016 to help ease the currency crunch and how these may have affected prices and pricing.

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7 APPENDIX

CHAPTER 2

Table 7.1: Price dispersion and exchange rate volatility

VARIABLES	(1)	(2)
Zimbabwe	0.167***	0.170***
	(0.00624)	(0.00623)
Trend	5.79e-06***	1.37e-05***
	(1.20e-06)	(1.26e-06)
Zimbabwe *X* Trend	-6.67e-05***	-6.96e-05***
	(1.64e-06)	(1.65e-06)
Border	0.302***	0.304***
	(0.00655)	(0.00654)
Border *X* Trend	-2.92e-05***	-3.09e-05***
	(1.45e-06)	(1.45e-06)
Exchange Rate Volatility$_{t-1}$		0.0165***
		(0.00526)
Exchange Rate Volatility$_{t-2}$		0.0179***
		(0.00527)
Exchange Rate Volatility$_{t-3}$		0.0140***
		(0.00522)
Exchange Rate Volatility$_{t-4}$		0.0591***
		(0.00341)
Exchange Rate Volatility$_{t-5}$		0.0423***
		(0.00317)
Exchange Rate Volatility$_{t-6}$		0.00163
		(0.00321)
Exchange Rate Volatility$_{t-7}$		-0.0129***
		(0.00317)
Exchange Rate Volatility$_{t-8}$		0.0128***
		(0.00317)
Exchange Rate Volatility$_{t-9}$		-0.000291
		(0.00309)
Exchange Rate Volatility$_{t-10}$		-0.0160***
		(0.00306)
Exchange Rate Volatility$_{t-11}$		0.00743**
		(0.00300)
Exchange Rate Volatility$_{t-12}$		0.00352
		(0.00297)
Constant	0.178***	0.148***

	(0.00445)	(0.00476)
Observations	742,474	742,474
R-squared	0.158	0.159
Number of Joint Commodity	88	88
N	742474	742474

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

ROBUSTNESS CHECKS

Price dispersion within Harare

In the regressions so far, we used city pairs in our calculation of price dispersion within and between Zimbabwe and South Africa. This potentially leads to correlations with the distance variable and underestimates the impact of distance on price dispersion. In this section, instead of calculating price dispersion across city pairs, we use the arithmetic mean for retail outlets within the Harare Metropolitan Province[31]. We use data acquired from the National Incomes and Pricing Commission (NIPC) in Zimbabwe[32]. Raw data is collected weekly and comes in excel files. Data is then converted into monthly price records by taking the middle of the month price as the reference price for that particular month and the data is available from January 2012. The data covers approximately 31 percent of products in the CPI basket. This approach has been used by Cecchetti *etal* (2002) and O'Connell and Wei (2002). Price variation is calculated as follows:

$$P_{ijt} = \ln(\frac{g_{ijt}}{\bar{g}_{jt}})$$

Where g_{ijt}denotes the raw price of product *j* in outlet *i* at time t, and $\bar{g}_{jt}$ denoted the geometric mean price in the Harare Metropolitan Province. We calculate price dispersion as the mean absolute price differential. We do the same calculations using the Zimstat dataset for Zimbabwe and plot price deviations from the geometric mean as shown in Figure 5.

[31] We chose Harare because it is the capital city of Zimbabwe and the behaviour of prices in Harare greatly mirrors that of Zimbabwe as a whole and lastly data for within city price variation was only available for Harare. Thirdly, we have a different dataset which includes prices in different retail outlets within Harare.
[32] The National Incomes and Pricing Commission only collects price data for the Harare Metropolitan province.

