Denominational inflation in Tanzania: The impact of cash transactions on price setting and monetary policy

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Abstract:

This study investigates how the limited divisibility of money affects price setting and inflation in Tanzania, a country with a reliance on cash transactions. Through analyzing bus fares and prices listed in both domestic and international online shopping platforms, the research highlights the economic implications of rounding prices to the nearest available currency denomination due to the absence of small denominations. The analysis reveals that ordinary bus users pay more due to price rounding to the nearest available denominations. Digital payment systems on the other hand, reduces the need for adjustments that inflate costs. Employing the Synthetic Difference in Difference method, the study compares Tanzania's Consumer Price Index (CPI) with countries possessing higher digital infrastructure indices, suggesting that digitalization can mitigate inflationary pressures from limited currency divisibility. The findings call for the promotion of digital payment systems to enhance monetary policy effectiveness, reduce transaction costs, and ensure price accuracy, thereby proposing policy directions for Tanzania to transition from cash-based to digital payment methods.

Key Words: *Denominational Inflation, Payment Systems, Currency, Inflation, Monetary Policy, Money.*

INTRODUCTION

Divisibility of money has been discussed by various scholars such as Berentsen & Rocheteau, (2002); Green & Zhou, (1998); and Lee & Wallace, (2006). Money's divisibility allows a government to create units that can be easily broken down for transactions, promoting equal exchanges of goods and services. Mishkin, (2012) writes five criteria for money to function effectively. On divisibility, which he mentions as one of the criteria he writes, 'it must be divisible so that it is easy to make change'. Without the ability to make change, the exchange becomes a bit challenging. In the exchange, either producer or consumer may be worse off if the divisibility is limited. That is, either, the consumer will pay more or less, the first favours the producer, and the former favours the consumer.

There is a consensus that before the 19th century, conveniently small denominations of currency were not widely accessible (Lee and Wallace 2006). While the problem of small change seems to be historical, it persists to the present time in some countries. For example, Hyperinflation made Zimbabwe introduce a banknote of 100 billion Zimbabwean Dollars, and during that time the loaf of bread was sold for more than 100 billion Zimbabwean Dollars (Coomer and Gstraunthaler 2011). Nyamunda, (2021) proves that the currency regime of Zimbabwe had difficulties in obtaining coins for use in smaller daily transactions, the Reserve Bank of Zimbabwe released bound coins totalling $10 million in denominations of 1, 5, 10, and 25 on December 18, 2015. In the 1980s coins which are less than 10 cedis were falling out in Ghana. Before that, the coins were starting from 5 pesewa (100 pesewa = 1 cedi)(Obuobi et al., 2020). That is, the problem with small change is not the historical problem, as it was in the 20th century, and it is in 21st century in some countries.

The number of denominations of the currency increases the efficiency of cash payments hence, the fewer denominations the less efficient the cash payments become (Yassine Bouhdaoui and Van Hove 2017). However, inflation makes some denominations out of circulation (Obuobi et al. 2020; Nyamunda 2021; Coomer and Gstraunthaler 2011; Linzmayer 2011). As demonstrated, there is clear evidence that the higher denominations of the circulating currency are the results of inflation. This causes the smaller units of currency to fall out of circulation. The phasing out of smaller units of money creates pricing problems because market players may not be able to set prices that are payable in the available denominations

Scholars have shown that cash payment systems are the costliest payment instrument for society. Bouhdaoui & Bounie, (2012) state that Central banks globally have consistently pursued strategies to minimize the expenses associated with banknote production. These approaches include measures like the withdrawal of certain denominations, replacing traditional paper banknotes with coins, and the adoption of innovative technologies. Withdrawing denominations as an approach to minimize costs needs a study to see if that way is efficient especially when a country's payment system relies much on cash payments.

Lee & Wallace, (2006) have shown the optimal divisibility of money, is related to the costs of producing and maintaining money. In this sense, the total cost of producing and maintaining money decreases in the size of the monetary unit. This means that the cost of providing the initial stock of money and the cost of maintaining the stock both decrease as the size of the monetary unit increases. As a result, the optimal degree of divisibility of money is influenced by finding a balance between the benefits of trade facilitated by having many small monetary

items and the costs associated with producing and maintaining those items. This idea is crucial in the cash payment system, but the world is in a digital era where money has become digital. Hull & Sattath, (2021) have revisited the properties of money, where the emphasis was not on the divisibility of the currency. As they considered non-physical currency some of the properties, they introduced are reversibility, throughput, untraceability and privacy.

In the big problem of small change, Sargent & Velde, (2002) ascertained that governments use a standardized approach for supplying and pricing coins and currency. The monetary authority establishes fixed prices by offering unlimited conversion of various denominations at set exchange rates. The small change is an issue with the physical currency. That is, if a country adapts the use of non-physical currency the problem will disappear. For example, in digital payments.

This paper discusses the effects of the limited number of denominations on the monetary policy. Inflation is among the macroeconomic problem that causes other macroeconomic problems like unemployment(Sasongko and Huruta 2019; Abu 2019). The long-run inverse relationship between inflation and unemployment is well explained in the Phillips curve (Hazell et al. 2022; McLeay and Tenreyro 2020). Inflation reduces the purchasing power of the consumers (Halim, Astuty, and Hubeis 2022). As limited denominational divisibility of money needs market player to set the price that can be paid by the circulating denominations. The failure to produce the smallest units the more the price and general price level increases.

There are limited studies on payment systems as one of the things that affects monetary policy. Existing studies discuss cost-push, demand-pull, built-in inflation and rising wages (Sharma and Yadgari 2023; Jain, Sharma, and Kumar 2022; Reis 2022; Lapavitsas 2022). This has made a discussion to be on supply side or demand side. There are limited studies on how the payment system can cause inflation. This study aims at introducing the concept of Transactional Inflation or Denominational inflation which explains how means of payment causes inflation.

Denominational inflation as on this study comes from the economy that uses more cash payments. It is a result of the limited divisibility of currency. The denominational inflation exists even when the product is divisible. For example, the product weighing 10.512 kilograms will need some small change to make the transaction fair, with the limited denominations in circulation the price will be approximated to the nearest units of circulating denominations. Nonetheless, some of the products are strictly indivisible and thus they need the divisibility of money to have a fair exchange.

This study examines the cash payment system, and how it causes denominational inflation. It has considered the fact that prices, after all other factors observed, will depend on the available denominations. The study used Tanzania as a case study. Recently, Tanzania had a challenge in transitioning from trial to consistent adoption of digital payment methods for purchasing goods (FinScope Tanzania 2023). The use of non-physical currency in Tanzania is not as big as in other countries. For example, in East Africa, Kenya uses mobile money more than Tanzania and Uganda (Suri 2017). This makes Tanzania the best-case study for this study as the adaptation of mobile payments is limited.

Monetary Policy in Tanzania

The Bank of Tanzania's (BoT) monetary policy is fundamentally designed to maintain inflation within a medium-term target of 5%, measured as the annual change in the Consumer Price Index (CPI). A stable inflation rate ensures predictability in the economy, fostering an environment conducive to investment and development. However, the BoT recognizes the inherent challenges of managing inflation in an open economy, particularly the impact of supply-side shocks and global commodity price fluctuations. These external factors, beyond the control of monetary policy, can occasionally lead to deviations from the inflation target. In addition to the external factors the BoT has not documented that the means of payments can also be a problem to the monetary policy. Florens Luoga, the then Governor of the BoT, highlighted the use of cash as a challenge to monetary policy during the inauguration of the BoT's Mwanza branch on July 13, 2021.

