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Table of Content

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Full Length Research

Stimulating farmer access to bank credit in Zimbabwe: The bankers' perspective

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Access to finance by farmers is recognized as a tool for poverty eradication in developing countries, where the majority depends on agriculture for survival. This study sought to establish strategies for enhancing farmer access to bank credit as prescribed by the lenders themselves. A structured interview guide collected primary data from a sample of 12 registered commercial banks in Zimbabwe, which were analysed by thematic analysis. Human capital formation activities that enhance agricultural production and business management knowledge were proffered as key strategies for stimulating bank credit access. On and off farm investments in physical assets were also suggested to equip farmers with productive assets for enhancing viability and loan repayment ability, and to fulfil stringent collateral requirements by banks. Social capital formation activities through building relationships that enhance farmer knowledge were also perceived as key for enhancing credit access. Therefore, policy should subsidize farm infrastructural development initiatives by farmers and intensify agricultural extension services for enhancing farmer knowledge. Farmers should pursue personal development programs in agricultural production and business management, and create farmer-based organizations for sharing risk and knowledge. Banks are encouraged to adopt locally adaptive lending models to meet the farmers halfway.

Key words: Bank credit, credit constraints, creditworthiness, CAMPARI, investments, human capital formation, physical capital formation, social capital formation.

INTRODUCTION

The African Union Maputo Declaration of 2003 implored African nations to dedicate at least 10% of their national budgets towards agriculture in recognition of the role it plays as a source of livelihood for the majority of the poor and food insecure populace (Garvelink, 2012; Gutsa, 2010). In Zimbabwe, agriculture generates self-employment opportunities for 59.3% of the economically active population, whilst an additional 23% are formally employed by the sector (Ministry of Agriculture Zimbabwe, 2017; Swinkels and Chipunza, 2018). Despite

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this, the Zimbabwean agricultural sector faces financing challenges, mainly access to formal bank credit (Masiyandima et al., 2011; Vitoria et al., 2012). According to Masiyandima et al. (2011), Zimbabwean banks have maintained small agricultural loan books ranging between 10 and 25% since the introduction of the multi-currency regime in 2009. The agricultural sector could also only attract 19% of the US$3.8 billion credit advanced by the banking sector since the economy was dollarized in 2009 (FACASI, 2015). In response to these financial constraints, the government of Zimbabwe formulated several policies, some of which are not yet operational. Between 2000 and 2004, the ZW$1.5 trillion Productive Sector Facility (PSF) availed ZW$1.2 trillion to the agricultural sector, whilst its successor policy, the Agricultural Sector Productivity Enhancement Facility (ASPEF), disbursed a cumulative amount of ZW$5.59 trillion by December 2005.

The government also introduced the Collateral Registry, which sought to enable individuals and businesses to utilize their movable property as collateral for credit (Reserve Bank of Zimbabwe (RBZ), 2013). The registry was enacted by the Parliament of Zimbabwe in 2017 under the Movable Property Security Interests Act (Chapter 14:35), but is however yet to be operationalized (Government of Zimbabwe, 2017). Command agriculture, a government-mediated contract farming arrangement in which international and domestic capitalists worked in collaboration with local banks, was another initiative put in place for easing the local farmers' financial access constraints (Echanove, 2017). In the 2018 Budget Statement, the Ministry of Finance and Economic Development (2017) declared that the thrust behind Command Agriculture was on the full, efficient and sustainable utilization of allocated land for increased investment and production. As a result, more than US$2 billion was channeled towards the program through treasury bills (Shonhe, 2018).

The government of Zimbabwe also sought to improve tenure security for its land reform beneficiaries to allow them to use their landholdings as collateral for accessing finance through the 99 Year Lease Agreements (Rukuni, 2012). The main objective of the 99 Year Lease was to give tenure to medium and large scale farmers (Inter Ministerial Taskforce (IMT), 2016). However, its acceptability as collateral by local banks remains contentious because of its non-transferability to third parties. Most of these highlighted remedial policies for addressing the agricultural credit scarcity problem in Zimbabwe were marred by delays in the release of funds to farmers, hyperinflation and political interferences, which rendered them less effective to the problem at hand. The majority of the policies were also targeted at solving the collateral problem among local farmers, and in some cases circumventing the problem altogether to ensure the perpetuity of agricultural activities despite the absence of collateral.

However, according to bank lending theory, collateral is not the only factor that lenders consider when assessing borrower creditworthiness. According to Safi and Lin (2014), creditworthiness is the intrinsic quality of people and businesses that is mirrored in their ability and willingness to fulfil their business obligations. The analysis of borrower creditworthiness involves a preliminary study of the factors that can adversely affect the duly repayment of credit like borrower's efficiency, reputation, capacity for making profit, asset value, economic situation, and also profitability (Feschijan, 2008). Advancing credit to creditworthy borrowers is regarded as one of the most significant functions of commercial banks, which is directly related to economic development (Otieno, 2013). Therefore, it is crucial in a bank's role as a financial intermediary to be able to extract data from borrowing and potential borrowing customers to complement the data it gathers from the general economic environment (Newton, 2000). Jakušonoka and Barakauska (2016) promulgated that a wrong evaluation of a borrower's credibility and related credit risk may result in non-performing loans, which may worsen bank key performance indicators like liquidity.

The assessment of creditworthiness and business health is the first crucial step to be taken before entering into any type of interaction, which was traditionally done through subjective methods but evolved to become more objective through automation (Safi and Lin, 2014). The lending models that are often used in credit analysis processes by lenders like banks describe the various structures of policies and procedures that ought to be followed before loans are advanced to customers (RBZ, 2006). Banks attach substantial importance to screening loans through these rigorous lending requirements with the aim of eliminating borrowers who are likely to default, adding incentives for borrowers to repay the loans, offsetting the cost to the lender of a loan default, and reducing the overall lending risk (Owusu-Dankwa and Badu, 2013). Different models such as the 5C's of credit (Character, Capacity, Capital, Collateral and Conditions); the 5P's (Person, Payment, Principal, Purpose and Protection), the LAPP (Liquidity, Activity, Profitability and Potential), the CAMPARI (Character, Ability, Margin, Purpose, Amount, Repayment and Insurance) model, and Financial Analysis and Past Experiences (FAPE) guide lenders in the assessment of their potential borrowers' creditworthiness (Abbadi and Karsh, 2013).

Zech and Pederson (2003) ascribe this existence of numerous credit analysis models to the lack of harmony on a unique set of variables that explain creditworthiness because individual institutions will be searching for specifications that best predict borrower performance and repayment capacity. The CAMPARI model is one of the popular credit evaluation models used by banks in approving or rejecting credit requests by potential borrowers from their limited resources (Seyoum, 2017). Such a credit evaluation model is not based on a single

factor, but upon how an applicant meets a set of lending criteria dictated by a bank, which reflect the risk appetite of the credit grantor concerned. The CAMPARI model therefore looks at aspects covering not just the finance that is being sought, but the people who are seeking it (Owusu-Dankwa and Badu, 2013). It is categorized as a judgmental or qualitative model of loan assessment. Rouse (1989), who is the proponent of the CAMPARI model, states that applying the CAMPARI technique during the initial assessment of the borrower helps in determining whether a loan is good or bad, recoverable or not recoverable. The CAMPARI model represents seven variables that banks can use to evaluate credit applications on the basis of character, ability to repay, margin of profit, purpose of the loan, amount being requested, the terms of repayment and the insurance in case of default (Abbadi and Karsh, 2013). According to Owusu-Dankwa and Badu (2013), the CAMPARI model provides bankers with a tried and trusted model of credit analysis.

Several studies have investigated the determinants of bank credit access among farmers from the demand side. Farmer and farm attributes like experience, income, collateral value, land ownership, past credit participation, assets owned, membership to farmer based organizations, education, marital status, sex, and age were identified as some of the important determinants of bank credit access by farmers (Abdul-Jalil, 2015; Adams, 2015; Ijioma and Osondu, 2015; Mayowa, 2015; Mukasa et al., 2017; Njogu et al., 2018; Odu et al., 2010; Saqib et al., 2018; Sebatta et al., 2014). Most of these studies also applied statistical modelling techniques to comprehend the determinants of bank credit access among farmers, especially regression analysis. This paper is one of the few (Wulandari et al., 2017), which recognize bank lending requirements as the ultimate determinants of bank credit access among farmers because lenders are the ones who set the requirements that are used at all times to screen potential borrowers. Moreover, the paper uniquely proposes that if the farmers are not enlightened on what the lenders want, then their access to bank credit will remain a big problem in Zimbabwe and beyond. The study is also one of the few, for example (Korir, 2013) who used content analysis, which refrained from the employment of quantitative modelling techniques in comprehending the determinants of bank credit access among farmers. Instead, it opted for an in-depth qualitative method to understand what can be done by various stakeholders to stimulate bank credit access among the farmers. Therefore, the study sought to understand what commercial banks in Zimbabwe recommended as strategies for stimulating bank credit access among farmers.

MATERIALS AND METHODS

The study was underpinned by interpretivism, a qualitative research paradigm, to achieve its objective of establishing strategies for stimulating bank credit access among farmers in Zimbabwe. Contrary to positivists, qualitative research purists believe that there are multiple realities in the social world that can be derived from the perceptions and resultant actions of people (Burrel and Morgan, 1979; Saunders et al., 2016). In addition, they believe that researchers cannot detach themselves from their own values when conducting research (Saunders et al., 2016). Qualitative research strategies also claim that the “knower” and the “known” cannot be separated because the subjective knower is the only source of reality (Terrell, 2012). Accordingly, in this study, the knower, who is the banker, was given the opportunity to convey perceptions and opinions regarding what could be done to enhance the farmers’ access to bank credit in Zimbabwe in recognition of the fact that they are the ones who set the rules or conditions for bank credit access.

Population, sampling procedure and sample size

The study was conducted in Harare, the capital city of Zimbabwe, which is home to all the commercial banks’ head offices. Its target population was made up of 13 registered commercial banks in Zimbabwe (RBZ, 2020). Due to the small number of commercial banks involved, the study decided to include all of them in the sample in order to gain an accurate picture of what has to be done to stimulate bank credit access among farmers in Zimbabwe. However, only 12 of the banks are currently operational. As a result, the 12 operational and registered commercial banks in Zimbabwe formed part of the study’s sample.

Data collection

Primary data were collected from the bank credit officers in the commercial banks’ agribusiness units making use of a pre-tested structured interview guide. Prior appointments were made over the phone with potential respondents to ensure that they would be available in office on the day of the oral interview. The structured interview guide enabled the researcher to manage bias issues that usually arise when the interviewer and interviewee become too involved with each other. Hence, the structured interview guide helped the researcher to strictly and objectively adhere to the agenda at hand.

