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Enhancing Growth and Productivity Through Mobile Money Financial Technology Services: The Case of M-Pesa in Kenya

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Abstract

Kenya's financial industry has been revolutionized and progressing to digital transformation since M-pesa, a mobile money financial technology service, was introduced in 2007. An M-pesa account allows subscribers to send and receive payments as well as store money. As the digital system grew rapidly, a high percentage of Kenyan households gained access to this service, subsequently helping the unbanked and underbanked populations toward broader financial inclusion. As an efficient and highly adaptable payments system communicating across all markets in the economy, M-pesa has contributed to financial deepening, hence promoting economic development. This study analyzed the effects of mobile money financial technology services on Kenya's output growth and productivity. The findings suggest evidence of a structural change in the growth of output and total factor productivity when M-Pesa was introduced. Mobile Money was established to have had a significant positive effect on enhancing output productivity and output growth.

Keywords: digital financial services, financial technology, mobile money, output growth, output productivity

1. Introduction

Mobile money is simply defined as the delivery of financial services via a mobile phone (UNCTAD, 2012; Ndungu, 2021). It is a digital system where users can deposit, withdraw, and store money in their mobile phones, as well as have access to three essential mobile money financial services namely mobile transfer, mobile payment and mobile banking. Mobile transfer is where one can send money to or receive money from other registered mobile phone users. Mobile payment, on the other hand, is where one can pay for goods and services, while mobile banking services help access one's traditional formal bank account through their mobile phone. An account in a traditional banking institution, however, is not a necessity for one to carry out mobile payments or mobile transfers. Accessing mobile money services requires one to have a registered Subscriber Identity Module (SIM) card, a mobile wallet- electronic money (e-money) account, and a Personal Identification Number (PIN) to ensure the safety of the account (APCOM, 2014).

The mobile money ecosystem, which is a network of partnerships, is made up of five key stakeholders. These are: (i) the mobile network operators who supply telecommunication services; (ii) the agents who serve as the customer's primary point of contact and provide deposit and withdrawal services; (iii) the commercial banks and fintech companies who offer banking solutions; (iv) the retail outlets providing business-to-consumer transactions, mainly mobile payments; and finally, (v) the regulators who create the guiding framework in which the players are to operate (Shrier, Canale, & Pentland, 2016).

In Kenya, the mobile money services financial innovation is popularly known as M-pesa. Launched in 2007, it is considered the first major mobile money service in the world (Ndungu, 2021). Its development is regarded as the third wave of financial technology (FinTech) enabled by the proliferation of mobile phone use, although internet connectivity is not a necessity (Chitavi, Cohen, & Hagist, 2021). Contrary to other advancements of earlier FinTechs, which relied on cutting-edge and new technology, mobile money, also called the African FinTech wave, is an application of existing technology, the mobile phone. The first wave of fintech occurred in 1950 in the USA with the introduction of credit payments for consumers and later led to the use of automated teller machine. The second wave happened in Asia in the 2000s, specifically in China which was marked by the invention and adoption of payment platforms such as WeChat and Alipay (see Chitavi et al., 2021).

In Kenya, M-pesa mobile money financial technology service has successfully penetrated virtually all sectors of the economy, including banking, retail business, transport, and utilities, as well as government institutions (Ndungu, 2021). It has revolutionized consumers' access to banking services, eliminating geographical and physical distance constraints. It has also made possible real time urban-to-rural remittances for urban dwellers with relatives in rural areas. For commercial banks, it serves as a technological platform to manage micro accounts and plays an intermediation role in handling large deposits from micro savers. Moreover, adopting the digital system has reduced transaction costs due to less dependency on physical services in the banking hall as people can conduct business using their M-pesa linked bank accounts. Additionally, consumers use the mobile money to make payments for transportation and utilities, thus avoiding queues. Further, the rapid growth of the mobile money payment system has enabled the Kenyan government to digitize its various services for more efficient service delivery (see Ndungu, 2021).

M-pesa has a tremendous positive impact on Kenya's population and economy. First and foremost, mobile money financial technology has advanced financial inclusion for the unbanked and underbanked populations. After a decade of operation, M-pesa facilitated access to formal financial services for nearly 83 percent of the Kenyan population (Ndungu, 2021). This includes access to services such as virtual savings, credit, micro insurance, and investments in government securities. The innovative digital financial service has also increased the money multiplier, but it has slowed down the velocity of money due to changing preferences from holding cash to cashless. The dampened velocity of money circulation and significant reduction in the proportion of currency outside banks are often associated with financial deepening (Berthelemy & Varoudakis, 1996; Ndungu 2021). The surge in savings and access to private sector credit due to financial inclusion are likely a signal of financial development (Ndungu, 2021).

The mobile money payment system has extended beyond Kenyan borders to become an important cross-border payment instrument. In Kenya, Uganda and Tanzania, mobile phone users can easily transfer and receive money from one another. Various mobile money services have also been launched in many other countries, thus creating a global mobile money industry. It is estimated that mobile money accounts has reached more than one billion in over 90 countries, with a combined daily transaction of about two billion USD (Ndungu, 2021). This underscores the growing importance of the mobile currency on a global scale.

Empirical literature shows evidence of a positive association between financial development and sustainable economic growth (e.g., King & Levin, 1993; Berthelemy & Varoudakis, 1996). The functions of financial markets affect growth through mechanisms such as capital accumulation and technological innovations (Levine, 1997; UNECA, 2008). In particular, the financial system's impact on growth is often through altering the rate of technological innovation. Additionally, Berthelemy and Varoudakis (1996) argued that the main contribution of a financial system to economic growth is possibly the establishment of an efficient and adaptable system of payments. The increasing complexity of economic exchange brings with it a growing monetization of economies to sustain the volume of economic activity. In Kenya, the use of M-pesa as a digital payment system is very well aligned with the characteristics of an efficient and adaptable payment system. M-pesa has not only eliminated numerous barriers within the Kenyan financial system but has also emerged as a versatile payment platform that connects different markets.