To achieve its inflation objectives, the BoT relies on the Central Bank Rate (CBR), which serves as the intermediate target. The CBR is set based on inflation forecasts and economic assessments, balancing the dual goals of inflation control and economic growth. Complementing this is the 7-day interbank cash market interest rate, which functions as the operating target. This dual-target system creates a structured pathway for achieving inflation and broader economic objectives.

BoT employs a range of monetary policy instruments to manage liquidity and influence inflation indirectly. Repurchase agreements (repo and reverse repo) are used for short-term liquidity management, allowing the Bank to adjust the money supply in response to market conditions. Open market operations, including the trading of debt securities and foreign currency, provide additional mechanisms for liquidity control. Structural liquidity is managed through tools such as the Statutory Minimum Reserve Ratio (SMR) and the discount rate. The BoT also offers standing lending facilities, such as intraday and Lombard loans, ensuring smooth banking operations and minimizing disruptions that could lead to inflationary pressures.

Despite its framework, the External shocks, such as fluctuations in global oil prices or disruptions in food supply chains, can exert upward pressure on inflation that monetary policy alone cannot mitigate. While the external shocks have been in number of literatures, the domestic challenges have not been discussed. In this study the domestic challenge of the denominational inflation is discussed to inform how central bank can control inflation. Central Bank can exert its powers through financial intermediaries in the financial market. But a good number of Tanzanians are financially illiterate(Capital Markets and Securities Authority 2022). While they are financial illiterate, they still do exchange and transact, this is the good line to start with when implementing monetary policy to financially illiterate people.

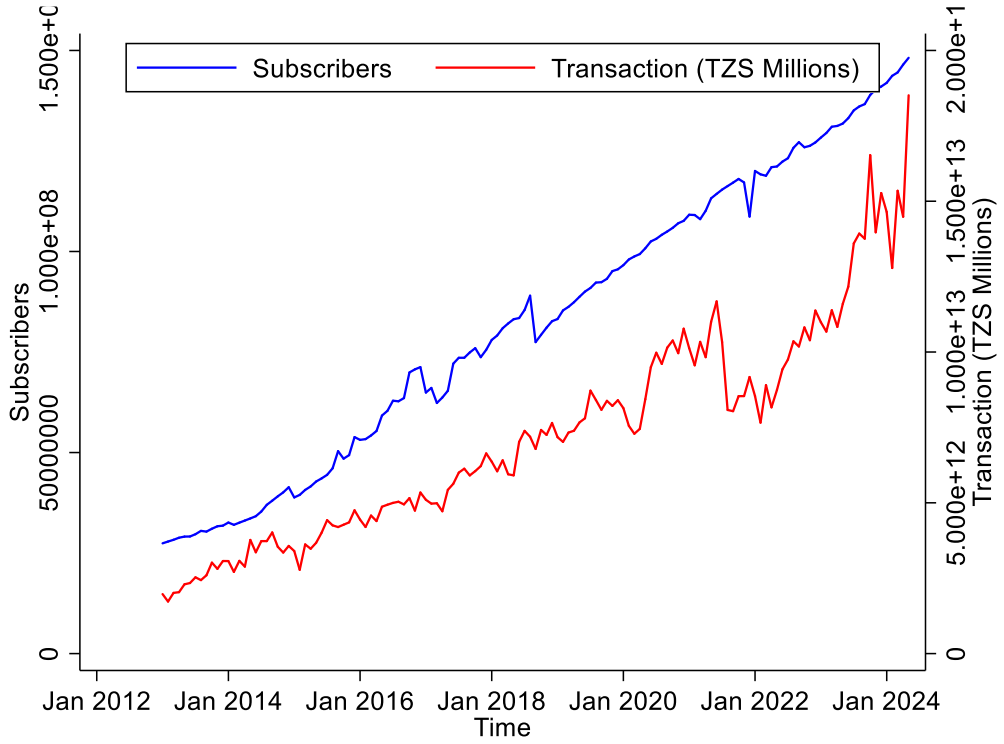
Mobile Money in Tanzania

Vodacom Tanzania implemented the use of Mobile phone-based money transfer technology called M-Pesa in April 2008 (Omwansa 2009). To 2024 there are six telecommunication companies which are offering the mobile money service. Global mobile money datasets from Global System for Mobile Communications Association (GSMA) have recorded that four mobile money services in Tanzania gives the service of merchant payment.

Mobile Money	Company	Launching date
Vodacom M-Pesa	Vodacom (Vodafone)	April 2008
Tigo Pesa	Tigo (Honora)	August 2010
Airtel Money	Airtel (Bharti Airtel)	April 2012
HaloPesa	Viettel eCommerce (Halotel)	October 2016
T Pesa	TTCL	August 2017
AzamPesa	AzamPay	March 2022

Table 1: *Mobile money in Tanzania and their launching dates*

The introduction of mobile money increased financial inclusion and financial deepening (Nyonzo 2022). This is from the fact the people who were limited to financial services can access the services using their mobile phones. Bank of Tanzania (BoT) has recorded Mobile transactions from 2008, however the data on monthly basis starts from 2013. And taking the year 2013 to May 2024, the average amount that every subscriber transacted in every month is 86,088 Tanzanian Shillings (31.92USD[1]). For the same period, every subscriber transacted on average three times a month.



Graph 1: Subscribers and total amount transacted

Digital infrastructure index for the year 2023 from International Monetary Fund (IMF) has shown that Sub-Saharan Africa has 0.06. Tanzania's index is 0.06, which is just as same as the sub-Saharan African digital infrastructure index. In East Africa, Kenya is the most advanced as it has 0.10 digital infrastructure index, followed by Rwanda, then Tanzania and Uganda. Similarly, on the mobile money transactions and payments these countries differ.

[1] Exchange rate pegged to 1 USD ≡ 2700 Tanzanian Shillings

In this study, in the first analysis Chinese online mall is compared to Tanzanian online mall. In the synthetic control as well the countries that Kikuu operates have been taken to create the synthetic control group. Kikuu operates in 21 countries of Sub-Saharan Africa.

S/N	Country	DII	S/N	Country	DII	S/N	Country	DII
1	Ethiopia	0.0511	8	Senegal	0.0802	15	Togo	0.0631
2	Ghana	0.0887	9	Nigeria	0.0796	16	Uganda	0.0629
3	South Africa	0.1240	10	Gabon	0.0760	17	Mali	0.0596
4	Kenya	0.0971	11	Cameroon	0.0676	18	Burkina Faso	0.0562
5	Rwanda	0.0835	12	Benin	0.0661	19	Malawi	0.0473
6	Côte d'Ivoire	0.0817	13	Zambia	0.0651	20	Congo	0.0456
7	Botswana	0.0814	14	Tanzania	0.0640	21	Congo, DRC	0.0378

Table 2: *Countries which Kikuu Operates and their Digital Infrastructure Index (DII)*

The Quantity Theory of Money

According to the quantity theory of money, variations in the money supply are the main factor influencing inflation. The theory suggests that substantial increases in the money supply led to corresponding increases in price levels. This relationship implies that inflation is primarily driven by monetary factors (Milton Friedman 1989). Although other elements like income levels, the demand for products, and the frequency of expenditure also matter, the influence of the money supply is thought to be greater.