Data analysis

Data were analyzed by thematic analysis making use of NVivo 12 Plus. The researcher initially read through the respondents’ verbatim responses, and subsequently created themes for responses that related to the same subject. The data were subsequently transcribed into NVivo, after which the responses were coded under the themes to which they belonged. The most popular themes were then identified and discussed in detail. Tables, exploratory diagrams, word clouds, comparison diagrams and word trees were used to present the analyzed data. In line with Gibbs (2018), a detailed protocol and database was set up to ensure that other researchers who would like to conduct the same study would be able to follow the same procedure. The researcher also employed member checking by going back to the study’s participants with the findings for them to confirm if they reflected the truth (Cresswell, 2014). This was done and the bank credit officers confirmed that the findings were valid.

RESULTS AND DISCUSSION

Out of the 12 targeted commercial banks, seven participated in the oral interviews after the point of

Table 1. Summary of emerging themes from oral interviews with commercial bank credit officers.

Theme	Number of banks that mentioned the same theme, n=7	Number of times the theme was mentioned
Human capital formation	4	8
Physical capital formation	4	7
Social capital formation	2	5
Account activity	2	2
Land tenure	2	2
Diversification	2	2
Own equity	1	1

Source: Primary Data (2019).

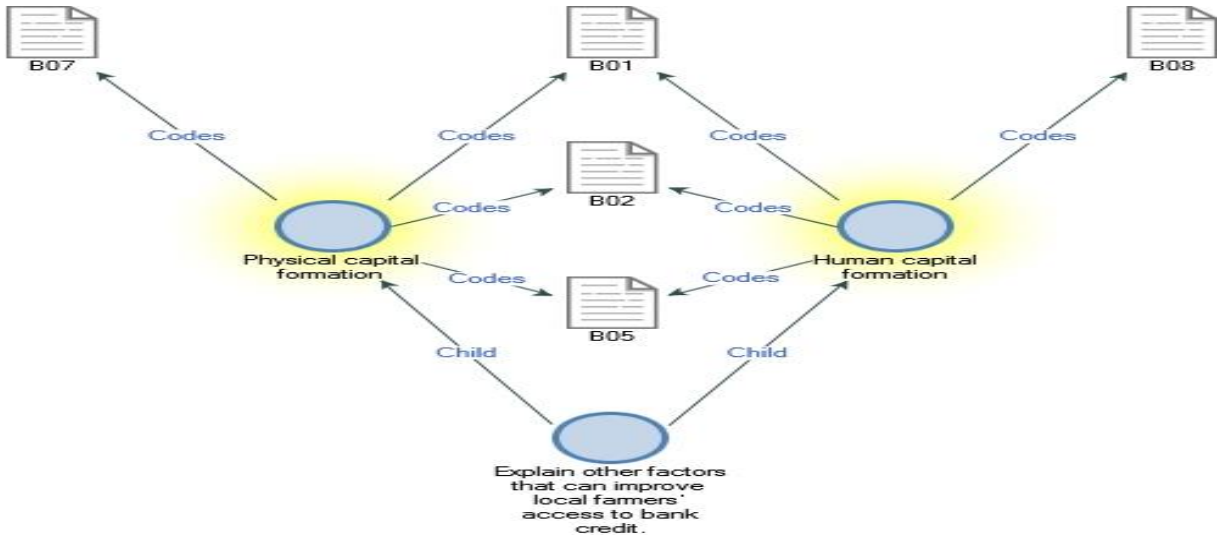

Figure 1. Comparison diagram of the top two themes; human capital formation and physical capital formation. Source: Primary Data (2019).

saturation had been reached when no new knowledge was being generated from the interviews.

Summary of emerging themes

The bank credit officers' verbatim responses on the factors they perceived as key for enhancing the local farmers' access to bank credit were grouped and coded under 7 emerging themes. These themes included the need for bank account activity, human capital formation, own equity, social capital formation, diversification, physical capital formation and the addressing of land tenure issues (Table 1). The summary of the number of commercial banks that discussed the aforementioned themes, and how frequent the themes were mentioned is tabulated in Table 1.

Three themes namely human capital formation, physical capital formation and social capital formation emerged as the dominant themes in the oral interview discussions with the bank credit officers. Four out of the seven bank credit officers mentioned words coded under the human capital formation theme for eight times. Hence, human capital formation emerged as the major theme in the study. Similarly, four bank credit officers mentioned words that were coded under the physical capital formation theme for seven times. Therefore, physical capital formation emerged as the second most discussed theme in the study. Words coded under the social capital formation theme were also mentioned by two banks for five times, and emerged as the third most discussed theme. The least mentioned theme was that of own equity contribution to the loan amount requested by the farmer. A comparison of the top two themes of human capital formation and physical capital formation was done (Figure 2).

Comparison of the top two emerging themes

The files coded B01…B08 (Figure 1) represent the individual commercial banks that participated in the

Figure 2. Word cloud of bank credit officers' verbatim responses coded under the Human Capital Formation theme. Source: Primary Data (2019).

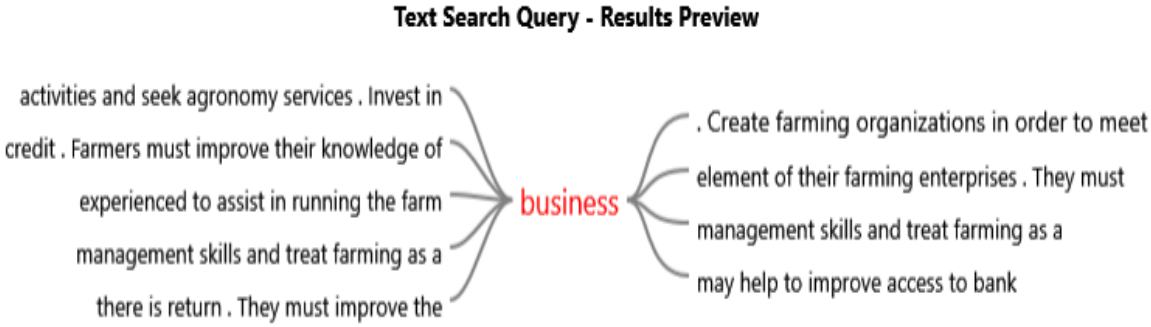

Figure 3. Word tree output of the sub-theme "business". Source: Primary Data (2019).

study. The child arrows represent the two major themes that arose when the bank credit officers were asked to explain the factors that could improve the local farmers' access to bank credit. In addition, the code arrows represent the individual bank credit officers' responses which were coded under the two main themes.

The comparison diagram (Figure 1) shows that a total of five bank credit officers from commercial banks B01, B02, B05, B07 and B08 identified human and physical capital formation activities as key strategies for stimulating bank credit access among farmers in Zimbabwe. Out of those five commercial banks, three (B01, B02 and B05) believed that a combination of both physical and human capital formation activities on the farm could enhance the farmers' access to bank credit in Zimbabwe. Only B07 believed that physical capital formation activities alone could be key for enhancing bank credit access among the farmers. On the other hand, B08 also believed that human capital formation activities could solely be adopted to improve bank credit access among farmers in Zimbabwe. Despite this, the majority (60%) of the 5 banks believed in the combination of both human and physical capital formation strategies to enhance bank credit access among farmers.

Human capital formation

A word cloud of verbatim responses coded under the top theme of human capital formation was extracted (Figure 2).

Three main sub-themes emerged from the word cloud, and they included business, knowledge and skills (Figure 2). The sub-themes are discussed in detail subsequently.

The word "business" was mentioned by two out of the four commercial banks that perceived human capital formation as a key strategy for enhancing bank credit access among farmers in Zimbabwe (Figure 3). The word "business" was also mentioned for five times by the commercial banks, and emerged as the most discussed sub-theme under the human capital formation theme. The bank credit officers implored local farmers to improve the business element of their farming enterprises through pursuing different ways of improving their knowledge of business. B02 specifically said, "Invest in business management skills and treat farming as a business." B02 also highlighted that if the farmer is lacking in business management skills, employing someone on the ground who is skilled and experienced in farm business management would help to enhance access to bank

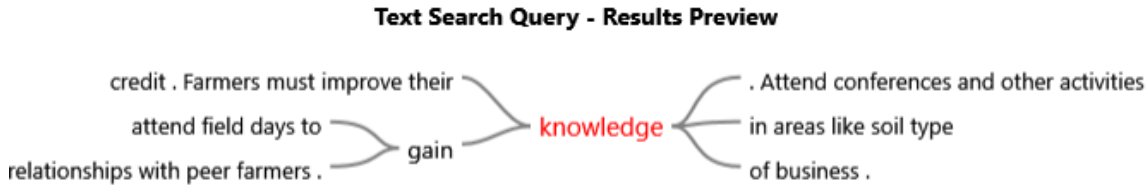

Figure 4. Word tree output for the sub-theme "knowledge".
Source: Primary Data (2019).

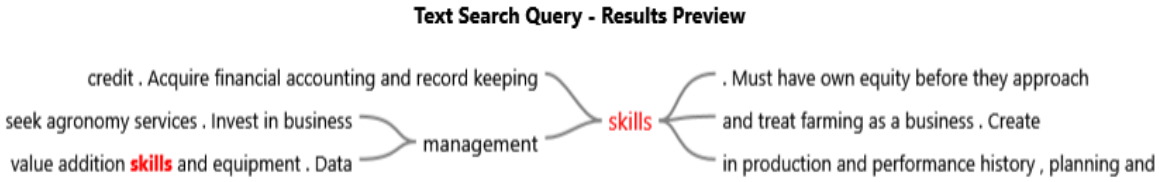

Figure 5. Word tree output for the theme "skills".
Source: Primary Data (2019).

credit.

The sub-theme “knowledge” was discussed by three out of the four banks whose responses were coded under human capital formation for three times (Figure 4). Hence, knowledge emerged as the second most discussed sub-theme under the human capital formation theme. Besides being encouraged to improve their knowledge of business, farmers were also obligated to gain knowledge in other crucial areas. B02 stated that, “Farmers must gain knowledge in areas like soil type and marketing that enhance their performance and loan repayment capacity.” CB1 also said, “Farmers must invest in short courses and attend field days to gain knowledge.”

The word “skills” was also mentioned by two commercial banks for three times in their discussion of human capital formation as a catalyst for bank credit access among farmers in Zimbabwe (Figure 5). Besides making investments in business management skills as already discussed, farmers were also implored to specifically acquire financial accounting and record keeping skills, as well as data management skills. B02 stated that, “Data management skills in production and performance history, planning and record keeping should be sought.” By so doing, farmers in Zimbabwe could enhance their chances of accessing bank credit finance according to the bankers. The need to develop a farm’s human capital base as revealed by this study is purported to directly influence agricultural productivity by affecting the way in which inputs are used and combined by farmers (David and Lopez, 2001), which also ultimately enhances access to bank credit as shown by this study. Musiime and Atuha (2011)’s study in Uganda also established better access to credit by trained farmers who had acquired knowledge, which enabled them to realize higher output and profits. In South Sudan, Ebaidalla and Abdalla (2015) also discovered that farmers who participated in capacity building programs in agricultural production and business management had higher chances of accessing credit from formal financial institutions. Odu et al. (2010)’s study in Nigeria explained that experience and skills of farming were advantageous to securing formal credit facilities because they acted as a guarantee that the agricultural project would mostly succeed.