Given the exponential expansion of mobile money and its widespread use, it is crucial to understand the intensity of its effects on the Kenyan economy. With greater financial inclusion and advancements in the financial markets within the country, this study seeks to establish whether the mobile money financial technology services have enhanced or improved output growth and productivity in Kenya. This is particularly significant given that Kenya has yet to achieve its Vision 2030 target of an annual growth rate of 10 percent. Specifically, the study investigates whether there has been a structural change in output growth and productivity in Kenya due to mobile money payment system and analyzes its effect on output productivity in Kenya. To accomplish this, the growth accounting method was adopted to breakdown the contributions of capital, labor and total factor productivity (TFP) to economic growth. This study argues that the introduction of M-pesa, as an efficient and adaptable payment system, has deepened financial development through the technological innovation. This, in turn, has directly contributed to favorable economic growth. It is believed that there is limited or perhaps no known empirical study has yet been undertaken to account for the effects of mobile money financial services on output growth and productivity in Kenya.

The remainder of the paper is organized as follows: Section 2 reviews the evolution of mobile money financial technology services in Kenya. Section 3 provides the literature review. Section 4 outlines the methodology used for analysis. Section 5 presents the empirical findings. Finally, section 6 concludes the paper.

2. M-Pesa: Evolution of Mobile Money Financial Technology Services in Kenya

According to Ndungu (2021), the evolution of mobile money financial technology services in Kenya occurred over five generations. The first generation focused on payments and transfers. At this stage, Safaricom, a mobile telephone service provider, introduced M-pesa as the pioneer mobile money service in Kenya. It was initially designed as a person-to-person money transfer system. The service was built upon an existing system where individuals were already trading pre-paid airtime, effectively transferring monetary value to other mobile users. Recognizing the potential of such services in the Kenyan market, several mobile network operators rolled out their products. The availability of transfers significantly reduced the travel costs associated with conducting bank transactions and the time taken for such transactions to be completed.

The second generation involves savings accounts, where commercial banks got into partnership with Safaricom. This enabled account holders to access their savings account through the M-pesa app. This innovation resulted in increased number of subscriptions as individuals could now lock their savings for a specific period and earn interest on their deposits. For savings, another platform was launched where individuals could save, and the transaction data used to create credit scores for individual users. The digital payment system then naturally progressed to the adoption of electronic retail payments, exemplified by "pay with M-pesa" in the different retail and wholesale outlets.

The third generation of mobile money services was microcredit, which enabled users to apply for and receive credit directly from the same platform. Transactions on this platform are used to create a subscriber's credit scores, which, in turn, are used to tailor credit offerings. One of the significant hurdles faced by traditional banking institutions is the requirement for collateral when offering credit. Microcredit through mobile money has eradicated this obstacle, as there is no requirement for collateral in the credit application process. Moreover, the processing time is significantly lower in comparison to applications through conventional channels. Additionally, mobile credit services are accessible from anywhere in the country as long as there is network connectivity. As a result, users can easily obtain financing to launch new businesses and agricultural ventures or grow already established ones, thereby increasing their productivity and income.

The fourth generation was international remittances, expanding M-pesa's reach from domestic money transfers to cross-border transfers. This expansion has had several advantages, as mobile money remittances are not only cheaper and more accessible, but they have also helped reduce the incidence of money laundering. Consequently, there has been an average increase in remittances of 14.3 percent annually. In 2019, the total M-pesa remittances reached 2.8 billion USD, accounting for 2.9 percent of Kenya's GDP.

The last generation of mobile money services has been partnerships with FinTech firms. Mobile networks and the use of mobile money have enhanced the uptake of other FinTech solutions. M-pesa has served as a platform for retail electronic transactions and has helped other FinTechs introduce long-term business plans that apply to all facets of the economy. For example, a FinTech company offers solar energy solutions across the country by utilizing microcredit payments for solar products, with payment instalments being made through M-pesa. M-pesa has also been utilized in service provision by the government through a digitized portal, which includes, among others, driver's license and passport applications.

The rapid expansion of mobile money financial technology services has brought about faster and more convenient transactions, including money transfers, bill payments, and other financial transactions. This has led to increased efficiency in the economy, as businesses can make and receive payments more quickly and easily. The transaction costs have also significantly reduced, especially for small transactions, which account for a larger proportion of all transactions. This has made it possible for even the smallest businesses to participate in the economy and has encouraged the growth of microenterprises. Mobile money has also made it easier for Kenyans to access credit, particularly those who would have been unable to obtain credit through traditional channels. This, in turn, has led to increased investment and entrepreneurship in the economy.

Since the introduction of mobile money financial technology services in 2007, there has been a steady increase in the value of M-pesa transactions, as presented in Figure 1. At the end of the first year of operation, the total value of transactions made through the M-pesa platform amounted to Ksh. 3.77 billion. Over the years, the M-pesa transaction value continued its upward trajectory and reached Ksh 708.06 billion in 2022. This can be attributed to several factors, with one of the key factors being the diversification of services offered through M-pesa, such as saving and credit access. The convenience and accessibility of mobile money have also made it an integral part of life for millions of Kenyans. Furthermore, the COVID-19 pandemic greatly impacted the value of transactions as Kenyans sought contactless methods of financial transactions. This shift is illustrated by the spike recorded between 2019 and 2020.

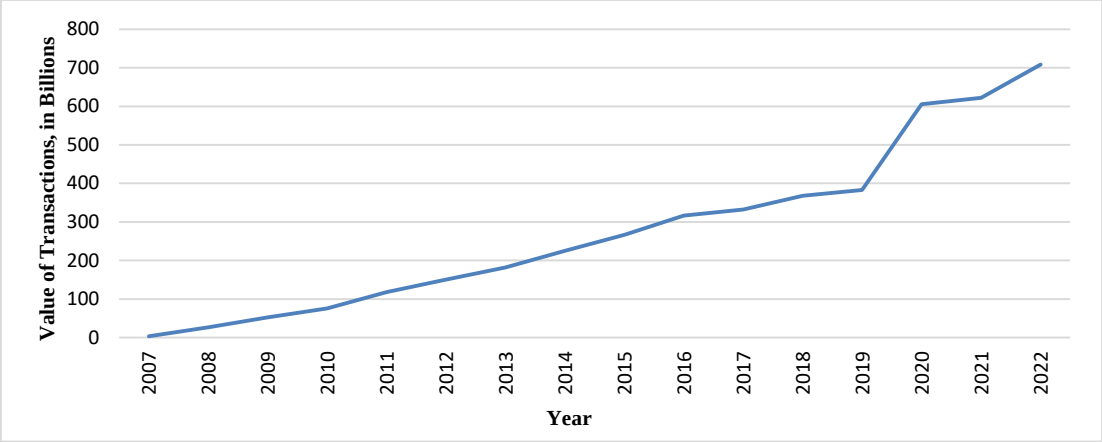

Figure 1. Value of mobile money transactions, In Billion Kenyan Shillings

Source: Central Bank of Kenya (CBK).