According to Mishkin, (2012), the quantity theory of money explained changes in the level of prices for classical economics. They maintained that changes in the amount of money are the only factors that affect price levels.

Quantity Theory of Money uses the equation of exchange. The product of the money supply and its velocity over a year must equal nominal income, which is the total nominal expenditure on goods and services during that time, per the equation of exchange.

That is,

$$M \times V = P \times Y \ldots\ldots (1)$$

where M is the total quantity of money (the money supply), V is the velocity of money which is the turnover rate of money refers to how often, on average each year. P is the price level and Y is the aggregate output (income).

Rearranging the equation $P = \frac{M \times V}{Y} \ldots (2)$

The equation shows positive relationship between money supply and price level. But in the economy where the divisibility of money is limited, there is the adjustment unit. That the price will be rounded to the nearest units that can make the transactions.

Let the adjustment unit = μ, that is price level $P = P + \mu$

Then $P + \mu = \frac{MV}{Y}$ …. (3)

$P = \frac{MV}{Y} - \mu$ …. (4)

The equation 4 shows that the adjustment unit is negatively related to price level, and it is positively related to money supply.

Looking at the relationship to money supply

$M = \frac{Y(P+\mu)}{V}$ …. (5)

As for this, the more currency experiences the indivisibility, the more it increases the adjustment unit and that increases the demand for money.

Money supply affects the general price levels. However, for this study, it is explained that the money supply is also affected by available currency denominations. And this affects the money supply and the price level. This is on the fact that the producers do set prices depending on the available denominations.

Objectives

General Objective

To examine how the limited divisibility of money increases prices and price levels

Specific Objectives

i. Examining how the problem of small change affects price setting.
ii. Examining the divisibility problem in payment system.
iii. Examining the effects of digital payments to consumer price index.

Statement of the problem

The divisibility of money is a critical characteristic that ensures efficient and equitable transactions in an economy. Given the costs of issuing currency some of the economies that have higher denominations fail to print some smallest denominations. When money is not sufficiently divisible, challenges arise in setting prices for goods and services because producers will set the prices depending on the currencies in circulation. While the problem of small change is often considered a historical issue, it persists in contemporary economies, particularly those reliant on cash payments. Given the digital gap, developing countries uses cash more than the developed countries which are getting to cashless societies. This has implications for monetary policy, as inflationary pressures arising from limited currency divisibility, termed here as "denominational inflation", are not well understood or documented. Denominational inflation occurs when transactions are rounded to the nearest available denomination, leading to price distortions. This study aims to inform policy strategies for transitioning to digital payment systems and enhancing the effectiveness of monetary policy in cash-reliant economies.

Significance of the study

Adam Smith identified four functions of government, which were later expounded upon by Milton Friedman. Protecting individuals from coercion and facilitating are among the functions of the government (Milton Friedman and Friedman 1990). The money facilitates voluntary exchange, however, the limit on the divisibility of money limits the flexibility of price setting. The study is then significant by contributing to the ways that the government can facilitate exchange and control inflation. It provides a way to minimize the inflation that results from the limited divisibility of the currency especially when the commodity is indivisible. The study will give reasons as to developing countries to promote other electronic means of payment to escape the problem of small change which is the result of limited divisibility of currency.

Friedman argues that inflation is a monetary problem, and he mocked the well-known reasons such as weather, greedy businesspeople, grasping trade unions etc. He argues that the mentioned reason cannot produce money, that is, the government avoids the fact that it is the government that is responsible for inflation *ibid*. From the problem of small change, which is also the monetary issue. This study will show that the failure to facilitate exchange by using highly divisible payment systems causes inflation. This study provides its contribution to inflation and the science of payment system in fighting Inflation, which Friedman called a dangerous and fatal economic disease.

METHODOLOGY

Data Collection

This study used different data samples. Data samples were obtained from data from online shopping malls, data from Land Transport Regulatory Authority of Tanzania (LATRA) and sample from World Bank.

Two online malls which operates in Tanzania were used in this study to compare the denominations used. One is the domestic online mall, and the other is an international online mall. In the domestic online mall customers pay in cash, while in the international online mall, customers pay electronically but all cite prices in Tanzanian shillings. For the international mall, Kikuu the Chinese online mall was used as it operates in Tanzania. The domestic online shopping mall is Dar Shopping. On this, 100 pages of the websites were scrapped using Data Miner, the Chrome extension that is used for data scrapping. Dar shopping, the domestic online mall customer pays in cash after the delivery of the product, the price is cited in Tanzanian shillings. As for Kikuu a customer pays for the product online and the order is given to the dealer and delivering process starts. To get this in more mathematical way multivariable logistic model was employed. The multivariable model is utilized for analysis involving a single dependent variable and multiple independent (Ebrahimi Kalan et al. 2021). The model is given by the following equation.

$$\log\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6$$

Where $\frac{\pi}{1-\pi}$ is the binary independent variable market. Which is 1 if the market does not have online payment and 0 if the market uses online payment. x_1 is the binary for the last digit of the price listed in the market, 1 if the price has zero as the last digit and 0 if the price has non zero as last digit. x_2 represents last two digits of the price, 1 if the last two digits are “00” and

0 if the last two digits are not. x_3 represents last three digits of the price, 1 if the last two digits are "000" and zero if otherwise. x_4 represents the last two digits of the price, 1 if the last two digits are 50 and zero if otherwise. x_5 represents the last three digits of the price, 1 if the digits are 100 and zero if otherwise. x_6 represents last three digits of the price, 1 if the digits are 500 and zero if otherwise. β_0 represents intercept term. β_1 to β_6 represent the coeficients of the predictors.

The government of Tanzania sets prices for some of the services such as transport through Land Transport Regulatory Authority of Tanzania (LATRA). Hence, I used fares for commuter buses and long travel buses to check the additional amount that a person pays to escape the problem of small change. This is on the basis that LATRA calculates prices per kilometre, but the displayed price is the one that is adjusted to the denominations in circulation.

Headline Consumer Price Index (CPI) data for African countries was collected on annual basis from a global database of inflation at World Bank (Ha, Kose, and Ohnsorge 2023). Tanzania as a country of treatment was compared to the countries that have higher Digital infrastructure index. The assumption is the countries with higher digital infrastructure index have higher likelihood of being cashless than the countries with low digital infrastructure. Tanzania has digital infrastructure index of 0.063975, the countries used to create synthetic group are those which have the digital infrastructure index of more than 0.07 in sub-Saharan Africa. Making the results robust, the results will be compared to the results when the synthetic group has the digital infrastructure index of less than 0.05. In Synthetic difference in difference, number of mobile subscriptions per hundred people was used as covariates.

Data analysis and Econometric model

Descriptive analysis was employed for online mall prices and the bus fares. That is comparing observations in the data sets. Comparing means and the frequencies to come out with a conclusion. In bus fares, there were some multiplications and comparisons of means using a t-test to show the significance of the differences in means.