Physical capital formation

A word cloud was also extracted from the verbatim responses of bank credit officers who had prescribed physical capital formation as a strategy for enhancing bank credit access among farmers in Zimbabwe (Figure 6).

The major sub-theme that emerged among bank credit officers who stated physical capital formation as a strategy for enhancing bank credit access among farmers was “invest” (Figure 7).

The word “invest” was mentioned by two out of the four banks that stated physical capital formation as a catalyst for credit access among farmers for four times (Figure 7). Farmers were implored to invest in off-farm collateral assets, post-harvest handling equipment and techniques, productive assets that could be sweated, and value addition skills and equipment. Haley (1991) supports the accumulation of physical capital assets on a farm, which instigates the employment of capital-intensive techniques in the agricultural sector by declining the use of labor-intensive techniques. According to Bisaliah (2012), this is known as capital deepening (giving each worker a little

Figure 6. Word cloud of bank credit officers' verbatim responses coded under the physical capital formation theme. Source: Primary Data (2019).

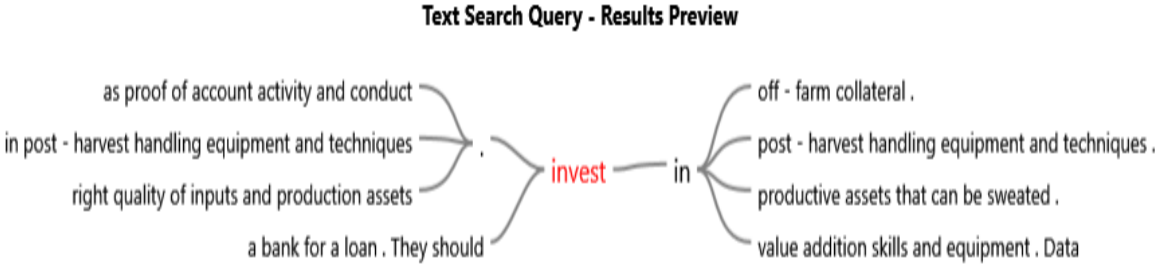

Figure 7. Word tree output for the sub-theme "invest". Source: Primary Data (2019).

more capital to work with), which positively affects agricultural productivity and output growth. B07 actually stated that, “Irrigation facilities enhance access to bank credit. Alternative power solutions like solar equipment and windmills help the farmer to manage the disruption of agricultural activities in light of utility supply challenges being faced by the country.” All these physical capital formation activities were prescribed as strategies that could be adopted for enhancing the farmers’ chances of accessing bank credit in Zimbabwe. In-depth interviews with the bank credit officers also revealed that besides productive farm assets, farmers were also encouraged to invest in properties off the farm (Figure 7). This was recommended to enable the farmers to circumvent the land tenure security issues presented by the lack of freehold land ownership among local farmers. Farmers were also implored to seize opportunities along the agricultural value chain, especially value addition, which was recognized as key in the augmentation of a farm’s income portfolio and loan repayment capacity (Figure 7). Mayowa (2015)’s study equally established that in the absence of legal title to land, farmers in peri-urban South African farms could access bank credit from the Land Bank making use of their farm assets that enhanced their productivity and repayment ability, and also fulfilled the collateral role.

Besides adding to the monetary value of the farmers’ primary products, bank credit officers argued that value addition could also protect farmers from the risk of loss of perishable products, especially during market gluts, low demand and low market price periods. Moreover, the bankers indicated that offering value addition services to peer farmers could also diversify the income portfolio of a farming enterprise, thereby enhancing its chances of access to more bank credit to enable it to pursue its growth objectives. Investments in post-harvest handling technologies were also believed to help in cushioning farmers from losses during low demand periods, which would help them to meet strict product specifications especially by contractors who produce for the

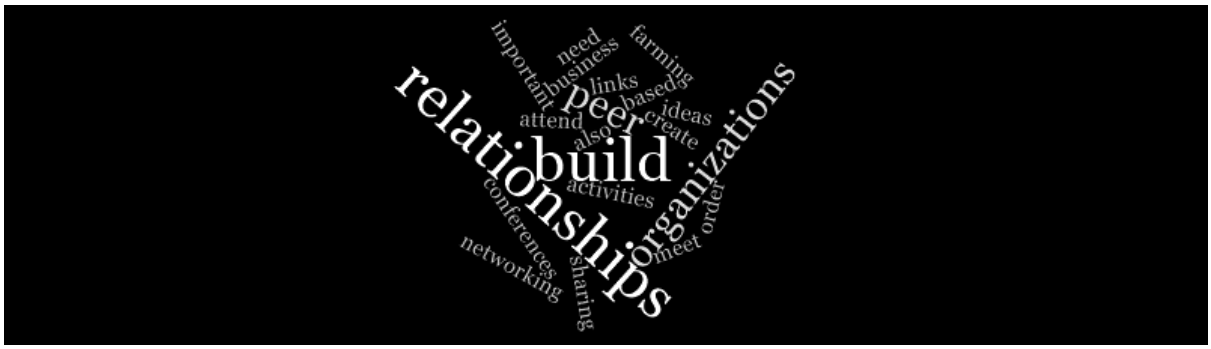

Figure 8. Word cloud of bank credit officers' verbatim responses coded under the social capital formation theme.
Source: Primary Data (2019).

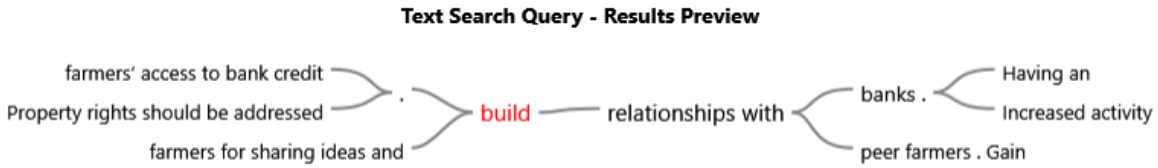

Figure 9. Word tree output for the sub-theme "build"
Source: Primary Data (2019).

international market, and in augmenting their income portfolios if they offer storage services to peer farmers.

Investments in alternative power solutions like solar and wind were also identified as key for enhancing bank credit access among farmers by bank credit officers at the current moment in Zimbabwe. This was recommended in light of the liquidity challenges that the country is facing in importing electrical power from other countries, and its constrained capacity to produce locally due to infrastructural issues and water level challenges at its key hydro-electric and thermal power stations in Kariba and Hwange, respectively. Irrigation infrastructure investments by farmers were also identified as key for escaping from the rainfall fluctuation risks that repel lenders as confirmed by various studies (Chakoma and Chummun, 2019; Ruete, 2015; Vitoria et al., 2012). The availability of irrigation facilities on the farm could also guarantee credit access by individual farmers because all the banks under study indicated that they did not fund dryland farming as a policy. All these physical capital formation activities were perceived as key in improving the local farmers' prospects of accessing the indispensable bank credit in Zimbabwe. Also supporting the need for physical capital formation in farms, FAO (2012) declares that physical capital formation has a positive effect on the optimum use of natural resources, the adoption of advanced technology, the development of infrastructure for agricultural activities, thereby ensuring food security and making agriculture a profitable commercial activity, a quality that is attractive to lenders as established by this study. Farm assets were also identified by various studies as key determinants of bank credit access (Chandio et al., 2017; Enimu et al., 2018; Isaga, 2018).

Social capital formation

Social capital formation emerged as the third most important strategy for enhancing the local farmers' access to bank credit in Zimbabwe. Social capital formation was discussed by two bank credit officers for five times. A word cloud of the bank credit officers' verbatim responses coded under social capital formation was extracted (Figure 8).

Two major sub-themes emerged from discussions with bank credit officers who perceived social capital formation as an important strategy for enhancing bank credit access among farmers in Zimbabwe. These themes included build and organizations (Figure 8). The sub-theme "relationships" was left out because it was always used alongside the word build by the bank credit officers.

The sub-theme "build" was mentioned by two commercial bank credit officers for three times. Farmers were encouraged to build relationships with banks and peer farmers (Figure 9). According to B01, establishing a relationship with a banker could start from the account opening process, and maintaining a certain level of activity within the account. B01 specifically stated that,

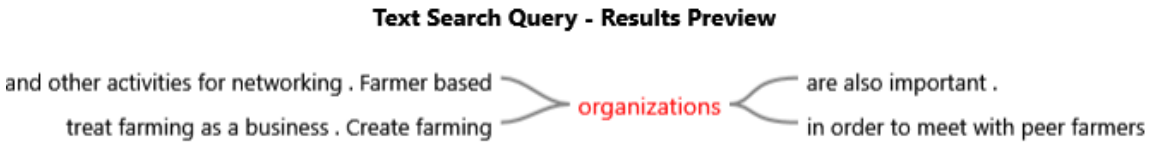

Figure 10. Word tree output for the word organizations.
Source: Primary Data (2019).

"Account activity within a farmer's bank account provides a record of transactions that will be visible to the banker. Account activity with other banks is also considered as proof of account activity and conduct." B02 similarly indicated that, "Having an account provides patterns of the farming enterprise's proceeds, which are a crucial set of information needed to make a lending decision." In addition, B02 implored farmers to build relationships with peer farmers to enable the sharing of ideas. According to Gómez-Limón et al. (2012), social relationships/networks may affect the economic sustainability of farmers through influencing their farming practices and their propensity to adopt new technologies from the information supplied through these networks, which ultimately enables them to learn new techniques, acquire know-how, obtain training from others, and in some cases obtain official assistance like finance to implement various practices. Several studies also link social networks to credit access (Kofarmata et al., 2016; Saqib et al., 2018). These results show that the emphasis of local commercial banks on social relationships and networks is on their ability to diffuse knowledge and skills among farmers, not necessarily on who they know to gain access to bank credit.

The word "organizations" was mentioned for three times by two commercial bank credit officers (Figure 10). B02 encouraged farmers to create farmer-based organizations that encourage networking and the sharing of ideas. Besides, farmers were encouraged to attend conferences and other activities created by other organizations to build social networks that are essential for enhancing farming knowledge. In Abdul-Jalil (2015)'s study, membership to a farmer-based organization positively and significantly impacted the amount of credit accessed by the farmers from formal credit sources. Farmers who also belonged to cooperatives could access credit better because of their higher productivity and risk sharing prospects in South Africa (Mayowa, 2015).