With the outbreak of the COVID-19 pandemic, the use of mobile money was encouraged in an attempt to control the spread of the disease by reducing contact with physical cash. As a result, new M-pesa incentives were introduced, such as zero-rating of person-to-person transfers of up to Ksh. 1,000, zero-rating of M-Pesa to bank account transactions and vice versa, and an increase in the daily cap of M-pesa transactions from Ksh. 70,000 to Ksh. 150,000 (Safaricom, 2020).

Since mobile money has increased the availability of financial services to consumers by bypassing conventional banking institutions, the technology has been referred to as a "leapfrog" technology. This is evidenced by the fact that the accessibility of mobile money agents in the world is 20 times greater than that of banks and their branches and 7 times greater than that of ATMs. Alternatively, for every 100,000 adults, there are 228 active mobile money agents, 11 banks, and 33 ATMs. Sub-Saharan Africa is the global epicenter for mobile money, with the region accounting for 63.4 percent, 65.7 percent, and 66.1 percent of the total value of transactions in the world in 2017, 2018, and 2019, respectively (GSMA, 2019).

3. Theoretical and Empirical Literature

3.1 Growth and Technology

According to the neoclassical growth model, production or output is a function of technology, labor, and capital (Solow, 1956; Swan, 1956). As such, growth comes from three basic sources: capital accumulation, expansion in labor and advances in technology. Capital accumulation broadens the economy's capacity to produce. It is accumulated when part of current income is set aside and invested to increase future output or income. Expansion in the labor force is associated with population growth and it is also crucial in stimulating economic growth. A larger labor force means that there is a higher capacity to produce. Finally, advances in technology or technical progress are argued as the key factor in the growth process (Allen, 1968; Zhao, 2018). Technical progress results from new and innovative ways of producing an output, such as more efficient use of labor and capital, improvements in the quality of products, and the introduction of previously unknown products. It is believed that the rapid pace of technological progress was the main contributor to the development of industrial capitalist economies (Wells, 1995).

Romer (1990) also argued that technology is central to the growth of an economy, contending that advances in technology are the result of deliberate and conscious decision-making by key economic actors responding to arising market incentives. However, Romer (1990) believed that technology is endogenously determined by the decision-making of economic agents such as entrepreneurs, contrary to the traditional neoclassical model assumption that it is exogenously determined.

Many other theoretical literature also highlighted the crucial role of technological progress in economic development. For example, in Rostow's (1960) stages of economic development, technology features in both the pre-condition for take-off and the drive to maturity. In the pre-conditions for take-off stage, modern science and technology are adopted and expected to spread, beginning the modernization influx in the take-off stage. Conversely, advanced technology is a necessary condition for the maturity stage, with the economy effectively adopting modern technology in most of its sectors and operations. The widespread use of technology allows for

local production, thereby boosting the economy's exports. The important role of technology in economic development was further reinforced by Kuznets (1973), who stated that structural change is driven by the adoption of technology across the different structures. Moreover, technological change is the most important aspect of growth, as the application of technological innovation is the sustaining factor of the economic growth experienced.

3.2 Growth, Innovations and Financial Development

Economic literature provides evidence that the financial system affects long-run economic growth. Financial markets assume an intermediation role that enables small savers to pool funds and channel them towards investment with highest returns (King & Levin, 1993; Pagano, 1993). Here, savings and investment help build up capital, which is critical to economic growth. Financial institutions not only influence the rate of capital accumulation, but also contribute to innovations (King & Levin, 1993). Improved financial services expand the scope and improve the efficiency of innovative activity, thus enhancing rapid economic growth. King and Levine (1993) considered that the link between finance and innovation is central to the process of economic growth, following the Schumpeterian idea that financial institutions are important because they evaluate and finance entrepreneurs in initiating innovative activities and bringing new products to the market.

It is apparent that innovation improves the financial system, and thus the level of financial development may predict future economic growth. For example, King and Levine (1993) demonstrated that there was a strong correlation between financial development indicators and growth through cross-country regression analysis. This is from observations of 77 countries over the 1960-1989 period. Similarly, Khan and Senhadji (2000) found that financial development is an important determinant of cross-country growth differences using regression analysis. In contrast, Gebremeskel and Chilanga (2022) only found a weak link between financial deepening and economic growth. However, this result was based on a regression analysis relying on observations from a single country.

3.3 Growth and Financial Technology

Financial technology (Fintech) is simply defined as the application of technology and innovation to solve the needs of consumers and firms in the financial space (Chitavi et al., 2021). Financial technology brings efficiency to the financial sector, particularly in how savings and investments are intermediated in an economy, thereby affecting growth (Zeidy, n.d.). The use of mobile phones to facilitate payments or mobile money payment systems is an example of financial technology, also known as African Fintech (Chitavi et al., 2021). The mobile money payment system brings efficiency to the financial market, promotes greater financial inclusion, encourages financial deepening, and better intermediation of a large number of micro savings (Ndungu, 2021). Additionally, it is observed that African countries that adopted this payment system benefited from the boom and achieved a higher economic growth rate (Chivati et al, 2021). Berthelemy and Varoudakis (1996) claimed that perhaps the major contribution of a financial system to growth comes from the setting up of an efficient and adaptable system of payments. Such a system is necessary in order to sustain the volume of economic activity, which is increasingly becoming more complex coupled with a growing monetization of the economies.