Synthetic difference in difference the method which was proposed by Arkhangelsky et al. (2021) was employed to show the causal relationship. Synthetic difference in difference method is an advanced approach that improves upon traditional difference-in-differences (DID) and synthetic control methods. It effectively addresses unobserved confounding variables, handles multiple treated units, and accounts for time-varying confounders, overcoming key limitations of both DID and synthetic control techniques. While this is the new method, Arkhangelsky et al. (2021) have shown that the method is more accurate as it gives low standard errors compare to Difference in Difference method and Synthetic control as they revisited the California smoking cessation program. The method has been employed by the number of researchers such as Li and Tang (2022); Berman and Israeli (2022); Bai et al. (2023); Campos, Coricelli, and Franceschi (2022); Mitre-Becerril and Chalfin (2021) in evaluating different policies.

Synthetic Difference in Difference uses unit weights. By applying unit-specific weights, Synthetic Difference in Difference matches observations in the control group with those in the experimental group. Time-specific weights are used to align pre-treatment observations with post-treatment ones. Together, these weights refine the identification and estimation process.

This ensures that the weighted average of Consumer Price Index (CPI) in the control group closely approximates that of the treated group. The result is a more accurate counterfactual analysis.

The weighted Average of the CPI for the control group is the following approximate,

$\sum_{i=1}^{N_{co}} \widehat{\omega}^{SDID} Y_{it} \approx N_{tr}^{-1} \sum_{i=N_{co}+1}^{N} Y_{it}$ ..... (1)

The independent variable is the CPI (Consumer Price Index), and the analysis uses countries as the unit of observation, where i denotes the country ($i = 1, 2, \dots N$). t denotes the year ($t = 1, 2, \dots T_{pre}$). N_{co} represents the number of control countries. $\widehat{\omega}^{SDID}$ is the weight of each country. Y_{it} denotes the dependent variable, which is CPI in this paper. N_{tr}^{-1} denotes the reciprocal of the number of treat country.

The treatment effects were determined by measuring the difference between the outcomes of the experimental and synthetic countries. Following the principles of SDID, the estimation process is outlined as follows:

First, compute the regularization parameters. This is achieved through the following steps:

$\zeta = \left(N_{tr} T_{post}\right)^{1/4} \widehat{\sigma}$ with $\widehat{\sigma}^{\,2} = \frac{1}{N_{co}(T_{pre}-1)} \sum_{i=1}^{N_{co}} \sum_{t=1}^{T_{pre}-1} (\Delta_{it} - \overline{\Delta})^2$,

where, $\Delta_{it} = \mathrm{Y}_{i(t+1)} - \mathrm{Y}_{it}$ and $\overline{\Delta} = \frac{1}{N_{co}(T_{pre}-1)} \sum_{i=1}^{N_{co}} \sum_{t=1}^{T_{pre}-1} \Delta_{it}$

Where ζ represents the regularization parameter, T_{post} denotes the number of months since the implementation of the digital payments (M-pesa), and T_{pre} refers to the period before the M-pesa.

Next, the weights ($\widehat{\omega}^{SDID}$) for each country are determined using the following formula:

$\left(\widehat{\omega_0}, \widehat{\omega}^{sdid}\right) = \underset{\omega_0 \epsilon \mathbb{R},\, \omega \epsilon \Omega}{arg\ min} \ell_{unit}(\omega_0, \omega)$ where,

$\ell_{unit}(\omega_0, \omega) = \sum_{t=1}^{T_{pre}} \left(\omega_0 + \sum_{i=1}^{N_{co}} \omega_i Y_{it} - \frac{1}{N_{tr}} \sum_{i=N_{co}+1}^{N} Y_{it}\right)^2 + \zeta^2 T_{pre} \parallel \omega \parallel_2^2$,

$$\Omega = \left\{ \omega \epsilon \mathbb{R}_+^N : \sum_{i=1}^{N_{co}} \omega_i = 1, \omega_i = N_{tr}^{-1} \text{ for all } i = N_{co}+1, \dots, N \right\}$$

$\mathbb{R}_+$ denotes the positive real lines

Where $\widehat{\omega}^{sdid}$ represents the country weights, $\zeta^2 T_{pre} \parallel \omega \parallel_2^2 2$ serves as the penalty term, designed to address overfitting and enhance the dispersion of the chosen control group. The definitions of the other variables remain consistent with those previously described.

Next, the time weight is determined using the following formula:

$\left(\hat{\lambda}_0, \hat{\lambda}^{sdid}\right) = \underset{\lambda_0 \epsilon \mathbb{R},\, \lambda \epsilon \Lambda}{arg\ min} \ell_{time}(\lambda_0, \lambda)$ where

$$\ell_{time}(\lambda_0, \lambda) = \sum_{i=1}^{N_{co}} \left(\lambda_0 + \sum_{t=1}^{T_{pre}} \lambda_t Y_{it} - \frac{1}{T_{post}} \sum_{t=T_{pre}+1}^{T} Y_{it} \right)^2,$$

$$\Lambda = \left\{ \lambda \epsilon \mathbb{R}_+^T : \sum_{t=1}^{T_{pre}} \lambda_t = 1, \lambda_t = T_{post}^{-1} \text{ for all } t = T_{pre} + 1, \ldots, T \right\}$$

Here, $\hat{\lambda}^{sdid}$ represents the temporal weight. Unlike the country weights, no penalty term is applied in the optimization process for determining the temporal weights. The SDID method accounts for the strong correlation of observations within the same province across different years. The definitions of the other variables remain consistent with those previously described.

Finally, the estimated SDID parameters are computed using the following equation:

$$(\hat{\tau}^{sdid}, \hat{\mu}, \hat{\alpha}, \hat{\beta}) = \underset{\tau, \mu, \alpha, \beta}{arg\ min} \left\{ \sum_{i=1}^{N} \sum_{t=1}^{T} (Y_{it} - \mu - \alpha_i - \beta_t - W_{it}\tau)^2 \hat{\omega}_i^{sdid} \hat{\lambda}_t^{sdid} \right\}$$

RESULTS

Bus fares

The Land Transport Regulatory Authority (LATRA) in Tanzania, gives new bus fares after having discussion with stakeholders. Recently, its regular meeting on October 25, 2023, approved fare revisions for both urban and long-distance buses, ensuring that the revised fares considered fundamental factors to maintain service availability and affordability for users. The Board approved the use of the new fare. The approved fare adjustments are analysed in the table 3 and table 4.

Distance	Previous Price (P_b)	Calculated Price (P_t)	Displayed/Paid Price (P_d)	Adjustment Unit (μ) ($P_d - P_t$)
<10KM	500	601.22	600	-1.22
11 to 15 KM	550	685.14	700	14.86
16 to 20KM	600	804.08	800	-4.08
21 to 25KM	700	897.22	900	2.78
26 to 30KM	850	1087.64	1100	12.36
31 to 35KM	1000	1284.87	1300	15.13
36 to 40KM	1100	1407.66	1400	-7.66
Σ	5300	6767.83	6800	32.17

Table 3: *Fares for Tanzanian urban buses (commuter buses)*

Data Source: LATRA, 2023

For the buses of long distances, the prices are charged in kilometres (LATRA 2023b). New fares were announced in November 2023.

Class	Old fare (in Tsh)	New Fare (in Tsh)
Ordinary Bus	41.29	48.47 Tsh
Semi Luxury Bus	56.88	67.84 Tsh

Table 4: *Old and New bus fare per Kilometer in Tanzanian Shillings*

The prices are listed on the LATRA fare document (LATRA 2023a).