CONCLUSION AND RECOMMENDATIONS

Human and physical capital formation activities linked to investments in farm productive assets and personal development skills in agricultural production and business management emerged as the key prescriptions for enhancing bank credit among farmers in Zimbabwe according to the commercial banks. Beyond investments in farm assets, the study also revealed that off-farm investments could assist farmers in solving the collateral problem induced by the lack of land ownership, thereby enhancing their chances of accessing bank credit. Moreover, the seizing of value chain opportunities by farmers in value addition and other post-harvest technologies could diversify the farmers' income portfolios and cushion them from various risks, thereby enhancing their credit access prospects. Business management skills in data management in areas of financial record keeping, budgeting and historical performance reporting were also prescribed by bankers as crucial catalysts of bank credit access among farmers in Zimbabwe. Social capital formation activities formed through building relationships with key stakeholders like the lenders themselves and peer farmers were also recognized as important for enhancing farmer access to bank credit. Farmer based organizations were also prescribed for farmers to share risk and provide a foundation for sharing knowledge.

In light of the earlier findings, the government should prioritize the addressing of land tenure security among farmers to ensure their sustainable access to bank credit. Agricultural extension services by the government in local farms should also be intensified to enhance farmer knowledge. Investments in farm productive assets should also be pursued by farmers to ensure that they enhance their production capacity, incomes and their repayment capacity in order to attract lenders. Farmers are also challenged to diversify into value addition activities off the farm in order to fulfil collateral requirements by banks for titled immovable property. Investments in alternative power solutions by farmers in solar and wind may also shield them from losses induced by disruptions in power utilities in the country, especially electricity and water. Personal development initiatives to acquire agricultural production and business management skills should also be prioritized by farmers in order to enhance their access to bank credit. Farmers should also create farmer-based organizations like cooperatives that can boost their production capacity potential, and also minimize their moral hazard risks in the eyes of the lenders to be able to qualify for alternative financing schemes like group lending. The bankers themselves are also implored to pursue such financing models given the collateral problem faced by farmers in Zimbabwe in the absence of

the preferred freehold tenure. The participation of farmers in development programs by government, private and donor communities may also enhance their knowledge in agricultural production and farm business management, which would all help to enhance their access to bank credit. Banks are similarly encouraged to devise farmer capacitation programs in order to educate them on what they expect for a potential borrower to be eligible for bank credit.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Micro-determinants of informal employment in Côte d'Ivoire: The role of socio-demographic factors

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This paper proposes to identify the micro-determinants of informal employment in Côte d'Ivoire, focusing on socio-demographic factors. Using data from the National Survey on Employment and the Situation of the Informal Sector (ENSESI) and the Logit method, the empirical results indicate that unschooled and less qualified individuals are more likely to be in an informal situation; that the probability of engaging in informal activities is higher for women than for men; that the probability of being informal decreases with the age of the individual; that single (or customarily married) individuals are more likely than married individuals to belong to the informal group; that individuals in the agriculture sector are more likely to be informal than those in the service and industrial sectors; and that individuals living in urban areas are less likely to fall into informal employment compared to individuals in rural areas. Consequently, economic choices and decisions must be targeted on the basis of these empirical findings to reduce the weight and consequences of the informal sector in Côte d'Ivoire's economy.

Key words: Informal employment, micro-determinants, socio-demographic factors, Cote d'Ivoire.

INTRODUCTION

The persistence and even growth of informal employment (De Soto, 1994), in all developing economies makes it a structural component of the labour market (Jutting and Laiglesia, 2009). Indeed, according to the IMF (2017), the informal sector is a key component of most sub-Saharan economies, where its contribution to GDP ranges from 25 to 65% and where it accounts for 30 to 90% of non-agricultural employment. Even more so, in francophone Africa, the informal sector accounts for more than 50% of GDP and 90% of total employment (IDRC, 2015). The growth of this sector is explained by an increase in the labour market caused by the structural surplus of labour and the insufficient absorption capacity of the modern sector in peripheral economies (Razafindrakoto et al., 2012).

The structure of Côte d'Ivoire's economy is no exception to the rule. Indeed, according to World Bank Data (2018), informal employment has grown significantly by more than 90% since the process of liberalization of the economy in the 1980s. This sector represents between 30 and 40% of GDP (IMF, 2017). In addition, it employs almost the entire working population. Indeed, according to data from the survey on employment and the situation of the informal sector (ENSESI, 2016), 93.6%

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of jobs in Côte d'Ivoire are in the informal sector.

Informality is therefore a subject of interest for political decision-makers and the business community in Côte d'Ivoire. In the sense that although the informal economy provides a safety net for a large and growing working-age population, the informal sector is seen as an impediment to economic growth and improved economic policies in many developing countries (Krakowski, 2005). Indeed, the dominant economic philosophy today is that governments should provide sufficient social services (education and health) to create pro-poor growth, with little reliance on debt financing. As a result, many developing countries focus on increasing tax revenues. This seems difficult if there is a large informal economy[1]. Reducing the informal economy, broadening the tax base and thus increasing tax revenues is the virtuous circle that many developing country governments are seeking. Thus, reducing the size of the informal sector could open up the possibility of lowering overall tax rates or improving public services. Indeed, although people working in the informal economy benefit from public services, they do not contribute to their financing. Thus, the growth of this sector creates unfair competition among firms and raises equity concerns related to the existence of unprotected workers without health insurance and pension protection (Angel-Urdinola and Tanabe, 2012). La Porta and Shleifer (2014) go even further by highlighting the low productivity and extreme inefficiency of the informal sector compared to the formal sector. Ultimately, in countries with a large informal sector, effective management of the economy by the state may be compromised (Krakowski, 2005).

It is for all these reasons that the empirical literature in recent years has devoted much attention to the identification and analysis of the drivers and disincentives of the informal sector. Thus, among the many factors (Aspilaire, 2014; BIT, 2002; Bounoua et al., 2012; Elbahnasawy et al., 2016; Elgin and Oyvat, 2013; Hassan and Schneider, 2016; Iguidia et al., 2016; Ouédraogo, 2017; Othmane and Mama, 2016; Medina et al., 2017; Sani, 2009)[2] identified in the literature, socio-demographic factors appear prominently. For example, a study by Başbay et al. (2018) using micro-data from seven developing countries (China, Ecuador, Egypt, Mexico, Peru, South Africa and Yemen) reveals that the socio-demographic characteristics of individuals are strong predictors of their employment in the informal sector. Similarly, Angel-Urdinola and Tanabe (2012), in their study of the informal sector in the Middle East and North Africa (MENA) region, examine the main micro-determinants of informal employment, namely age, gender, education level, employment sector, marital status, occupational status and geographical area. In a similar vein, Aikaeli and Mkenda (2014), modelling the choice of employment type using the multivariate logistic model, found that lack of capital and low education levels prevent micro and small entrepreneurs from engaging in broad formal activity. Such results were also found by La Porta and Shleifer (2008). Indeed, by exploring the sources of productivity differences between formal and informal firms, they conclude that the most striking differences between formal and informal firms are in the human capital of their managers. The work of Gennaioli et al. (2013) also corroborates these results. Still in a similar vein, Malam (2018), using Probit's method, sought to identify the determinants of informal employment in Niger, focusing on the effect of types of degrees. The author's results reveal that workers with some schooling at all levels are more likely to leave the informal sector than those who have never attended school; the better the chance of leaving the informal sector, the higher the level of education. Moreover, the more educated a father is, the less his child is in the informal sector. Also, the father's education is the main difference in the determinants of informal employment between urban and rural areas. Finally, the regions with the lowest gross school enrolment rate are also those that offer the most opportunities for informal activities.

For the specific case of Côte d'Ivoire, scientific studies on the determinants of informal employment are rather rare due to the scarcity of micro-data on the employment situation in Côte d'Ivoire (Premand and Tien, 2017). To our knowledge, the only one that can be cited is that of Günther and Launov (2012), based on the Living Standards Survey (ENV, 1998), showed that the Ivorian informal sector is heterogeneous and that the labour market is characterized by barriers to entry into the sectors, thus reflecting the violation of the competitive market hypothesis. In addition to this study, a number of reports of studies conducted by AGEPE[3] (2013, 2014) can be attached, which focus more on the quantitative evaluation of the phenomenon without understanding the factors explaining access to the informal sector that condition public employment policies.

As can be seen, the issue of factors influencing the informal sector is still insufficiently addressed in Côte d'Ivoire due to data limitations, although it is a crucial issue. This deprives political decision-makers of scientific

[1]In Côte d'Ivoire, for example, according to the Table of State Financial Transactions (TOFE), the informal sector contributes only 1% to tax revenues while formal companies account for almost all the tax burden.

[2]Among others, we can cite the work of Ouédraogo (2017), Hassan and Schneider (2016), Medina et al. (2017) who highlight institutional failures as factors encouraging the growth of informal activities; Elbahnasawy et al. (2016) show that political instability and autocratic power are associated with a larger informal economy; the studies by Elgin and Oyvat (2013) and Othmane and Mama (2016) find a growing relationship between the rate of urbanization and the level of informality; for Iguidia et al. (2016), the social conditions of individuals lead them to resort to informal employment; for Aspilaire (2014) and Bounoua et al. (2012), inflation is a factor stimulating informal activities; the occurrence of economic crises has been cited as a factor favouring the growth of the informal sector (BIT, 2002; Sani, 2009); according to the work of Medina et al. (2017), the degree of trade openness impacts the informal economy, etc. (ILO, 2002; Sani, 2009).

[3] The Agency of Study and Employment Promotion (Agence d'Etudes et de Promotion de l'Emploi) of Côte d'Ivoire.

reflections on effective public policies to combat the progress or better orientation of the informal sector, despite its dynamism. This paper therefore fills this gap as far as Côte d'Ivoire is concerned by making exclusive use of the most recent micro-data from the National Survey on Employment and the Informal Sector (ENSESI), collected by the National Institute of Statistics of Côte d'Ivoire in 2016. Therefore, the objective of this article is to identify the micro-determinants that explain informal employment in Côte d'Ivoire with a focus on socio-demographic factors.

METHODOLOGY

Model specification

The dichotomous nature of the explained variable (informal employment), whether or not belonging to the informal sector, leads to binary choice models (Bourbonnais, 2015), namely the Probit model or the Logit model. In this study, to avoid arbitrariness in the choice of estimation method, we have chosen the best model with as a criterion the minimization of the AIC and BIC information criteria and the maximization of the different R-squares. The results show that the Logit model is the most suitable in our case (Annex A-1).