Empirical literature supports the link between fintech and economic growth. For example, Song and Otoo (2022) assessed the impact of fintech on economic growth in 31 provinces in China for the period between 2011 and 2017. The study examined three key aspects. First, it explored the overall effect of fintech on China's economic growth, finding a significant and positive effect. Moreover, the study found that fintech was associated with significant increase in labor productivity within the country. Second, the research delved into the effects of fintech at the regional and provincial levels. The eastern region was found to have had the highest growth effect compared to the central and western regions. Notably, significant and positive effects were observed across all provinces under study. Third, the study examined the causal relationship between fintech and economic growth. While unidirectional causality was established between the other variables in the study, such as credit to economic growth and economic growth to insurance, bi-directional causality was observed between fintech and economic growth.

Further inquiry by Narayan (2019) also observed a positive impact of fintech on growth. The study explored the role of fintech in spurring economic growth in Indonesia from the onset of fintech startups in 1998 to 2017. The study established a lagged positive effect on economic growth. During the first year of their introduction, the innovative firms did not exhibit a significant impact on Indonesia's economic growth. However, this changed in the second year as the firms increased, contributing to a positive and significant effect on economic growth in Indonesia. This positive impact on growth was observed throughout the remainder of the study period.

4. Method

4.1 Theoretical Framework

The study adopted a quantitative and non-experimental approach using secondary data for the period 1980 to 2020. The analysis of the association between economic growth, output productivity and mobile money was undertaken using the neoclassical framework or the Solow-Swan Growth model. The most used representation of the production function is the Cobb-Douglas equation expressed as:

$$Y_t = A_t\, K_t^{\alpha} L_t^{\beta} \tag{1}$$

Where *A* represents neutral technological change, *K* is capital, *L* is labour, α is the elasticity of output with respect to capital and β is the elasticity of output with respect to labor and t is the time index. The assumption held in the model is that there is constant returns to scale, implying that the sum of the elasticity of capital and labor equal to one, that is $\alpha + \beta = 1$.

The growth accounting approach is then used to find the TFP contribution. Equation (1) is linearized using natural logarithms as follows:

$$ln\, Y_t = ln\, A_t + \alpha\, lnK_t + \beta\, lnL_t \tag{2}$$

The differentiation of the above equation with respect to time yields the growth accounting equation,

$$\frac{Y_t^*}{Y_t} = \frac{A_t^*}{A_t} + \alpha\, \frac{K_t^*}{K_t} + \beta\, \frac{L_t^*}{L_t} \tag{3}$$

Where; $\frac{Y_t^*}{Y_t}$ is the output growth rate, $\frac{A_t^*}{A_t}$ is the total factor productivity growth rate, $\frac{K_t^*}{K_t}$ is the capital growth rate and $\frac{L_t^*}{L_t}$ is the growth rate of labor. α and β remain to be the elasticity of capital and labor, respectively. The TFP growth is then obtained as:

$$\frac{A_t^*}{A_t} = \frac{Y_t^*}{Y_t} - \alpha\, \frac{K_t^*}{K_t} - \beta\, \frac{L_t^*}{L_t} \tag{4}$$

The residual in equation (4) is also known as the Solow Residual (Romer, 2012).

4.2 Model Specification

The empirical model is specified based on the Cobb-Douglas function in equation (2). To capture the effects of mobile money financial technology on growth, the time variable (t) is included in the model to indicate technology increasing with time. In Kenya, M-pesa was adopted as digital payment system in 2007.

$$Ln\, Y_t = \delta + \theta t + \alpha\, Ln\, K_t + \beta\, Ln\, L_t + \varepsilon_t \tag{5}$$

Where t = 0 before 2007; and t = 1 after 2007.

The TFP model adopted was anchored on Romer (1990) and Hammouda, Karingi, Njuguna and Jallab (2010). Romer (1990) argues that one can give an endogenous explanation to the sources of technological change. The model is specified as,

$$\text{TFP} = \text{f (control variables, mobile money variable, leapfrogging)} \tag{6}$$

Again, dummy variables were introduced to determine the presence of structural change and the empirical model is as follows:

$$TFP_t = \gamma_0 + \gamma_1 HC_t + \gamma_2 OPEN_t + \gamma_3 MM_t + \gamma_4 LEAP_t + \gamma_5 CONFLICT + \gamma_6 FDEEPENING + \gamma_7 D + \varepsilon_t \tag{7}$$

Where HC is Human Capital, OPEN is Openness to Trade, MM is Mobile Money, LEAP is leapfrogging, FDEEPENING is financial deepening, Conflict is a dummy to indicate the presence or absence of conflict and D is a dummy for the introduction of mobile money with D=1 from 2007 and D=0 before 2007. TFP is the total factor productivity which will be obtained as the anti-log of the TFP obtained in the growth model. The control variables are standard in literature as in Hammouda et al. (2010).

Leapfrogging can be measured in two ways- the relative measure or the absolute measure. The relative measure is appropriate for this study as the absolute measure is adopted in studies where there is cross country comparison. The relative measure is calculated as a ratio of the new technology to its predecessor (James, 2009). It is computed as $LF = X/Y$, where X represents the adoption of the modern/new technology and Y represents the adoption of the predecessor system.

4.3 Variable Definitions

The variables used in the study are defined and measured as shown in Table 1:

Table 1. Definitions and measurements of variables

Variable	Definition and Measurement
Gross Domestic Product	This refers to the GDP of Kenya.
Capital Stock	This is the aggregate level of capital within the economy, derived using the Perpetual Inventory Method (PIM).
Labor Force	This is the number of people who are currently employed.
Total Factor Productivity	This is the measure of the rate of technical progress or change.
Human Capital	This refers to the knowledge and skills attained by individuals that lead to increased labor efficiency. This is measured as primary school enrolment as a ratio of gross enrolment.
Openness to Trade	This is the degree of the country's participation in the global markets. It is measured as the ratio of the exports and imports to the GDP.
Mobile Money	This is the ratio of the M-pesa value of transactions to the banks' value of customer transactions.
Financial Deepening	This is credit to the private sector expressed as a percentage of the Gross Domestic Product.
Leapfrogging	This is the ratio of the number of mobile money accounts to the number of traditional bank accounts.
Conflict	This is a dummy variable to indicate the presence or absence of conflict.