Data from LATRA shows there are 1262 bus routes, however, some of the routes are the reverse routes. For example, the data has listed the route from Lindi region to Mtwara via Mingoyo, but then lists the route from Mtwara region to Lindi via Mingoyo, this has the same price and same distance. I have had to remove the duplication problem and thus remained with 657 routes. The routes have mentioned the distance in Kilometers and therefore the calculated price is the price per kilometer times the distance of the route.

For semi-luxury the suppliers are paid less than the required amount, while for ordinary customers are paying more. Because adjustment unit is the paid price minus the calculated price, when it is negative it means calculated price is greater than the displayed price. When it is positive, it means displayed price is greater than the calculated price.

Adjustment Units (Average)	Year 2022	Year 2023
Ordinary bus	566.4218	266.1164
Semi-Luxury bus	-0.975972	-13.09237

Table 5: Summary for the long journey buses and adjustment unit

61% of the ordinary buses' fares are less than the calculated price, and 39% of the fares are more. For semi-luxury buses, 47% pay less and 53% pay more than the calculated prices. On average the passages pay 13.10 Tsh less than the calculated fares for 2023.

Using the t-test to compare fares for those who pay more and those who pay less in ordinary buses the result is significant that people are paying more than the calculated fare. It is also significant that people using ordinary buses pay more than the semi-luxury busses.

Online mall prices

Taking the domestic online market, Dar Shopping I scrapped the first 100 pages, and I removed the duplicate products which made data remain with 2133 observations, that is the price and the product name. The minimum price for the products I scrapped is 150 Tsh (0.05USD) and the highest price is 22,862,500Tsh (8,467.59USD). In Kikuu, the online Chinese mall that operates in Tanzania, the issues are different. Kikuu uses electronic payments that are available in Tanzania such as mobile money, and Kikuu has a wallet, the K-Pay. Customers may deposit money in K-Pay and start marking payments to purchase a product at Kikuu. There was a total of 4,954 observations collected from the Kikuu online market. Some variables were randomly removed to remain with 2133 observations, the number that is equal to the observation in Dar shopping mall. The minimum price collected is 5,394 Tsh (1.99USD) and the maximum price is 663,710 Tsh (245.82USD).

While the 50Tsh coin is still in use, the data shows it is less cited unit when people pay in cash. In Dar shopping mall only 2.58% of the prices listed has 50 as its last two digits, and in Kikuu mall it is only 5.44%. Taking another value, which is 100 the data shows Dar shopping mall has 0.42% and Kikuu has 0.47% of the prices listed have 100 as last three digits. And taking another value that is 500, Dar shopping has 11.48% of the listed prices having 500 as its last digits. While Kikuu has no price which ends with 500Tsh. This is summarized in table 6.

		Last digits = 50	**Last digits = 100**	**Last digits 500**
Kikuu	Yes	5.44	0.47	00.00
	No	94.56	99.53	100.00
Dar Shopping	Yes	2.58	0.42	11.58
	No	97.42	99.58	88.42

Table 6: *Last digits of the prices cited at Kikuu mall and Dar shopping in %*

Checking the zeros in the last digits also gives the picture on which market lists the prices which show high divisibility. Dar shopping has only 1.17% of its prices which have the non-zero unit as its last digit while Kikuu has 44.02%. This means, Dar shopping does not list the prices which have the smallest units while Kikuu has the smallest units. When it comes to last two digits, Dar shopping 3.84% of the prices which do not have two zeros at the end while Kikuu has 93.86%. This means Kikuu's prices are more divisible compared to Dar shopping by checking the last two digits of their prices. As for the last three digits of the prices, Dar shopping has 24.14% of its prices having no three zeros as the last digits while Kikuu scored 99.39% as it is summarized in table 7. By checking the last digits, the Kikuu mall shows using smallest monetary units compared to Dar shopping mall which is cash based.

		Last three digits	**Last two digits**	**Last single digit**
Kikuu	Zero	0.61	6.14	55.98
	Non-Zero	99.39	93.86	44.02
Dar Shopping	Zero	75.86	96.16	98.83
	Non-Zero	24.14	3.84	1.17

Table 7: *Last digits of the prices cited at Kikuu mall and Dar shopping in %*

Using logistic regression to determine the likelihood of the means of payments and their effects to the price setting the outcome is as shown in table 8. The model achieved a significant fit, as indicated by the Wald chi-squared statistic 413.05 and p-value <0.001 demonstrating that the predictors collectively explain a substantial proportion of the variance in the payment method.

The coefficient for last digit in price is −6.1598 which indicates a significant and negative association with cash-only markets. This suggests that products priced with a zero as the last digit are significantly less likely to be found in cash-only markets compared to markets supporting electronic payments. The coefficient for last two digits is 6.6539 and significant. This suggests that prices ending in "00" are strongly associated with cash-only markets. This indicates that such round pricing is more commonly used in domestic, cash-driven transactions. The coefficient for last three digits of the price is 4.3300 and significant. This implies that prices ending in "000" are more likely to appear in cash-only markets. Such pricing may be reflective of the preference for whole-number denominations in cash transactions.

The coefficient for 50 as last two digits in price is 5.4134 and significant. This suggests that prices ending in "50" are more frequently associated with cash-only markets, likely due to the convenience of rounding for cash payments. The coefficient for 100 as last three digits is −0.5995 but not statistically significant. This indicates no strong evidence that prices ending in "100" are more or less likely to be associated with either type of market. The coefficient for 500 as last three digits of the price is 17.7961 but not statistically significant. This limits any meaningful interpretation for this variable.

Predictors	Coefficients (β)	Std. Err.	z	P>z	95% Conf.	Interval
Last digit	-6.159796	.7077276	-8.7	0.000	-7.54692	-4.77268
Last 2 digits	6.653883	.7181835	9.26	0.000	5.24627	8.061497
Last 3 digits	4.330038	.3040726	14.24	0.000	3.734066	4.926009
50 as last digits	5.413402	.7264174	7.45	0.000	3.98965	6.837154
100 as last digits	-.5994576	.4754161	-1.26	0.207	-1.53126	0.332341