Our variable of interest is thus specified as follows:

$$Y_i = \begin{cases} 1 \; If \; individual \; i \; is \; in \; informal \; employment \\ 0 \qquad\qquad\qquad\qquad otherwise \end{cases} \text{ for } i \in \{1, \ldots, 14622\}$$

Assuming that y_i^* a latent variable underlying the phenomenon of underemployment defined by:

$$y_i^* = x_i\theta + \varepsilon_i$$

where θ is the vector of parameters and ε_i the vector of residuals. x is the vector of explanatory variables. The probability that individual i is in informal employment $(y_i = 1)$ is defined as follows:

$$p_i = P(Y_i = 1) = P(y_i^* > 0) = P(x_i\theta > -\varepsilon) = F(x_i\theta)$$

With F the distribution function of $-\varepsilon$, that is, the function defined by:

$$F(w) = P(-\varepsilon < w)$$

For the binary Logit model used in this study, F denotes the distribution function of the logistic law:

$$F(w) = L(w) = \frac{e^w}{1 + e^w}$$

Study data and variables

The most recent data source that provides the most complete information on socio-demographic characteristics and employment in Côte d'Ivoire is the National Survey on the Employment Situation and the Informal Sector (ENSESI) conducted in 2016[4]. Quality control of data collection was ensured by ENSEA. The general objective of quality control was to contribute to the respect of the survey protocol and to improve the overall quality of the data collected. To this end, in addition to active participation in the preparatory phase of the study, the methodology proposed by ENSEA focused on the organization of a counter-survey in a sub-sample. The strategies mobilized for the collection of data for the National Survey on Employment and the Informal Sector (ENSESI, 2016) have provided a good knowledge of the labour market. In two phases, the first one, known as the main phase, was carried out among households and made it possible to identify Informal Production Units (IPUs). The second one, called the "Informal Sector" survey, was conducted among heads of IPUs. The 2016 National Survey on Employment and the Informal Sector was conducted using a probability survey, which made it possible to extrapolate the results of the observed sample to the entire surveyed universe and to calculate the sampling errors in terms of coefficient of variation and confidence interval. The sample design was used to calculate extrapolation coefficients that represent the absolute or relative weight of the drawn household (number of households represented) in the sample. ENSESI (2016) covered the national territory. Also, the two-stage stratified sample allowed estimates of indicators at the national level and by region/district (the stratum) with precision variable per stratum but greater than or equal to 92.5%. The study specifically covers 14622 individuals in employment in Côte d'Ivoire.

Following the literature, gender, place of residence, age, nationality, marital status, level of education and disability variables are used to explain the exercise of informal activity in Côte d'Ivoire. These different explanatory variables are detailed in Annex A-2.

Descriptive statistics of variables

Hejase et al. (2012) contend that informed objective decisions are based on facts and numbers, real, realistic and timely information. Furthermore, according to Hejase and Hejase (2013), "descriptive statistics deals with describing a collection of data by condensing the amounts of data into simple representative numerical quantities or plots that can provide a better understanding of the collected data" (p. 272). Therefore, this study analysed data collected with descriptive statistics such as percentages supported with tables for clarity. Several pieces of information emerge from the aforementioned descriptive statistics. The results reported in Table 1 reveal that employment is almost exclusively informal in Côte d'Ivoire. In fact, 96% of respondents carry out their economic activities in the informal sector against only 3% in the formal sector. It also shows that women are much more exposed than men in terms of informal employment. Also, the figures show that 99.67 and 96.46% respectively of young people between 14-24 and 25-35 years old are more likely to work in the informal sector as opposed to adults. In terms of marital status, almost one-third of those with civil marriages are in formal employment, while those in cohabitation, divorced, never married, customary and religious marriages are mainly concentrated in the informal sector. With regard to place of residence, the results of the survey reveal that employment is practically informal in rural areas. In urban areas, particularly in the capital (Abidjan), informal employment remains very high, but formal employment is still present, at 6.62% (11.17% respectively). In terms of education level, people with higher

[4]ENSESI (2016) was financed by the State of Côte d'Ivoire and the World Bank. It was carried out by the National Institute of Statistics (INS) in collaboration with the Youth-Employment Agency and the Directorate General of Employment. It received technical support from the World Bank, the International Labour Office (ILO), UNDP and ENSEA.

Table 1. Descriptive statistics of variables.

Nature of employment	Formal (%)	Informal (%)
Gender		
Female	2.10	97.90
Male	5.40	94.60
Place of residence		
Abidjan	11.17	88.83
Rural	1.10	98.90
Other Urban	6.62	93.38
Nationality		
Ivorian	4.81	95.19
Non-Ivorian	1.17	98.83
Level of education		
No level	0.60	99.40
Primary	1.27	98.73
Secondary	12.72	87.28
Tertiary	43.16	56.84
Sector of activity		
Agriculture	0.33	99.67
Trade	2.24	97.76
Industry	6.97	93.03
Service	16.44	83.56
Marital status		
Cohabitation	5.30	94.70
Divorced (e)	2.46	97.54
Never married	3.20	96.80
Civil marriage	30.26	69.74
Customary marriage	2.48	97.52
Religious marriage	2.02	97.98
Separate (e)	1.91	98.09
Widow/Widower	1.51	98.49
Limb disability		
Yes	97.25	2.75
No	95.96	4.04
Age		
Age group 14-24	99.67	0.33
Age group 25-35	96.46	3.54
Age group 36-59	93.61	6.39
Age group 60+	97.41	2.59

Source: ENSESI (2016).

education are most often found in the formal sector (43.16%), while those with no education or a relatively low level of education (primary and secondary) are more likely to be in the informal sector. With regard to the sector of activity, the primary sector (agriculture, livestock, forestry, and fishing) is dominated by informal employment, with almost 99.67% of jobs in this sector being informal. Commercial activity has a high proportion of informal employment (97.76% of jobs are informal). In services, 16.44% of

Table 2. Estimation results.

Explanatory variables (reference modality)	Marginal effects	P-values	Coefficient
Education (No level)			
Primary	-0.005	0.036	-0.47
Secondary	-0.062	0.000	-2.27
Tertiary	-0.112	0.000	-3.01
Gender (Male)			
Women	0.017	0.000	0.69
Nationality (Ivorian)			
Non-Ivorian	0.014	0.000	0.61
Age (14-24 years)			
25-35 years	-0.027	0.000	-1.79
36-59 years	-0.042	0.000	-2.31
60 years and over	-0.045	0.000	-2.41
Sector of activity (Agriculture)			
Industry	-0.044	0.000	-2.39
Trade	-0.021	0.000	-1.64
Service	-0.072	0.000	-2.98
Limb disability (Yes)			
Yes	0.011	0.308	0.471
Place of residence (Rural)			
Abidjan	-0.002	0.509	-0.104
Other Urban	-0.006	0.069	-0.260
Marital status (Customary marriage)			
Civil marriage	-0.034	0.000	-0.960
Religious marriage	0.003	0.481	0.135
Cohabitation	0.002	0.527	0.102
Divorced (e)	0.014	0.246	0.622
Separate (e)	0.015	0.113	0.696
Widow/Widower	-0.0003	0.974	-0.012
Never married	0.006	0.092	0.259
Number of observations		14622	
LR $Chi^2(6)$		2106.14	
Prob > Chi^2		0.0000	
Pseudo R^2		0.42	

Source: ENSESI (2016).

all jobs held by the active population are formal jobs, compared to 6.97% in the industrial sector. These two sectors have a large number of formal enterprises, which could explain this high proportion of formal employment for these two sectors. The results also reveal that foreigners (non-Ivorians) are mostly employed in the informal sector (98.83%). Finally, we find that people with physical disabilities are mostly employed in the informal sector.

EMPIRICAL RESULTS

Estimation results

The results of the regressions using the Logit method are summarized in Table 2.

Model validity tests

At the end of the likelihood ratio test, the p-value associated with the Chi-square test is well below the 1% threshold. We therefore reject the null hypothesis. Thus, all the explanatory variables provide significant information to explain the model. To apprehend the predictive qualities of the model, we analysed the confusion matrix (Annex A-3). The predictive power of the model is 91.77% for a threshold cut-off = 0.9. Overall, we can say that the model predicts an acceptable classification of individuals. This means that just over 91 out of 100 informally employed individuals are well ranked by the model. The area under the ROC curve, estimated at 0.9386, also indicates that the discriminant power of the model is good (Annex A-4).

DISCUSSION

The results of the test are globally significant. Indeed, according to the model's maximum likelihood estimates, the p-value associated with the Chi-square test is 0.000, which means that there is at least one variable that can explain whether an individual is in informal employment or not.

The results show that the level of education, age, gender, sector of activity, place of residence, nationality and marital status are significantly associated with informal employment at the 5 and 10% thresholds, while the presence of a disability (limb disability) was not significant in predicting those in informal employment.

Level of education

With respect to education level, the results of the model show that the probability of being in the informal sector decreases with the level of education. In other words, individuals with no education and those with fewer qualifications are more likely to be in an informal situation. Indeed, according to our results, when we move from an individual with a primary, secondary or tertiary education level, the probability that this individual falls into informal employment decreases by 0.5, 6.22 and 11.23% points, respectively compared to an individual with no education level. This result is perfectly in line with those obtained by Adair and Bellache (2012) then Souag (2018) in Algeria, Aikaeli and Mkenda (2014) for Tanzania, Tsafack et al. (2019) in Cameroon and Malam (2018) for Niger.

Marital status, gender, and age

Preference for informal employment also depends on other characteristics such as marital status, gender and age. Indeed, the probability of a person working in informal employment decreases by 3.40% point for those who have had a civil marriage compared to those who have had a customary marriage[5]. This means that customarily married persons are more likely to choose a job in the informal sector than married persons who are looking for permanent jobs. Also, we find that gender is another factor that significantly influences informal employment. Indeed, being a woman increases the probability of working in the informal sector by 1.76% point compared to a man. Such a result, which joins those of Malam (2018), Aikaeli and Mkenda (2014) and Tegoum (2012), Tansel and Kan (2012) and Adair and Bellache (2012), could be explained by the fact that women in developing countries are most often housewives and practice income-generating activities to meet their extra-familial expenses. These activities are mostly informal (Malam, 2018). Also, age reduces the likelihood of being in informal employment rather than formal employment. In fact, being in the 25-35, 36-59 and 60+ age groups decreases the probability of falling into informal employment by 2.7, 4.2 and 4.5% points, respectively, compared to an individual in the 14-24 age group. Young people, given their low experience and lack of employment, tend to work in informal employment. As a result, informal employment could be considered a transitional job before obtaining a formal job (Tsafack et al., 2019).

The sector of activity

According to our descriptive analyses, there is a high concentration of informal employment in agriculture compared to other sectors. Our econometric results support these findings. Indeed, our estimates reveal that individuals working in the agriculture sector have a higher probability of being informal than individuals in the services, industry and trade sectors[6]. The largest decrease is in the service sector where it is 7.26% point.

Place of residence and nationality

The results reveal that the place of residence significantly influences informal employment in Côte d'Ivoire at the 10% threshold. Indeed, people living in Abidjan (resp. other urban) are less likely to fall into informal employment compared to individuals in rural areas. Indeed, being in Abidjan (resp. other urban) reduces the probability of informal employment by 6.95% point compared to individuals in rural areas. This result is similar to that of Malam (2018). This result, which runs counter to the findings of the 1-2-3 survey conducted in

[5]Customary or traditional marriage is still not legalized in Côte d'Ivoire. Only civil marriage is officially recognized.