4.4 Data Sources

The study used annual data for the period between 1980 to 2020. Data was collected for the following variables: Gross Domestic Product (GDP), Labor Force (LF), Gross Fixed Capital Formation (GFCF), Exports (EXP), Imports (IMP), Credit to Private Sector, Number of Mobile Money Accounts, Number of Deposit Account Holders, Value of Mobile Money Transactions, Value of Bank Transactions, Financial Deepening and Human Capital. The GDP, GFCF, Human Capital, credit to private sector and Labor Force were obtained from the World Development Indicators. GDP and GFCF were obtained in Constant 2015 US Dollars. Exports and Imports data were obtained from KNBS (1980) to KNBS (2020). The values of the remaining variables namely, number of mobile money accounts, value of mobile money transactions, number of deposit accounts and value of bank transactions were obtained from the Central Bank of Kenya (CBK) online database.

4.5 Descriptive Statistics

The summary statistics: mean, standard deviation, minimum and maximum values of the variables were calculated and are presented in Table 2.

Table 2. Summary statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
GDP (Billions USD)	43.29	18.92	20.43	84.13
Labor (Millions)	13.45	5.53	5.34	24.13
Capital (Billions USD)	21.69	5.14	17.03	32.15
Openness (%)	35.87	8.64	13.11	61.80
Human Capital (%)	101.17	7.68	88.24	118.17
Financial Deepening (%)	24.57	5.05	18.40	36.70
Leapfrogging	0.328	0.49	0	1.38
Mobile Money	1.682	2.80	0	8.54

Source: Author's Compilation.

The country's GDP with an average of 43.29 billion USD for the period between 1980 to 2020, reached a maximum value of about 84.13 billion USD in 2019 and the lowest value of 20.43 in 1980. Capital and Labor had experienced steady growth, with the lowest value for labor at 5.34 million in 1980 and the maximum value at 24.13 million in 2020. On the other hand, capital had the lowest value in 1985 at USD 17.03 billion and the highest value given at USD 32.2 billion in 2020. Mobile money and leapfrogging had minimum scores of 0, which were recorded for all years prior to the introduction of M-pesa in 2007.

5. Empirical Results

5.1 Diagnostic Tests

All variables were tested for stationarity using the Augmented Dickey Fuller (ADF) test and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test. The test results are as shown in Table 3 and Table 4. The two unit root

tests were used for robustness checks. Using the ADF tests, human capital and mobile money were found to be stationary (intercept only), as were openness and financial deepening (trend and intercept). Meanwhile, under the KPSS test, all variables were found to be stationary.

Table 3. Augmented Dickey Fuller test results

Variable	Test Statistics (Intercept Only)	Conclusion	Test Statistic (Trend and Intercept)	Conclusion
Ln_GDP	1.071	Non-Stationary	-2.593	Non-Stationary
Ln_Capital	-0.466	Non-Stationary	-1.746	Non-Stationary
Ln_Labor	-1.147	Non-Stationary	-2.470	Non-Stationary
Openness	1.888	Non-Stationary	-3.608	Stationary at 5%
Human Capital	-2.904	Stationary at 5%	-2.901	Non-Stationary
Mobile Money	-2.952	Stationary at 5%	-3.952	Stationary at 1%
Leapfrogging	-0.471	Non-stationary	-1.782	Non-Stationary
Financial Deepening	0.102	Non-Stationary	-3.149	Stationary at 10%

Note. Asymptotic Critical Values for Intercept only are -3.58, -2.93 and -2.60 at 1%, 5% and 10% respectively while those for Trend and Intercept are -4.15, -3.50 and -3.18 at 1%, 5% and 10% respectively.

Table 4. KPSS test results

Variable	Test Statistic (Intercept Only)	Conclusion	Test Statistic (Trend and Intercept)	Conclusion
Ln_GDP	0.696	Stationary at 1%	0.178	Stationary at 1%
Ln_Capital	0.701	Stationary at 1%	0.199	Stationary at 1%
Ln_Labor	0.704	Stationary at 1%	0.195	Stationary at 1%
Openness	0.701	Stationary at 1%	0.172	Stationary at 1%
Human Capital	0.438	Stationary at 5%	0.175	Stationary at 1%
Mobile Money	0.663	Stationary at 1%	0.192	Stationary at 1%
Leapfrogging	0.645	Stationary at 1%	0.185	Stationary at 1%
Financial Deepening	0.645	Stationary at 1%	0.136	Stationary at 1%, 5%

Note. Asymptotic Critical Values for Intercept only are 0.739, 0.463 and 0.347 at 1%, 5% and 10% respectively while for Trend and Intercept are 0.216, 0.146 and 0.119 at 1%, 5% and 10% respectively.

ADF has drawn criticism for its low power of test as it does not distinguish between a near unit root and the presence of a unit root, and as a result KPSS is suggested as an alternative given that it does not suffer from this problem (Enders, 2015). The KPSS results are thereby preferred and serve as a justification for the level analysis of the variables.

To establish the degree of association between the explanatory variables, pairwise correlation analysis was done. The highest correlation recorded was 0.84 for financial deepening and mobile money, followed by 0.78 for mobile money and leapfrogging. This is presented in Table 5.

Table 5. Pairwise correlations

	Openness	Financial Deepening	Mobile Money	Human capital	Leapfrogging	Conflict
Openness	1.0000					
Financial Deepening	-0.7186	1.0000				
Mobile Money	-0.7447	0.8356	1.0000			
Human capital	0.2960	-0.0355	0.2206	1.0000		
Leapfrogging	-0.6241	0.6137	0.7770	0.3221	1.0000	
Conflict	0.1149	-0.2576	-0.1801	0.1629	-0.1219	1.0000

Source: Author's computation.