500 as last digits	17.79605	596.081	0.03	0.976	-1150.5	1186.093

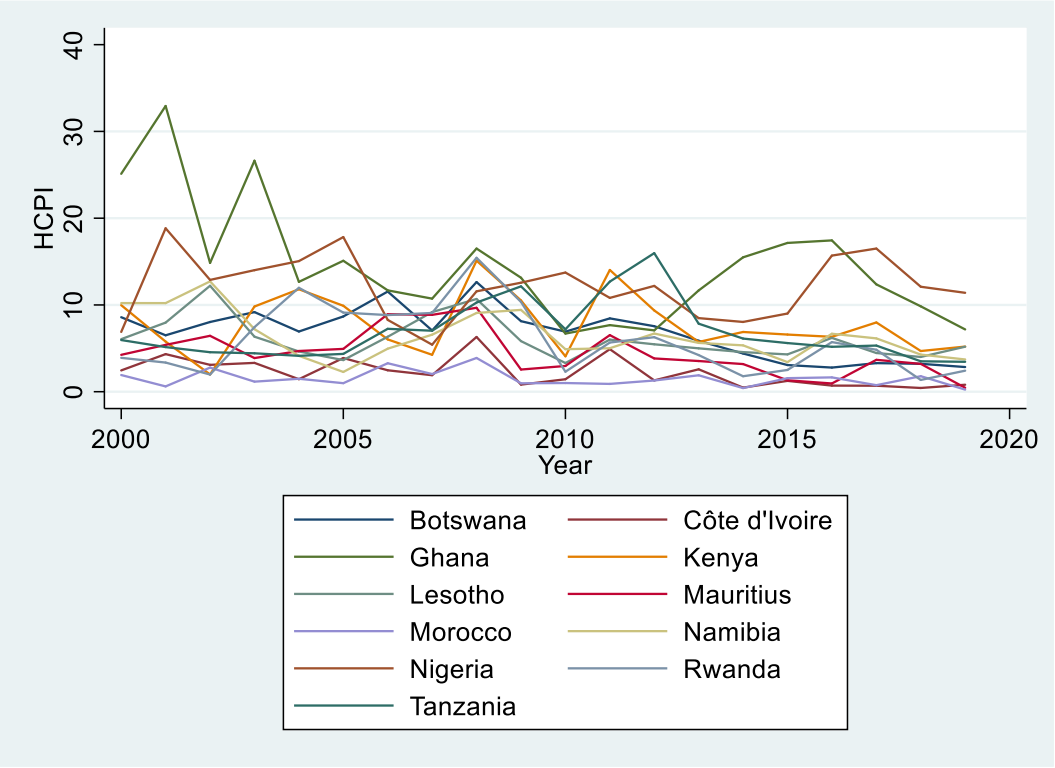
Table 8: Logistic regression results

Pricing patterns ending in “00,” “000,” or “50” are significantly more prevalent in cash-only markets, suggesting a tendency toward round-number pricing in such contexts. Pricing with a single zero as the last digit is significantly less common in cash-only markets, reflecting the potential influence of electronic pricing standards in international online platforms.

Pricing patterns ending in 100 and 500 lack sufficient evidence for a definitive association with either market type. This highlights the influence of pricing strategies on payment methods in the Tanzanian online marketplace.

Synthetic Difference in Difference

The data has a 220 as a total number of observations and 11 cross-sectional units which are countries for this study. The period for each unit is 20. For the overall, arithmetic mean across observation is 6.802016 and standard deviation is 4.948507. Minimum value of CPI is 0.24 and maximum is 32.932. In between the standard deviation is 3.808202. This shows how much HCPI varies across different units. The minimum average across units is 1.532421 and 14.59573 is the maximum average CPI across the units.

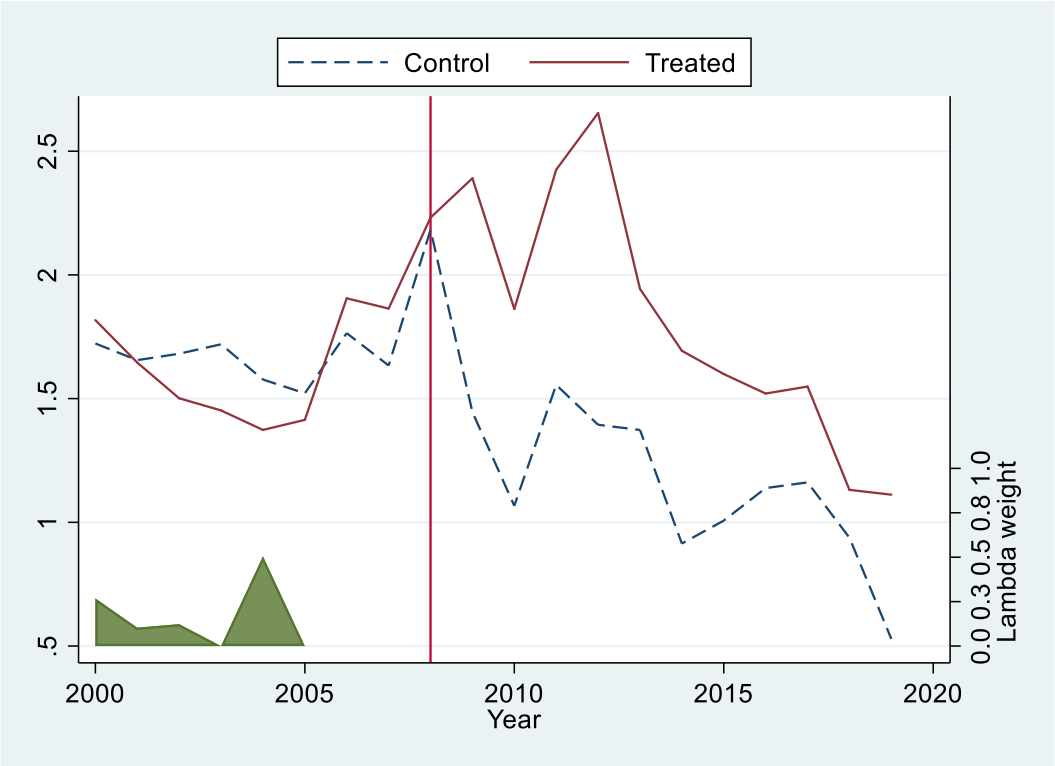


Graph 2: The Consumer price index

Within groups the standard deviation is 3.353135. This measures the variability of CPI within each unit over time after subtracting the unit's mean. It shows how much CPI fluctuates within a unit over the time periods. The lowest deviation being -1.09857 and 25.1383 is the highest deviation from a unit's mean CPI.

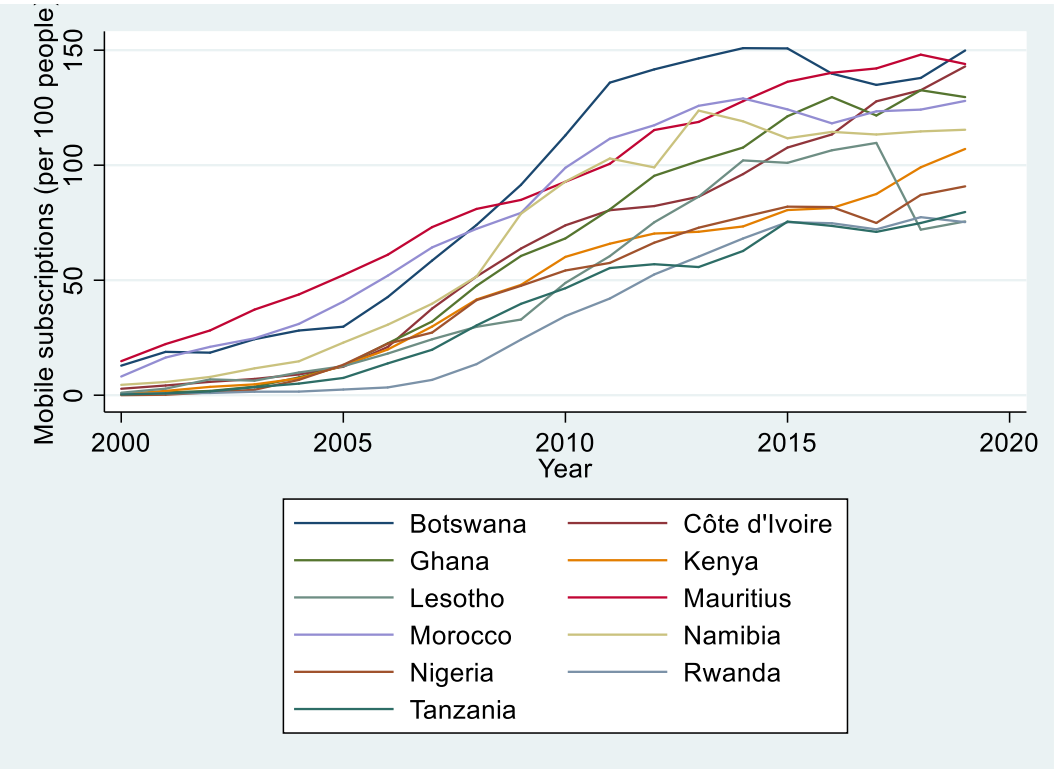
The Synthetic difference in difference result for this shows how Tanzania is affected and graph 3 is the graphical output produced from the model. Average Treatment Effect on the Treated

is 0.71808: This is the estimated effect of the treatment on the treated group in terms of logarithm of CPI. Since it's a logarithmic scale, this can be interpreted as an approximate percentage change; specifically, an increase of about 71.8% post-treatment compared to the counterfactual scenario without treatment. This is statistically significant as p-value is 0.031, confirming that the observed effect is highly unlikely to be due to random chance.