Figure 7.1: Price Dispersion Zimbabwe and Within Harare

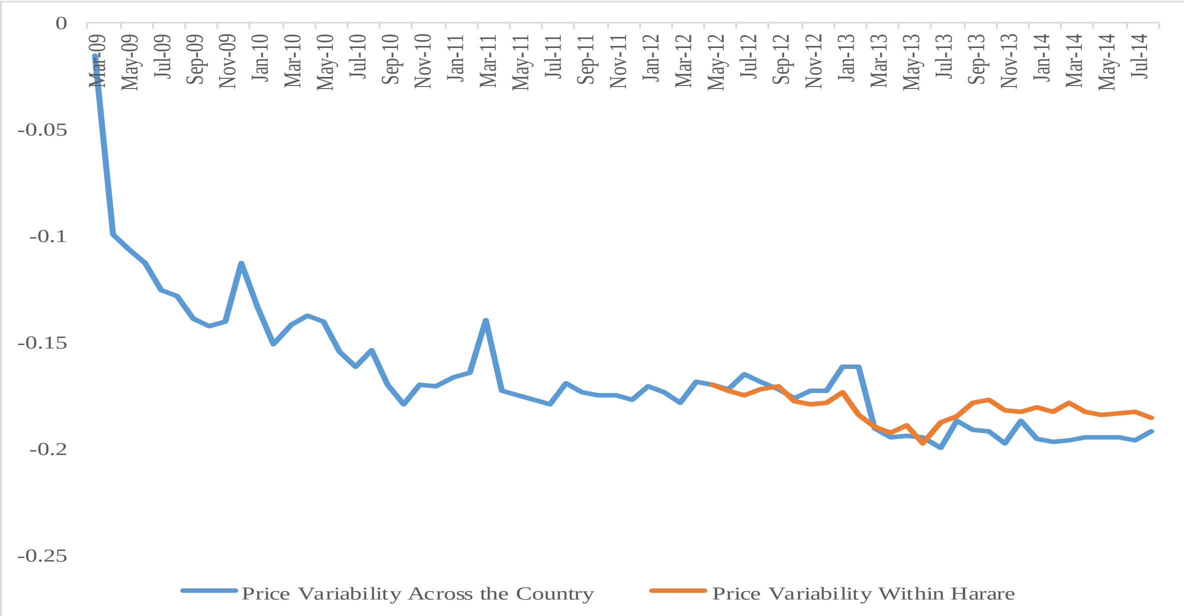

Figure 5 plots price dispersion across different provinces in Zimbabwe and price dispersion within retail outlets in Harare. Due to data limitations, prices for retail outlets within Harare only start from January 2012 to August 2014 with data for all the outlets across the country starting from March 2009 to August 2014. Price dispersion for within Harare co-moves together with price dispersion for all products in Zimbabwe. There is a huge fall in price dispersion at the beginning of the 2009. This corroborates with our earlier findings using city pairs data.

This section measure price dispersion within Zimbabwe using Harare and the natural benchmark. We show that price dispersion across different provinces in Zimbabwe sharply dropped soon after the introduction of a new currency system. The fall was observed within tradable goods compared to non-tradable which were fairly constant throughout the study period. We show that distance is positively related to price dispersion, with locations closer to Harare having a lower predicted price dispersion compared to locations which are farther away from Harare. Conclusively, there is evidence that prices across different provinces in Zimbabwe converged towards Harare prices with time.

CHAPTER 4

The changing retail landscape in Zimbabwe

Prior to the introduction of a new currency system, the retail trading industry was dominated by big supermarket chains. OK supermarket and Spar dominated the industry with TM taking the remaining market share. Small retailers were pushed out of the market due to the deteriorating trading environment. Due to hyperinflation and low capacity utilisation of the local manufacturing sector, the government started enacting price controls on basic commodities and this created shortages. This, coupled with foreign currency shortages, made it difficult for retailers to cover up for these shortages through imports. This had a huge impact on profits for the retailers and most of them liquidated and were pushed out of the market with the exception of the big retail chains which had 'good' balance sheets.

The introduction of a new currency system in Zimbabwe changed the retail landscape significantly. Inflation declined to an average of 3 percent ((IMF Country Report, 2009)), as foreign currency shortages were mitigated by the use of a basket of currencies dominated by the US dollar levelling the playing field of the retail trading sector. Small retailers took advantage of the stability in the market after the new currency system and took market share from the big supermarkets. This meant that the 'big' retail chains needed to strategize in order to recover the lost market share from smaller retailers. Big retailers started to invest more in their operations and started to offer more promotions in order to outcompete the small retailers.

How it influenced pricing behaviour?

The adoption of a new currency system not only meant that small retailer were only able to penetrate the market, but foreign competitors too and this increased competition. A key strategy which big retailers such as OK, Spar and TM started adopting was to streamline their procurement operations and leverage it so as to buy in bulk at discounted prices[33]. Small retailers were affected by this since they did not have a proper business model and could not afford to buy in bulk.

Since these big retail chains started buying in bulk at lower prices, they started repricing in order to push small retailers out of the market. However, the biggest challenge they started facing was the 'coarseness' of the new currency which was strong in value but less fine in terms of denominations. For example, retailers found it difficult to change the price for a loaf of bread, which was initially priced at $1 to $0.90 due to lack of change. This meant that for some products, retailers found it convenient for both to keep the price of bread at $1. Some retailers changed the prices and were giving sweets and other small products as change. This situation introduced another form of price stickiness which none has studied in literature.