According to Kleinbaum, Kupper, Nizam, and Rosenberg (2014), the assessment of variance inflation factors (VIF) should follow the pairwise correlations analysis to assess whether high pairwise correlations among explanatory variables indicate the presence of collinearity. The rule of thumb being that a VIF greater than 10 is indicative of a serious collinearity problem. The VIFs obtained were all less than 10, with the highest VIF being 8.16 for mobile money. This led to the conclusion that the explanatory variables did not suffer from multi-collinearity.

5.2 Production Function Analysis

The production function was estimated to establish the shares of capital and labor in output. In the regression model, the restriction of constant returns was imposed. The Jarque Berra tests for normality and the Breusch Godfrey test for serial correlation were undertaken to ensure that the results obtained were reliable. The results of the diagnostic tests are shown in Table 6. In these tests, the residuals are found to be normally distributed and there is no presence of serial correlation.

Table 6. Diagnostic test results

Diagnostic Test	Computed Test Statistic	P-Value
Jarque-Berra test	0.29	0.864
H0: Residuals are normal.		
Breusch- Godfrey Test	22.909	0.000
H0: No Serial Correlation.		

The computed p-value of the Jarque-Berra test is greater than 0.05 and therefore the null hypothesis of normality is not rejected therefore implying that residuals are normally distributed at 5 percent level of significance. The computed p-value for the Breusch Godfrey test was less than 0.05 and therefore the null hypothesis of no serial correlation was rejected. To correct this, robust standard errors were used. The results of the production function analysis are presented in Table 7 below.

Table 7. Production function estimation results

Dependent Variable: Log of GDP	Coefficient (p-value)
Constant	5.8620 ***
	(0.000)
Elasticity of Output with respect to Labor	0.7082 ***
	(0.000)
Elasticity of Output with respect to Capital	0.2918 ***
	(0.000)
D (Dummy Variable: D=1 if year ≥ 2007; 0 if year < 2007)	0.1208 ***
	(0.000)
Adjusted R-squared	0.99

Note. *** p-value < 0.01.

The shares of capital and labor in output are found to be 0.29 and 0.71, respectively and are both statistically significant at 1 percent level. The dummy variable, D (D=1 if year ≥ 2007; 0 if year < 2007) is significant and thus indicative of the presence of structural change or shift in output as a result of the introduction of mobile money. This is graphically illustrated in Figure 2.

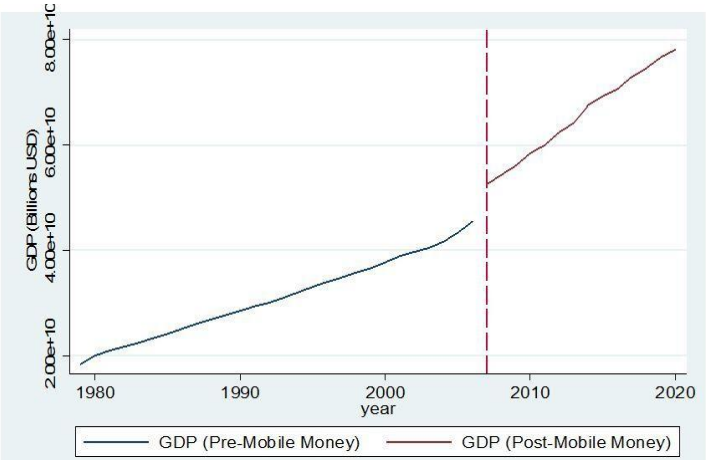

Figure 2. Structural change in Output

The findings on the elasticities of labor and capital are consistent with studies such as Hammouda *et al.* (2010) whose results indicate that African countries had capital and labor elasticities of 0.371 and 0.629, respectively. In a study focused on Kenya, Njuguna, Karingi and Kimenyi (2003) found that the shares of capital and labor are, respectively, 0.24 and 0.76. This indicates that African economies such as Kenya are labor-intensive rather than capital-intensive.

To find the contribution of each factor to the overall growth in output, the elasticities obtained are multiplied with their respective growth rates. The results from this growth accounts are then summarized in 5-year periods for the years 1981 to 2020 as presented in Table 8.

Table 8. Capital, labor and TFP contributions to GDP growth

Years	GDP Growth	Contribution of Labor	Contribution of Capital	Contribution of TFP
1981-1985	2.53	4.13	-0.27	-1.33
1986-1990	5.64	3.19	0.21	2.23
1991-1995	1.61	2.82	0.19	-1.40
1996-2000	2.16	2.41	0.28	-0.53
2001-2005	3.65	2.40	0.43	0.83
2006-2010	4.98	2.25	1.39	1.35
2011-2015	4.70	2.49	0.97	1.23
2016-2020	3.66	2.12	0.33	1.22

Source: Author's computation.

The highest recorded average growth rate was between 1986 and 1990, attributed to the implementation of Sessional Paper No.2 of 1986- Economic Management for Renewed Growth- that resulted in structural adjustments within the economy (Opondo, Etyang, Okeri, & Njuguna, 2019). The subsequent 5-year period of 1991-1995 was marred by political tensions after the 1992 elections and the rise in oil prices due to the Gulf war (Ichwara, 2003). These results are graphically illustrated in Figure 3.