[6]In general, countries where agricultural employment accounts for a large share of overall employment, such as Côte d'Ivoire, are associated with higher levels of general informality (Angel-Urdinola and Tanabe, 2012).

the seven capitals of WAEMU[7] member countries could be justified by the fact that, nowadays, carrying out economic activity in the urban environment requires compliance with several administrative formalities. The proximity of the services in charge of regulation, permanent monitoring and incentives such as tax reductions granted to small and medium-sized enterprises (SMEs) declared to the tax authorities are factors that reduce informal employment and are specific to the urban environment (Malam, 2018). Thus, nationality has a significant impact on informal employment at the 5% threshold. In fact, non-Ivorians are more likely to fall into informal employment compared to Ivorians, with a probability of 1.48%. This could be explained by the fact that most foreigners in Côte d'Ivoire engage in street vending or work in agricultural plantations.

Conclusion

To remedy the lack of scientific research in Côte d'Ivoire on the informal sector, we attempt in this paper to identify the micro-determinants of informal employment by focusing on socio-demographic factors. The data come from the most recent database of the National Survey on the Situation of Employment and the Informal Sector (ENSESI, 2016), of the National Institute of Statistics. The results of the binary logistic regression allowed us to highlight a number of determining factors in access to informal employment. These include level of education, gender, age, nationality, sector of activity, place of residence and marital status.

In the light of these results, a number of policy implications can be formulated. Firstly, it is important to note that education should not be neglected if policy-makers want to reduce the weight and consequences of the informal sector in the economy of Côte d'Ivoire. In the sense that the results reveal that the probability of being in the informal sector decreases with the level of education. This result reaffirms the crucial role of human capital in a country's development. Moreover, to combat the informal sector, policy makers must facilitate access to formal jobs for certain disadvantaged populations, namely women and young people because of their level of education, lack of work experience or geographical residence. And finally, special attention must be paid to customary marriage to legalize it, as results show that customarily married people are more likely to choose employment in the informal sector than married people who are more likely to seek permanent employment in the formal sector.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

[7]Except Guinea-Bissau

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Annexes

Annex A-1. Choice of the Model.

Variable	Current	Saved	Difference
Model:	Probit	logit	-
N:	14622	14622	0
Log-Lik Intercept Only:	-2465.586	-2465.586	0.000
Log-Lik Full Only:	-1407.464	-1400.166	-7.297
D:	2814.927(14592)	2800.332(14592)	14.595(0)
LR:	2116.245(21)	2130.840(21)	-14.595(0)
Prob> LR:	0.000	0.000	0.000
McFadden's R^2:	0.429	0.432	-0.003
McFadden's Adj R^2:	0.417	0.420	-0.003
Maximum Likelihood R^2:	0.135	0.136	-0.001
Cragg & Uhler's R^2	0.471	0.474	-0.003
Mckelvey and Zavoina's R^2:	0.488	0.584	-0.096
Efron's R^2:	0.302	0.304	-0.002
Variance of y*:	1.953	7.912	-5.959
Variance of error:	1.000	3.290	-2.290
Count R^2:	0.963	0.963	0.000
Adj Count R^2:	0.082	0.075	0.007
AIC:	0.197	0.196	0.001
AIC*n:	2874.927	2860.332	14.595
BIC:	-137126.476	-137141.070	14.595
BIC':	-1914.849	-1929.444	14.595

Warning: Current model estimated by probit, but saved model estimated by logit. Difference of 14.595 in BIC' provides very strong support for saved model.
Source: ENSESI (2016).

Annex A-2. Description of study variables.

Variable	Modalities
Gender	1= Man 0= Woman
Place of residence	1= Abidjan 2= Other Urban 3= Rural
Limb disability	1= Yes (limb disability) 2= No (no limb disability)
Age	1= 14-24 years 2= 25-35 years 3= 36-59 years 4= 60 years and over
Nationality	1= Ivoirian 2= Non-Ivoirian
Marital status	1= Civil marriage 2= Customary marriage 3= Religious marriage 4= Cohabitation 5= Divorced 6= Separate 7= Widow/Widower 8= Never married

Annex A-2. Contd.

Level of education	1= No level 2= Primary 3= Secondary 4= Tertiary

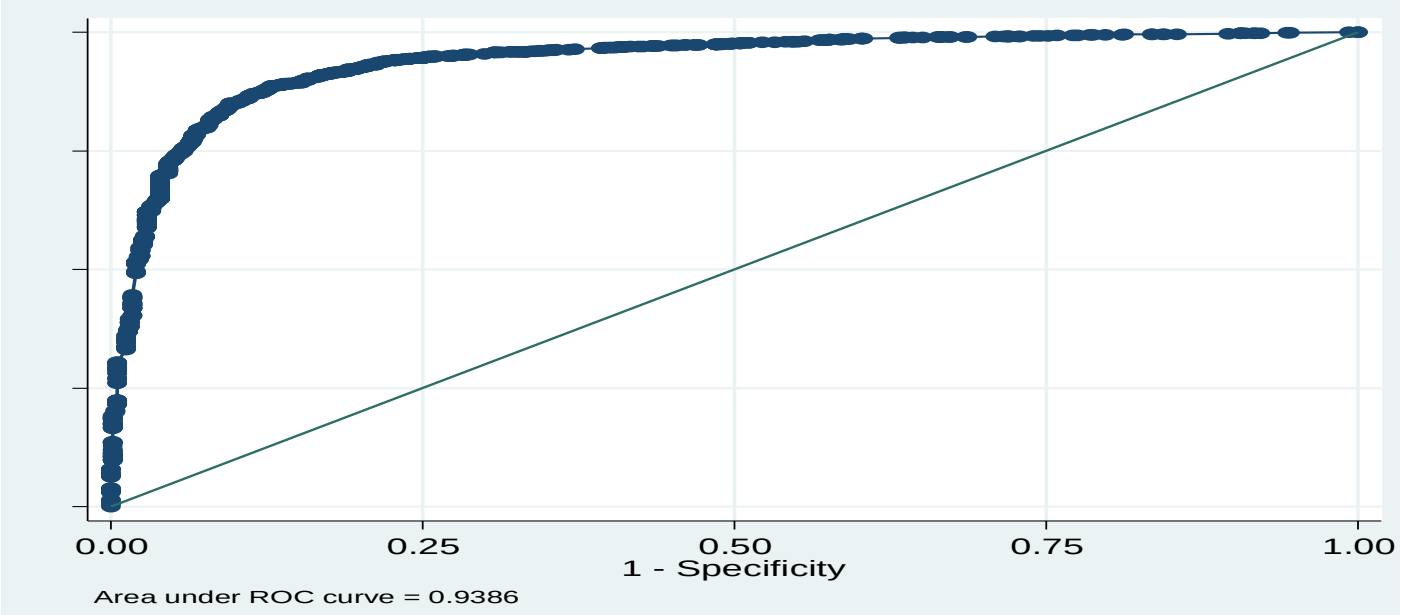
Source: ENSESI (2016).

Annex A-3. Confusion matrix.

Probit model for emploi_inf	**True**		**Total**
Classified	**D**	**~D**	-
+	12943	112	13055
-	1091	476	1567
Total	14034	588	14622

Classified + if predicted Pr(D)>=0.9, True D defined as emploi_inf! =0		
Sensitivity	Pr(+/D)	92.23%
Specificity	Pr(-/~D)	80.95%
Positive predictive value	Pr(D/+)	99.14%
Negative predictive value	Pr(~D/-)	30.38%
False + rate for true ~D	Pr(+/~D)	19.05%
False - rate for true D	Pr(-/D)	7.77%
False + rate for classified +	Pr(~D/+)	0.86%
False - rate for classified -	Pr(D/-)	69.62%
Correctly classified	91.77%	

Source: ENSESI (2016).



Annex A-4- Representation of the ROC curve.
Source: Our calculations.

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Macroeconomic effects of improving road transport infrastructure in Ethiopia: A computable general equilibrium model analysis

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The main objective of this study is to investigate the economy-wide effect of improving road transport infrastructure. The study uses the updated and adjusted version of the 2005/2006 social accounting matrix of Ethiopia. The study applies a single country computable general equilibrium model. The simulation scenario is a reduction of trade and transport margin and an increase in the total factor productivity (TFP) of activities that produce trade and transport services due to public investment in road infrastructure (and hence better access to road infrastructure). The simulation results indicate that improving road transport infrastructure reduced the purchaser and supply price of marketed commodities. This facilitates transportation of commodities to the market and stimulates production; leading to an increase in domestic production in agriculture, trade, and manufacturing sector. The simulation results also indicate that expansion of road infrastructure results in welfare improvement among rural and urban households. Furthermore, better road transport infrastructure facilitates investment flow, foreign trade and hence accelerates economic growth (GDP) of the country. Therefore, public investment in road transport infrastructure should be considered as one of the policy pillars in the design of development policy and strategies of Ethiopia.

Key words: Road transport infrastructure, trade and transport margin, computable general equilibrium model, social accounting matrix, Ethiopia.

INTRODUCTION

Road infrastructure is one of the core components to attain broad based and sustainable development. In the context of the geographical features of Ethiopia, settlement pattern and economic activity, road transport has a very significant importance for accelerating socio-economic development. Access to improved road creates an enabling environment for the promotion of agricultural and non-agricultural activities and stimulates the growth of all sectors of the economy. Ethiopia heavily relies on road infrastructure for public transport service

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Table 1. Performance of RSDP.

Indicators	1997 (RSDP starts)	2014 (Fourth year of RSDP IV)
The percentage of total roads network in good condition	22%	70%
Road density per 1000 square km	24 km	90.5 km
Road density per 1000 population	0.46 km	1.1 km
Total road length (in km)	26,550 km	99,522 km

Source: Author's computation based on Ethiopian Roads Authority (2014).

and its freight. Roads is the main transport modality in Ethiopia; it accounts for over 95% of passenger movement and motorized inter-urban freight (Ethiopian Road Authority, 2009). For the past two decades, the Ethiopian government massively engaged in the upgrading, rehabilitation, and widening of the road network across the country. Ethiopia's road infrastructure expenditure is more than 3% of GDP in recent years.

Road network in the country quadrupled from 1997 to 2015, but the density of road is the lowest in Africa. About 60% of the Ethiopian rural populations are without access to all-weather roads (World Bank, 2016). Accessibility of rural roads is very low in Ethiopia; 10% of population in rural areas resided 2 km away from all-weather roads. This is only half of the benchmark level for Sub-Saharan Africa countries (Foster and Morella, 2011). Poor road transport is the major constraint of market access in the country. Long travel times and higher transportation costs arise because of poorly developed road infrastructure. This adversely affects economic activities and market access to rural households. Better access to road transport reduces travel time, it also reduces trade, and transportation costs. This facilitates access to market and rural non-agricultural employment, which have economy-wide effects. Furthermore, an improved access to road infrastructure potentially accelerates poverty reduction in the country. Trade and transport margins can be reduced through public investments on road infrastructure. The objective of this paper is to investigate and discuss the economy-wide effect of improving road transport infrastructure.