However, as, the government of Zimbabwe introduced 'bond' coins whose value was at par with the US dollar in March 2015 in order to solve this stickiness in prices. The main aim of

[33] For example, prior to the introduction of a new currency system, most Spar retail outlets were operating independently. However, soon after the introduction of a new currency system, they streamlined their procurement processes and started buying in bulk and have a common warehouse.

this paper is to evaluate the impact of the introduction of bond coins on price stickiness of lower priced commodities. We posit that the introduction of these coins led to a downward shift in prices since retailers had scope to purchase at discounted prices, therefore passing this to consumers with lower prices.

Table 7.2: Impact of introduction of bond coins on price stickiness (year on year frequency of price changes)

VARIABLES	(1) Equation 1	(2) Equation 2	(3) Equation 3
Post intervention	-0.0414		
	(0.131)		
Transition		-0.403***	
		(0.0921)	
did	0.262***	0.308***	0.172
	(0.0476)	(0.0482)	(0.127)
Constant	0.655***	0.643***	0.857***
	(0.0451)	(0.0436)	(0.150)
Observations	1,738	1,627	1,366
R-squared	0.059	0.061	0.056
Number of unid	361	346	331
N	1738	1627	1366

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7.3: Regression discontinuity design

VARIABLES	(1) Equation	(2) Equation 2	(3) Equation 3
Post Intervention	0.681***	0.666	-0.114
	(0.108)	(0.414)	(1.200)
Trend	-0.00282***	-0.000130	-0.000895
	(5.92e-05)	(0.000134)	(0.000666)
Regression discontinuity	-0.00105***	-0.00101	0.000187
	(0.000162)	(0.000622)	(0.00181)
Constant	2.409***	0.0840	1.264***
	(0.0381)	(0.0865)	(0.430)
Observations	70,964	2,380	652
R-squared	0.104	0.007	0.004
Number of unid	4,705	358	160
N	70964	2380	652

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 7.2: Impact of introduction of bond coins (pooled set of products), RDD result

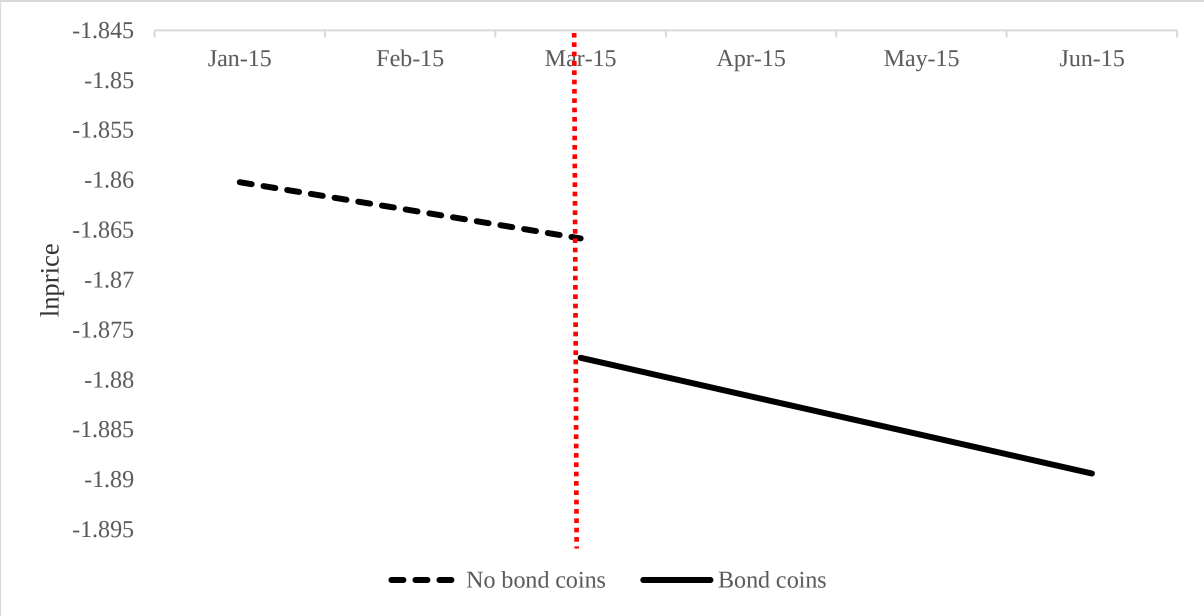

Figure 7.2 shows that there was a downward shift in prices in March 2015. This means that for a pooled set of products, consumers started paying less than there were paying before the introduction of bond coins.

Figure 7.3: Impact of bond coins for products priced at $1 the previous year, RDD result