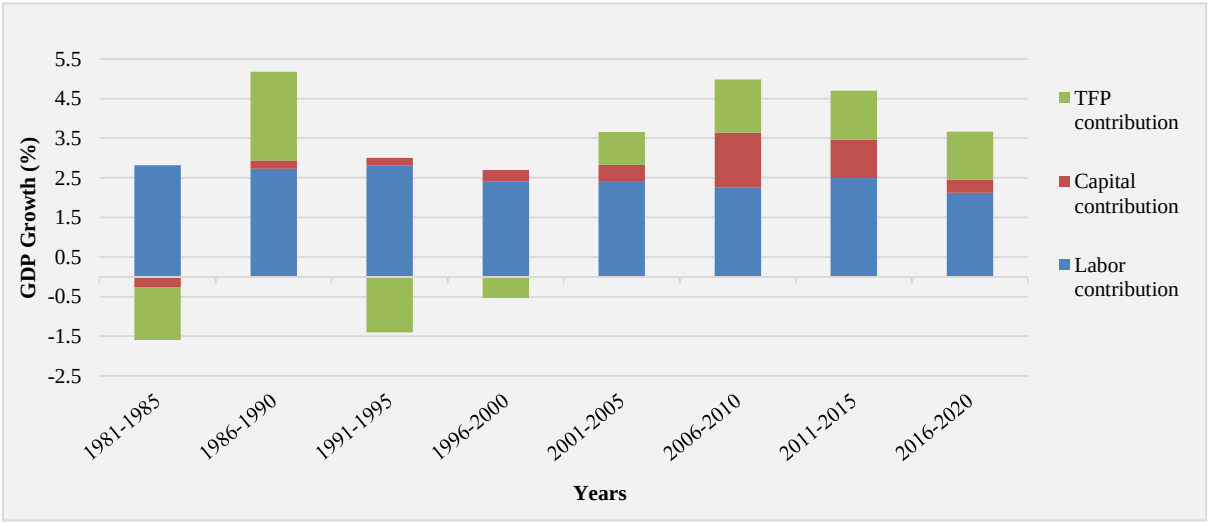

Figure 3. Labor, capital and TFP contribution to growth

The highest contribution of TFP to economic growth was recorded from 1986 to 1990, the same period that had the highest average economic growth. The periods 1981-1985, 1991-1995 and 1996-2000 recorded negative TFP contributions to growth. For each of these periods, there was an unfavorable political environment with the occurrence of events such as the 1982 coup d'état and post-election violence after the 1983, 1992, and 1997 elections. However, in each of the 5-year period after the introduction of mobile money, TFP's contribution to growth has been positive. Since 2007, only three years have had a negative contribution to growth by TFP-2008, 2014 and 2020. This can be attributed to the post-election violence experienced in 2007/2008 and the impact of the COVID-19 pandemic in 2020. The decline in 2014 could be explained by the fact that there were heightened security concerns as the country had a surge in Al Shabaab terrorist activities (World Bank, 2014).

5.3 Total Factor Productivity Analysis

The TFP was obtained as a residual using equation (8).

$$LnTFP = LnGDP - \hat{\alpha} * LnCap - \hat{\beta} * LnLab \quad (8)$$

Where:

$\hat{\alpha}$= 0.2918, $\hat{\beta} = 0.7082$ are the estimated shares of capital and labour, respectively.

Once the TFP was obtained, two regression models were run to establish the relationship between TFP, Openness, Human Capital, Financial Deepening, Mobile Money, Leapfrogging and Conflict. TFP was calculated as the anti-log of LnTFP. The first model, which was the benchmark model, includes all the aforementioned variables while the second model includes all variables in the first model as well as a dummy variable D where D=0 if year<2007 and D=1 if year>=2007. Diagnostic tests were undertaken to verify the reliability of the obtained results, ensuring that they are not spurious. The outcomes of the tests are presented in Table 9.

Table 9. Diagnostic tests results

Diagnostic Test	Model 1	Model 2
Jarque-Bera Test	2.84	2.45
H0: Residuals are normal.	(0.2418)	(0.2942)
Breusch-Godfrey Test	8.436	9.011
H0: No serial correlation.	(0.0037)	(0.0027)
Ramsey RESET Test	0.51	0.52
H0: No model misspecification.	(0.6810)	(0.6693)

Note. p-values are in parenthesis.

In both models, the p-values in the Jarque Berra test for normality and the Ramsey RESET test for model misspecification were greater than 0.05. Therefore, the null hypotheses of normality of the residuals as well as that of no model misspecification were not rejected at 5 percent level of significance in both models. The models did not also suffer from multicollinearity as the previously determined VIFs were all less than 10. However, the results of the Breusch Godfrey test indicate presence of serial correlation as the p-values in both models were less than 0.05. Consequently, the null hypothesis of no serial correlation was rejected at 5 percent level of significance. This was corrected by using robust standard errors. The results obtained were as presented in Table 10.

Table 10. TFP regression results

Dependent Variable : TFP	**Model 1 Coefficient (p-value)**	**Model 2 Coefficient (p-value)**
Constant	396.395 ***	396.834 ***
	(0.000)	(0.000)
Financial Deepening	-1.237 *	-1.3333 **
	(0.056)	(0.049)
Mobile Money	9.305 ***	8.5800 ***
	(0.000)	(0.000)
Leapfrogging	6.1139	-6.3951
	(0.146)	(0.413)
Openness	-0.1821	-0.1644
	(0.735)	(0.754)
Human Capital	-0.0994	-0.0877
	(0.778)	(0.797)
Conflict	-2.1885	-5.5663
	(0.661)	(0.336)
D = Dummy Variable:	--	17.4240*
(D=1 if year ≥ 2007; 0 if year < 2007)		(0.10)
Adjusted R-Squared	0.8478	0.8534

Note. *** p-value < 0.01; ** p-value < 0.05; * p-value<0.10.

Dummy variables were used to test for the presence of structural change in TFP as a result of the introduction of mobile money in order to achieve the first study objective. For years before the introduction of mobile money in 2007, the dummy variable D is equal to 0 and 1 if otherwise. In the second model, the coefficient obtained for the dummy variable is weakly significant, suggesting the presence of a structural change since the introduction of mobile money, as illustrated in Figure 4.