AN OVERVIEW OF ROAD INFRASTRUCTURE IN ETHIOPIA

Road sector development strategies of Ethiopia

Public investment in road infrastructure is acknowledged as one of the pillars of rural development strategies of Ethiopia for the past two decades. Specifically, by recognizing the socio-economic significance of road transport, the government launched a Road Sector Development Program (RSDP) in 1997. The main objectives of RSDP were rehabilitation, upgrading and expanding road network by construction of new road across the country. RSDP was implemented in four separate phases: RSDP I (run from July 1997 to June 2002), RSDP II (run from July 2002 to June 2007), RSDP III (run from July 2007 to June 2010) and RSDP IV run from July 2010 to June 2015 (Ethiopian Roads Authority, 2014).The major achievements of RSDP from 1997 to 2014 include the total network of road increased from 26,550 to 99,522 km and the share of roads in good condition increased from 22 to 70%. Furthermore, road density per 1000 square km increased from 24 to 90.5 km and road density per 1000 population increased from 0.46 to 1.1 km (Table 1).

Trends of road network in Ethiopia

The aggregate road network stock in Ethiopia was 6400 km in 1951 and the size of the road network reached to 9160 km in 1973 with the annual growth rate of 2.05%. In the derg regime (1974-1991), the total stock of road network reached 19017 km with 6.2% annual rate of growth (Ethiopian Roads Authority, 2009; Worku, 2011). Since the inception of RSDP, rehabilitation and construction of new road network has been widening across the country. Road network size of the country from 1997 to 2014 is described in Table 2. The total road network in Ethiopia increased from 26,550 km in 1997 to 99,522 km in 2014 and the sizes of road network annually grow on average by 8.4 km. The rates of growth of road networks are bigger in the current regime relative to the past regime of Ethiopia.

Road density in Ethiopia

Road density defined as the ratio of the length of the aggregate road transport network in the country to the total area of land in the same country. In other words, road density can be defined as road length per 1000 square km of land area or length of road per 1000 person. Density of road is a rough indicator for measuring road accessibility (World Bank, 2008). In Ethiopia, road density per 1000 person increased from 0.46 km in 1997 to 1.1 km in 2014. On the other hand, density of road per

Table 2. Road network in km in Ethiopia (1997-2014).

Year	Road network (km)	Growth rate (%)
1997	26,550	-
1998	27,737	4.5
1999	28,662	3.3
2000	31,554	10.1
2001	32,871	4.2
2002	33,297	1.3
2003	33,856	1.7
2004	36,496	7.8
2005	37,018	1.4
2006	39,477	6.6
2007	42,429	7.5
2008	44,359	4.5
2009	46,812	5.5
2010	48,793	4.2
2011	53,997	10.7
2012	63,083	16.8
2013	85,966	36.3
2014	99,522	15.8

Source: Author's computation based on Ethiopian Roads Authority (2014).

1000 square km increased from 24.14 km in 1997 to 90.5 km in 2014 (Table 3).

Financing of road development

Large amounts of capital are invested for the development of road transport network throughout the country. Table 4 shows annual expenditure for road construction in Ethiopia from 1998 to 2014. During this period, a total of 180.7 million birr was invested for road development in the country. The main source of funding to finance road investment was obtained from domestic source (78.8%) and the remaining 21.2% collected from international sources. The external source of finance for road development mainly acquired from World Bank, European Union, China, African Development Bank and Japan (Ethiopian Roads Authority, 2014).

Data

The source of data for this study is the 2005/06 updated social accounting matrix (SAM) of Ethiopia (Mosa, 2018). The 2005/06 SAM of Ethiopia was built by Ethiopian Development Research Institute in collaboration with the University of Sussex (Tebekew et al., 2009). However, the 2005/06 SAM of Ethiopia is updated by Mosa (2018); specifically, the household, factor, activity, and commodity accounts in the SAM are updated. A SAM represents the circular flow of the economy that captures transactions and transfers between all economic agents in the system for a particular period, usually for a year. Every transaction in the SAM is shown in a cell. Each cell in the SAM describes the flow of funds from the column to the row account. The receipts (income) are recorded in the row whereas the payments (expenditures) are recorded in the column (Pyatt and Round, 1985; Round, 2003). SAMs are generally built by incorporating the following account groups: activities, commodities, factors, institutions (household, enterprise, and government), savings and investment, and the rest of the world.

The updated SAM used for this study comprises of 199 activities and 194 commodities, 34 household groups, 31 factors of production (10 labor categories and 21 other factors), 17 tax accounts, trade and transport margins, savings and investment, stock changes, enterprises, government and rest of the world. Therefore, the updated SAM comprises of 481 row and column accounts. The detail documentation of the updated SAM can be referred to in Mosa (2018).

Relevant activities and commodities accounts are included in the SAM for making the SAM suitable for addressing the objectives of this study. Specifically, in the updated SAM, separate activity accounts such as trade, transport, communication, and storage are created. Similarly, separate commodity accounts such as trade, transport service and communication included in the updated SAM. Furthermore, trade and transport margin is treated as separate account in the updated SAM. The

Table 3. Road densities (1997-2014).

Year	Road density per 1000 population (road in km per 1000 persons)	Road density per 1000 square km (road in km per 1000 square km)
1997	0.46	24.14
1998	0.46	25.22
1999	0.47	26.06
2000	0.50	28.69
2001	0.50	29.88
2002	0.49	30.27
2003	0.49	30.78
2004	0.51	33.18
2005	0.51	33.60
2006	0.53	35.89
2007	0.55	38.60
2008	0.56	40.30
2009	0.57	42.60
2010	0.58	44.39
2011	0.66	49.09
2012	0.75	57.30
2013	1.0	78.20
2014	1.1	90.5

Source: Author's computation based on Ethiopian Roads Authority (2014).

Table 4. Expenditure of money (in birr) for road construction (1998-2014).

Year	Amount of money (in million birr)
1998	1138.1
1999	1275.1
2000	1147.6
2001	1722.1
2002	2001.7
2003	2355.9
2004	2339.5
2005	3,114.1
2006	4,088.1
2007	6,215.3
2008	9,000.5
2009	10,918.7
2010	15,038.6
2011	19490.9
2012	28,616.3
2013	33,658.6
2014	38,617.6
Total	180738.7

Source: Author's computation based on Ethiopian Roads Authority (2014).

balanced macro SAM of Ethiopia is depicted in Table 5. For example, the margin in the SAM is 23.09 billion birr that is cost of trade and transport margin for supplying marketed commodities. The total commodity supply in the

Table 5. Macro SAM of Ethiopia (in billions Ethiopian birr).

Accounts	Commodity	Margin	Activity	Factor	Household	Gov	Tax	Enterprise	Investment	Row	Total
Commodity		23.09	64.99		162.79	15.91			31.89	16.77	315.45
Margin	23.09										23.09
Activity	235.25										235.25
Factor			170.26							0.45	170.7
Household				163.80		1.55				15.79	181.14
Gov							14.15	5.37		3.73	23.26
Tax	10.10				2.73			1.32			14.15
Enterprise				6.69							6.69
Investment					15.53	5.37			3.72	10.99	35.61
Row	47.01			0.21	0.09	0.43					47.74
Total	315.45	23.09	235.25	170.7	181.14	23.26	14.15	6.69	35.61	47.74	

Source: Mosa (2018).

market is 315.5 billion worth of birr, out of this 235.3 billion birr (81.9%) sourced from domestic supply of commodities, 47 billion birr (14.9%) derived from commodities imported from the rest of world, and the rest 10.1 billion birr (3.2%) is a tax payment (Table 5).

METHODS

This study uses Computable General Equilibrium (CGE) model. The CGE model is a system of equations that illustrate the economy as whole and the interaction among its parts. The term CGE composed of three terms: “Computable,” “General” and “Equilibrium.” “Computable” means that the model has a solution or solvable and can generate numerical results. “General” refers that the model integrates the behaviour of the entire agents in the economy. Agents in the economy incorporate producers, households, government, saving-investment, and the rest of the world. “Equilibrium” refers to agents in the economy are optimizing their objectives given budget, time and other resource constraints (Burfisher, 2011).

The analysis of this study applies the STAGE CGE model developed by McDonald (2015). STAGE is a single country CGE model and it is implemented in General Algebraic Modelling System (GAMS). It is a SAM based model. The SAM helps to distinguish economic actors, and it provides the database for calibration of the model. Behavioural relationships in the STAGE model comprise of linear and non-linear relationships. Households choose a bundle of commodities to consume in order to maximize Stone-Geary utility function. The commodities consumed by households are a composite of imported and locally produced commodities. The constant elasticity of substitution (CES) is used to combine imported and locally produced commodities by assuming that these commodities are imperfect substitutes using the Armington assumption (Armington, 1969).

In the STAGE model, a single activity can produce multiple commodities and commodities can be produced using multiple activities by assuming that the proportionate composition of each activity’s production of commodity outputs remains the same. Domestically produced commodities are provided to the domestic market or to export. Domestically produced and exported commodities are aggregated by a constant elasticity of transformation (CET) function. The relative prices control the optimal supply of domestically produced commodities for local and export markets. This model is flexible for modelling small countries (that is, being a price taker) or large countries (that is, being a price maker). The STAGE CGE model is calibrated using the updated SAM of Ethiopia. STAGE CGE is an appropriate model for addressing the objectives of this study. This is because the model has a separate block of equations for accommodating the trade and transport margin. Trade and transport margin refers to the cost of transporting commodities to consumers that is the difference between producer price and consumer price excluding indirect taxes. The detailed documentation of STAGE CGE model can be referred to McDonald (2015).

Policy simulations and model closure rules

Policy scenarios

Scenario one (reducing trade and transport margins): Investment in road infrastructure expands the size of the road transport network and increases road density in the country. Road density is defined as the ratio of aggregate length of road transport in the country to the total size of the country. It is also described as road length per 1000 square km of land area or length of road per 1000 person. Increased road density facilitates transportation services that reduce the costs of transportation and hence transport margins. The effect of road density on transport margins can be obtained through the estimation of the elasticity of the transport margin with respect to road density. The elasticity of the transport margin with respect to road density is estimated by Schürenberg-Frosch (2014) and adopted for the purpose of this study.

Schürenberg-Frosch (2014) estimated these elasticity using an econometric model based on a panel data sourced from a sample of 58 countries, 28 of which are Organisation for Economic Co-operation and Development (OECD) countries and 30 developing and transition economics including some of sub-Saharan countries such as Tanzania, Egypt, and Zambia. Alike to Ethiopia, most of these sub-Saharan countries have low road density and have comparable economic characteristics that make sense to adapt transport margin to road density elasticity calculated from these countries. Schürenberg-Frosch (2014) estimated the elasticity of transport margins with respect to road density to be 0.19 and 0.16 for agricultural and non-agricultural commodities, respectively. In other words, 1% increase in road density results in a transport margin decline by 0.19% for agricultural commodities and by 0.16%

Table 6. Summaries of policy scenarios.