Graph 3: Graphical Output of Synthetic difference in difference. Control group has Digital Infrastructure index of greater than 0.07

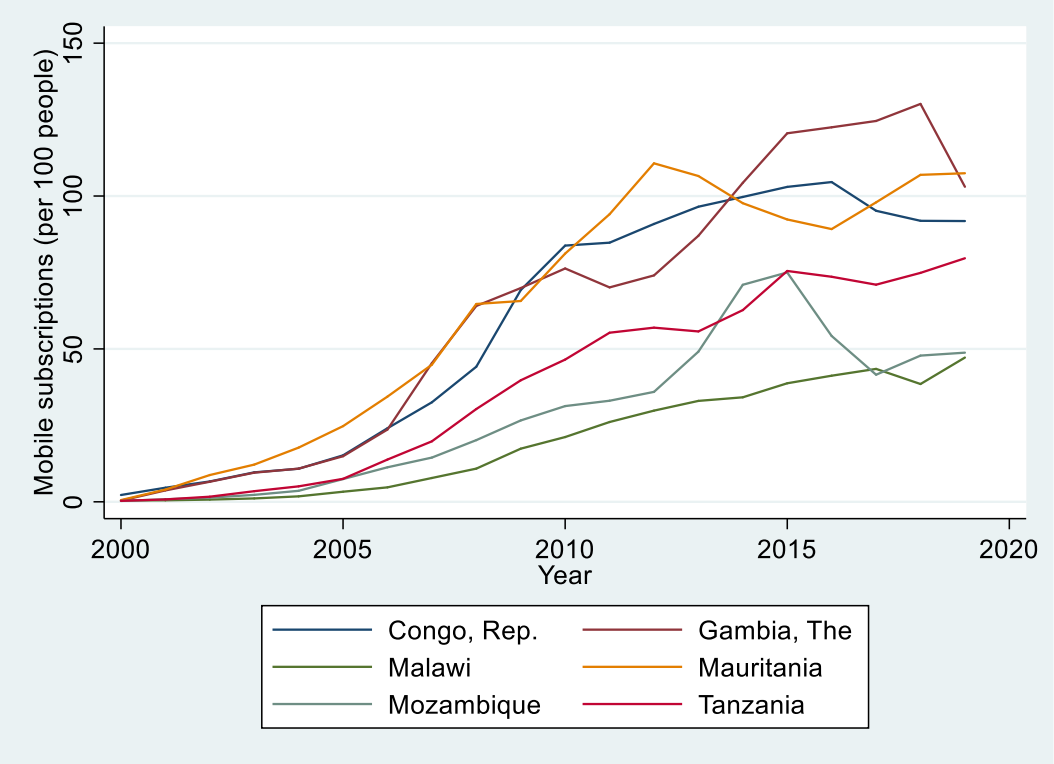
The graphical output shows that CPI for Tanzania was below the synthetic group until after 2005 where countries picked and increased the use of digital means of payments. It is after 2005 that even the number of mobile subscribers per 100 people increased as shown in Graph 4.



Graph 4: The mobile service subscribers per 100 people

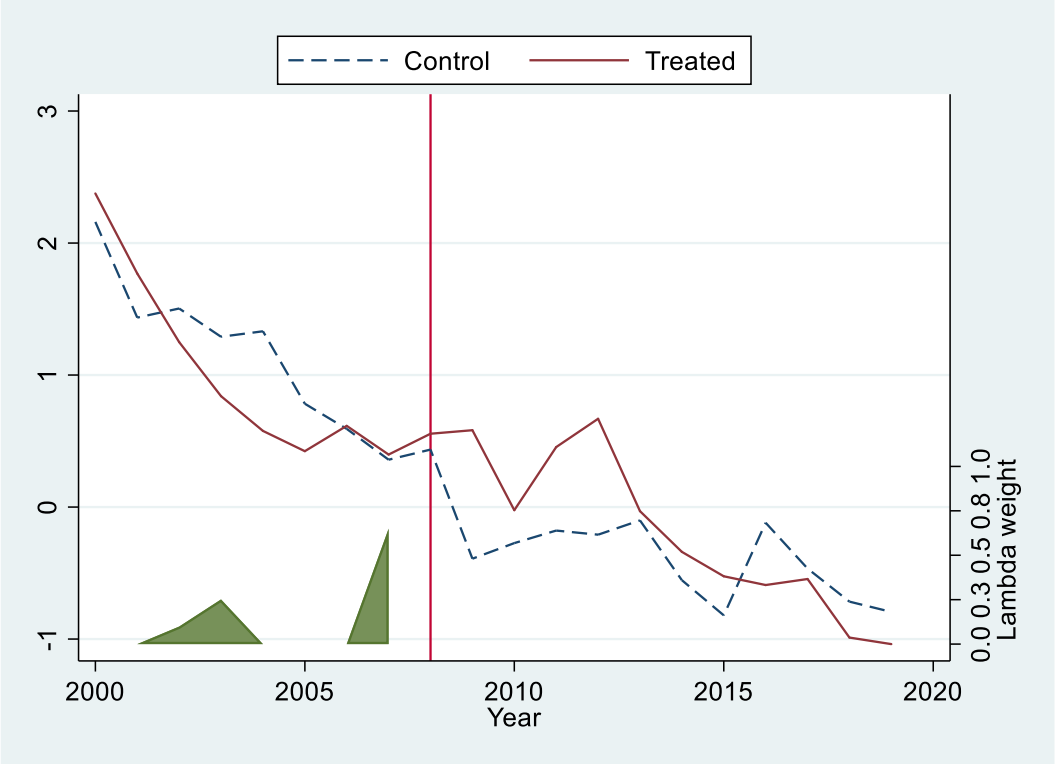
When using the countries with less than 0.05 digital infrastructure index, the number of observations goes down to 120 with six cross-sectional units. The average CPI across all observations is approximately 7.22, with a standard deviation of 5.59, indicating a considerable spread in inflation rates over the dataset. The average standard deviation between countries is 3.71, showing that there's significant variation in average inflation rates across these countries. The average standard deviation within each entity over time is 4.44, which is higher than the between variation, suggesting that inflation rates can fluctuate significantly over time within each entity.