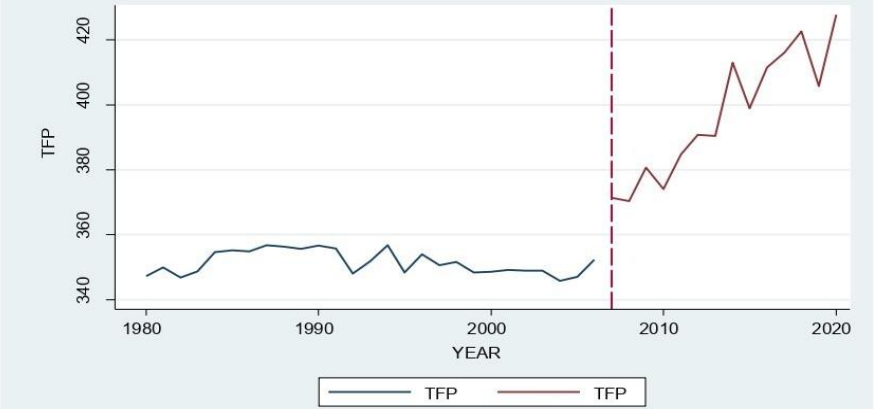

Figure 4. Structural change in TFP

It is evident that with the introduction of mobile money financial technology services, there has been an increase in overall productivity within the economy. This is explained by the fact that mobile money greatly reduces the time required for financial transactions, freeing up more time to develop new goods and services. There has also been an increase in the flow of money within the economy, and the easy access to money in the form of digital currency by consumers has resulted in an increase in goods and services purchased. Additionally, the volume of trade has increased as businesses expand due to easy credit access and access to a larger market as mobile money facilitates easy cross-border transactions.

Consistent with theoretical expectations, mobile money has had a significant positive effect on TFP. This finding is also consistent with other studies such as Beck, Pamuk, Uras and Ramrattan (2015), who found that mobile money in Kenya has had a significant positive effect on TFP. According to GSMA (2019), notable increases in productivity have been observed in the agricultural and Micro, Small, and Medium Enterprises (MSMEs) sectors. In the agricultural sector, farmers have been able to adopt productive practices through the acquisition of more modern equipment and input. On the other hand, for MSMEs, mobile money use has meant quicker processing of payments, easier credit access, and greater client access.

Financial deepening was measured as credit to the private sector as a proportion of GDP. In both models, it had a significant negative effect on TFP. Studies such as Hammouda et al. (2010) and Opondo et al. (2019) also obtained similar results. This is in contrast to the expectation that financial deepening will boost TFP by increasing investment through savings mobilization and increased dissemination of information on investment projects. Two arguments have been put forward to explain the negative association. First, according to Hammouda et al. (2010), the credit accessed by the private sector has not been channeled towards the acquisition of new technologies for production or in research and development (R&D), but rather has been used for personal consumption. Second, Opondo et al. (2019) argue that the low value of transactions carried out through M-pesa has dampened productivity gains through the reduction of the time taken and costs incurred during transactions. The Kenyan mobile money system is characterized by high-volume, approximately 4.8 million daily transactions, of low value, averaging at Ksh. 2,740 (Ndung'u, 2021).

Leapfrogging was found to have no significant effect on TFP despite having been accompanied by an increase in financial inclusion. The findings are similar to those of Wang, Wei, and Wong (2010), who assessed whether the adoption of a leapfrogging growth strategy resulted in an increase in the economic growth rate across countries and within regions in China. The study findings indicated that leapfrogging could not be relied upon to sufficiently and sustainably increase the growth rate, and adoption of the strategy would be the equivalent of taking a gamble. The insignificant effect of leapfrogging could also be explained by the fact that the leapfrogging process also requires that labor be concentrated mainly in the tertiary sector rather than the primary sector. This implies that production processes in both the primary and secondary sectors need to be automated through the

adoption of productive and efficient technologies. The production function analysis, however, shows that the economy remains labor-intensive rather than capital intensive.

Similarly, human capital, openness, and conflict had no significant effect on TFP. Hammouda, Karingi, Njuguna and Jallab (2016) attribute the insignificant effect of openness to imports being more likely to be final consumer goods, rather than technology enhancing imports that would have a positive contribution to TFP. Furthermore, Kenya's export portfolio is dominated by goods and services that have undergone low value addition and are not technologically intensive.

6. Conclusions

M-pesa has had a significant positive effect on both output growth and TFP. From the analysis, it is evident that M-pesa has not only led to an increase in economic growth and productivity, but has also resulted in a structural change in both output growth and productivity since its introduction in 2007. However, leapfrogging has not significantly impacted productivity, casting doubt on its sustainability as a path to Kenya's economic development.

The benefits accrued since the introduction of mobile money, such as the reduced costs of transactions and transaction time, ease in credit access, increased trade volume, and increased financial inclusion, indicate that digitization has been a force for good and should therefore be encouraged in the different sectors of the economy. With this, there will also be a transition of the informal markets into formality through the reliance on traceable mobile payments and access to credit and savings. For greater productivity, it is crucial to eliminate the barriers that prevent the adoption and usage of digital technologies, such as poor network quality, high costs, and a lack of digital skills.

Given that Kenya is the SSA country with the highest rate of cybercrime, with over 70 percent of the Kenyan population having been victims of cybercrime, cyber security is still a major concern (Didenko, 2017). This has in turn been a major contributing factor to the low-value transactions, as concerns about the vulnerability of the mobile money platforms to cybercrime create scepticism among the users. In order to ensure that mobile money users are protected from cyber risks, a robust regulatory framework should be created for combating cybercrime, and standards should be established for the minimal cyber security infrastructure that mobile network operators should have.

The empirical findings indicate that the leapfrogging strategy is not a viable option for Kenya's economic development. The traditional path of development achieved through the gradual transition from the primary sector to the secondary sector, and in turn the secondary sector, is therefore preferred. Government efforts should therefore be directed towards ensuring that the secondary sector- manufacturing- is robust and resilient. Private sector firms should channel credit towards investment through the acquisition of new technologies and increased research and development rather than personal consumption.

Despite the increase in literacy and education levels among Kenyans, human capital has not significantly contributed to TFP, thereby pointing to a possible mismatch between the education and training received and the job market requirements. The institutions of higher learning should tailor their curricula to ensure that the future workforce is equipped with the right skills for the labor market. Additionally, to stop brain drain, which is caused by people seeking "greener pastures" abroad, a good working environment that fosters professional advancement within their fields of competence should be fostered.

Local manufacturing for export should also be encouraged and supported. The government should also take deliberate action to ensure that the country's export portfolio is dominated by goods marked by high market growth, high technology intensity, and high value addition to be competitive in the global market and increase the volume of trade. Imports should also be technology-advancing rather than finished consumer products in order to positively contribute towards productivity.

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