As for mobile cellular subscriptions per 100 people, graph five shows the trends for each country. The mean subscription rate is about 45.31 per 100 people, but with a very high standard deviation of 37.72, indicating a wide range in mobile phone usage across the sample. There is a moderate variation with standard deviation of about 18.68 in average mobile subscriptions between countries. This is lower than the within variation, suggesting that while there is diversity in mobile use across countries, changes within each entity over time are even more pronounced. The within-country variation has standard deviation of 33.61 which is high, highlighting significant changes in mobile subscription rates over time for each entity.



Graph 5: Mobile service subscriptions for the countries with less than 0.05 Digital infrastructure index

The Synthetic difference in difference results for both are shown in table 9. As for the results when the digital infrastructure index low compared to the Tanzanian index is insignificant. The average treatment effect is 31%. This is low compared to when the digital infrastructure index is higher than that of Tanzania. Graph 6 which is the graphical output of the synthetic difference in difference shows the trends of CPI from 2000 to 2022.



Graph 6: Graphical Output of Synthetic difference in difference. Control group has Digital Infrastructure index of less than 0.05

LogHCPI	ATT	Std. Error	t	P-value	95% Confidence interval	
Treat (DII> 0.07)	0.71808	0.33283	2.16	0.031	0.06575	1.37040
Treat (DII<0.05)	0.31010	0.94641	0.33	0.743	-1.54484	2.16503

Table 9: Results for the synthetic difference in difference

DISCUSSION

The lack of some currency denominations because of limited divisibility of money affects the price setting and the price level. One of the key findings of this study is the pervasive impact of denominational constraints on pricing. The absence of smaller denominations forces businesses to round prices to the nearest available unit, often inflating costs for consumers. This problem is particularly evident in transport services. Ordinary bus users bear a disproportionate burden, paying more than calculated fares due to rounding. Conversely, semi-luxury bus fares, are sometimes set lower than calculated costs, negatively affecting producers. This dual impact illustrates how denominational limitations exacerbate economic inequities.

From the online market, the prices are using even the smallest units when using digital payment system. Cash transactions in markets often require rounding prices to 100 Tsh. Prices rounded to the nearest available denomination leads to higher consumer prices. This is evidenced by the low percentage of prices ending in non-zero digits or small denominations like 50 or 100 Tsh in Dar shopping mall which uses cash.

Digital payment systems present a viable solution to these challenges. Unlike cash transactions, digital platforms allow for precise pricing, eliminating the need for rounding. Data from Kikuu shows that digital transactions support finer price granularity, ensuring prices reflect actual values. Electronic payment reduces the need for price rounding and thus maintaining price accuracy. This is reflected in the higher frequency of prices with non-zero last digits and smaller units of currency, which supports a more efficient market dynamic. The logistic regression analysis confirms these observations, showing a significant association between cash-only markets and pricing strategies that favor round numbers, which are less flexible and less consumer-friendly in terms of price fairness.

The study also finds that countries with higher digital infrastructure indices experience less inflation, suggesting that digital payment systems can act as a buffer against denominational inflation. Tanzania experiences high consumer price index than other countries that have higher digital infrastructure index. This suggests that digitalization can mitigate the inflationary pressures caused by limited currency divisibility.

Moving to electronic payments is going with the pace of currency evolution. Since the barter system, commodity money and fiat money. Remaining in the previous forms with little effort to migrate into the new forms of money costs the nation. This calls for increasing adoption of digital payment systems to circumvent the issues of small change.

CONCLUSION

Government actions frequently result in significant advantages for a select few, while inflicting minor burdens on a larger number of individuals (M Friedman 1993). In this issue, people on the demand side, who are more than people on the supply side are impacted by the problem of the limited divisibility of money. Consumers who are using cash payments are paying more than the exact amount when the divisibility of money. The results for the bus fares show that the ordinary people pay relatively more. This suggests that the problem of limited divisibility of money affects the people of low income more than the other income classes.

While the problem has been proved in the bus fares. The online mall that uses non-cash for payments has shown high level of dividing the currency than the mall that uses cash. This makes it logical to say that digital payments divide the money more. And that is giving the customers the price that is the real one without the need for adjusting by rounding the currency to the nearest denomination. The digital payments are affected by infrastructure index and the costs for transactions. I have shown how the cost of transaction affects the how people use the service (Nyonzo 2024; 2022). That is to say, the good way of promoting digital payments is by improving digital infrastructures and making the transaction costs low. And as for this study, it is logical to suggest that the digital transaction cost should not exceed the adjustment unit.

Looking at the consumer price index, the study suggests that the higher the digital infrastructure index the more likely the consumer price index lowers. The more digitalized the country is the more the digital payments are used. Central banks perform a function of regulating the price level and they are in the supply side of money. This adds another way of regulating price by making the regulation that promotes the usage of digital currency than cash.

In Tanzania, like many other countries, cash payments affect the efficiency of Monetary Policy. However, the study like those of Mawejje & Lakuma, (2019); Wiafe et al., (2022) have shown

that mobile money possesses the capability to enhance the efficacy of executing monetary policy. Popovska-Kamnar, (2014) argued that the impact of electronic money on monetary policy becomes evident when considering its capacity to replace physical currency in circulation. Thus, the use of electronic payment systems will not only benefit the market players but also the central banks. And for the prevalence of mobile money in Tanzania, the central bank needs to regulate how prices are set to make it affordable and desirable means of payments.

The central banks will benefit in two ways, first for reducing the cost of producing money and also for making the monetary policy even more efficient. In encouraging electronic payments, governments which relatively rely more on cash should make the services available and cost-effective.

This study leaves the area for further research, that is, to determine the cost for transaction for digital payments. Recently, customers have been charged when they pay for goods. If the transaction charges are greater than the adjustment unit in cash payment, the problem will persist, although will be in another form.

The move towards digital payment systems appears not only as an evolution in currency usage but also as a critical strategy for mitigating the economic distortions caused by limited currency divisibility in Tanzania. This transition could lead to more equitable pricing, control inflation, and foster a more inclusive economic environment.

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APPENDIX

Repository for data and do files

Files used for analysis are available at Open Science Framework (OSF) repository https://osf.io/6wqxf/

Stata Results

```
. sdid logHCPI ST Year treat, vce(placebo) covariates(logMob, projected) seed(1234) graph g1on
Placebo replications (50). This may take some time.
----+--- 1 ---+--- 2 ---+--- 3 ---+--- 4 ---+--- 5
..................................................     50

Synthetic Difference-in-Differences Estimator
```

logHCPI	ATT	Std. Err.	t	P>|t|	[95% Conf.	Interval]
treat	0.71808	0.33283	2.16	0.031	0.06575	1.37040

```
95% CIs and p-values are based on large-sample approximations.
Refer to Arkhangelsky et al., (2021) for theoretical derivations.
```

Stata Results for the Digital Infrastructure index greater than or equal to 0.07

```
. sdid logHCPI ST Year treat, vce(placebo) covariates(logMob, projected) seed(1214) graph
Placebo replications (50). This may take some time.
----+--- 1 ---+--- 2 ---+--- 3 ---+--- 4 ---+--- 5
..................................................     50

Synthetic Difference-in-Differences Estimator
```

logHCPI	ATT	Std. Err.	t	P>|t|	[95% Conf.	Interval]
treat	0.31010	0.94641	0.33	0.743	-1.54484	2.16503

```
95% CIs and p-values are based on large-sample approximations.
Refer to Arkhangelsky et al., (2021) for theoretical derivations.
```

Stata results for the Digital Infrastructure index less than or equal to 0.05