Scenarios	Policy shocks
Scenario one	2.1% decrease in trade and transport margins for agricultural commodities 1.8% decrease in trade and transport margins for non-agricultural commodities
Scenario two	1.1% increase in TFP of trade, transport and communication activities
Scenario three	Combination of scenario one and two

Source: Author's compilations.

for non-agricultural commodities.

The first scenario is carried out based on the road budget and the growth rate of road network density during the period of the Growth and Transformation Plan of Ethiopia (GTP) (2010-2015). During the GTP period, 7.4 billion birr was invested for road construction annually and on average the road density annually expanded by 22% (Ministry of Finance and Economic Development, 2014). Since the Ethiopian government made huge investments in the road sector in the past two decades, only a small increase in road investment is assumed for the future. In this scenario, we assumed only half of the GTP period's annual road budget (that is 3.7 billion birr) is invested for road infrastructure that would expand road density by 11% $\left[\frac{22\% * 3.7 \text{ billion birr}}{7.4 \text{ billion birr}}\right]$ (based on the GTP period's road density growth and road budget). Based on the above-mentioned elasticity of transport margins with respect to road density, this is equivalent to a 2.1% (11%*0.19) reduction of trade and transport margins for agricultural commodities and a 1.8% (11%*0.16) reduction for non-agricultural commodities. Therefore, this scenario is a 2.1% reduction of trade and transport margins for agricultural commodities and 1.8% reduction of trade and transport margins for non-agricultural commodities.

The cost of financing road infrastructure can be acquired from domestic sources and international donors. During the GTP period (2010-2015), 79% of the funds for the road investment came from domestic sources and the remaining 21% were collected from international sources (Ethiopian Roads Authority, 2015). Based on these figures, the government savings and foreign savings are considered the sources of finance for building road infrastructure in all scenarios. Government treasury is the largest source of funds for road investment and hence the larger share of funds is obtained from the government savings relative to foreign savings. In the SAM updated for this study, the total government savings are 5.4 billion birr and foreign savings are 10.9 billion birr in the updated SAM. Thus, the required fund (3.7 billion birr) is generated through a 38% increase in government savings (that is 2.1 billion birr) and a 15% increase in foreign savings (that is 1.6 billion birr). This funding leads to the road network density expanding by 11%.

Scenario two (Increasing TFP of activities that produce trade and transport services: Improved access to road infrastructure facilitates transportation of commodities to the market. Better access to road transport potentially increases the efficiency of activities that produce trade and transport services such as trade, transport, and communication. The TFP effect of better access to road infrastructure is obtained through the elasticity of the TFP of activities that produce trade and transport services with respect to public expenditure on road infrastructure that is adopted from Fan and Rao (2003). Fan and Rao (2003) using an econometrics model estimated the elasticity of public expenditure to productivity of trade and transport service based on the aggregate data from 1980 to 1998 for 17 sub-Saharan countries including Ethiopia.

According to Fan and Rao (2003), the elasticity of TFP of trade and transport services with respect to public expenditure on road infrastructure is 0.021 for Sub-Saharan African countries that is a 1% increases in public expenditure for road infrastructure results in a 0.021% increase in the TFP of activities that produce trade and transport services. The increased government savings and foreign savings for building road infrastructure from scenario one is applied to this scenario.

Thus, a 38% increase in government savings and a 15% increase in foreign savings results in a 0.79% (38%*0.021) and 0.32% (15%*0.021) increase in the TFP of activities that produce trade and transport services respectively. Therefore, in this scenario, TFP of activities produces trade and transport services increase by 1.1% (0.79 + 0.32).

Scenario three: Combination of scenario one and two: Since improved access to road infrastructure reduces trade and transport margins and simultaneously increases TFP of activities that produce trade and transport services, it is expected that the combined scenarios would have larger economy-wide effects relative to the separate effects.

Therefore, scenario one and scenario two are combined to constitute scenario three; a reduction of the trade and transport margin by 2.1% for agricultural commodities and by 1.8% for non-agricultural commodities and in the same scenario, the TFP of trade, communication and transport activities increasing by 1.1%. For financing road infrastructure, government savings exogenously increase by 38% and foreign savings increase by 15% in all scenarios. The policy scenarios are summarized in Table 6.

Model closure rules

The external balance is fixed and the exchange rate is flexible to clear the external balance. The exchange rate is flexible to produce the required level of foreign savings for funding road infrastructure. Investment driven saving is assumed where investment is fixed and saving adjusted for the change in the investment demand. Government raises funds through income tax replacement. Government savings are fixed and income tax rates endogenously adjusted to produce a fixed level of government savings for financing the building of road infrastructure. The consumer price index (CPI) is chosen as a numeraire.

Furthermore, factor supply is fixed and in order to enable the mobility of water fetchers and firewood collectors across different sectors, perfect factor mobility is assumed in the model. Next is reports of the policy impact on domestic commodity prices, household consumption, domestic production, welfare, and major macroeconomic indicators.

RESULTS AND DISCUSSION

Changes in commodity prices

The effect of a decline in trade and transport margins and

Table 7. Simulated changes (percentage) in PQD and PXAC.

Simulated changes (percentage) in PQD			
Commodities	**Scenario one**	**Scenario two**	**Scenario three**
Market food	-0.81	-0.40	-0.89
Market non-food	-0.83	-0.86	-0.96
Simulated changes (percentage) in PXAC			
Commodities	**Scenario one**	**Scenario two**	**Scenario three**
HPHC food commodities	0.76	0.32	0.88
HPHC non-food commodities	0.82	0.70	0.87

Source: Author's computation based on model results.

Table 8. Simulated changes (percentage) in household consumption.

Commodities	Scenario one	Scenario two	Scenario three
HPHC food commodities	0.26	0.19	0.34
HPHC non-food commodities	0.31	0.15	0.51
Market food	0.29	0.21	0.36
Market non-food	0.33	0.24	0.52

Source: Author's computation based on model results

increase in TFP of activities that produce trade and transport services are injected in the economy through the purchaser price of composite commodities (PQD), which is defined as follows:

$$\mathrm{PQD_c} = \mathrm{PQS_c} * (1 + \mathrm{TS_c} + \mathrm{TEX_c}) + \sum_{\mathrm{m}} (\mathrm{ioqttqq_{m,c}} * \mathrm{PTT_m})$$

Where $\mathrm{PQS_c}$ is the supply price of commodity c, $\mathrm{TS_c}$ is the sales tax rate, $\mathrm{TEX_c}$ is the excise tax rate, $\mathrm{ioqttqq_{m,c}}$ is the quantity of transport margin 'm' used per unit of domestic demand and $\mathrm{PTT_m}$ is the price of the trade and transport margins.

Better access to road transport infrastructure mainly affects prices of marketed commodities. This is because these groups of commodities use the services of trade and transport. The decrease in trade and transport margins and increase in TFP of activities that produce trade and transport services reduce the gap between consumer price and producer price. Table 7 depicts the implication of lower trade and transport margins and increase in TFP of activities that produce trade and transport services on consumer price (PQD) and producer price (PXAC). In response to less trade and transport margins and higher TFP, the consumer price for marketed commodities declines in all scenarios. In scenario one, the consumer price decreases by 0.8% for both market food and market non-food. In the second scenario, PQD decreases by 0.4% for market food and by 0.9% for market non-food commodities. Furthermore, the PQD for market food and market non-food decreases by 0.9 and 1%, respectively, in the third scenario.

The producer price for own consumed commodities increased in all scenarios. Specifically, it increases by 0.8% for both Home production for home consumption (HPHC) food and HPHC non-food commodities in the first scenario and by 0.3% for HPHC food commodities and by 0.7% for HPHC non-food commodities in the second scenario. In the third scenario, the producer price increases by 0.9% for both HPHC food and HPHC non-food commodities. Even though the policy scenarios do not directly affect HPHC commodities, the producer price of these commodities is influenced indirectly through the income effect. Specifically, improved road transport infrastructures facilitate market supply of commodities that enhances domestic production and increases income of households. This leads to increases in the demand for own consumed commodities and hence the PXAC for these commodities rises in all scenarios.

Changes in household consumption

The policy scenarios also affect household consumption. Table 8 describes the impact of improved road transport on the consumption of commodities. Consumption of marketed and HPHC commodities increases in all scenarios. Lower trade and transport margins result in lower PQD for marketed commodities that make these commodities relatively cheaper and hence household

Table 9. Simulated changes (percentage) in domestic production.

Economic sectors	Scenario one	Scenario two	Scenario three
Agriculture	0.07	0.08	0.15
Service	0.57	0.77	0.83
Industry	1.06	0.79	1.36

Source: Author's computation based on model results.

consumption increases. Furthermore, increased TFP of activities that produce trade and transport services facilitates the transportation of commodities. This results in extra commodity supply in the market and lower PQD and enhances consumption.

Accordingly, household demand for marketed commodities increases in the first scenario: by 0.3% for both market food and non-food commodities. In the second scenario, the consumption of marketed commodities also increases: by 0.2% for both market food and non-food commodities. Similarly, the consumption of marketed commodities also increases in the third scenario: by 0.4% for market food and by 0.5% non-food commodities. Trade and transport margins constitute a higher share of the cost of marketed non-food commodities in comparison to marketed food commodities. Therefore, due to less trade and transport margins, consumption of marketed non-food commodities increases more compared to marketed food commodities.

The policy simulations also influence household consumption of HPHC commodities. Consumption of HPHC food commodities increases in all scenarios: by 0.3% in scenario one, by 0.2% in scenario two and by 0.3% in the third scenario. Likewise, the consumption of HPHC non-food commodities also increases in all scenarios: by 0.3% in the first scenario, by 0.2% in the second scenario and by 0.5% in the third scenario. Although trade and transport margins do not directly affect HPHC commodities, the consumption of these commodities increase due to the income effect. Particularly, domestic production is enhanced by improved road infrastructure (Table 9) that led to increased household income and hence increased consumption of HPHC commodities.

Changes in domestic production

Less trade and transport margins and higher efficiency facilitate trade activities, encourage larger supply of commodities to the market, and enhance domestic production. Table 9 depicts the implication of lower per unit margin requirements and improved TFP on domestic production. The simulation results indicate that production increases in agricultural and non-agricultural sectors (industry and services) in each scenario. Agricultural production increases in all scenarios: by 0.1% in scenario one and scenario two and by 0.2% in the third scenario. Service production also increases: by 0.6% in the first scenario, by 0.8% in the second scenario and third scenario. Similarly, industrial production increases: by 1.1% in the first scenario, by 0.8% in the second scenario and by 1.4% in the last scenario.

Since trade and transport margins are higher for non-agricultural commodities relative to agricultural commodities, the reduction of margins provides bigger incentives for non-agricultural production. For instance, industrial production increases by a larger proportion relative to other sectors in all scenarios. Furthermore, domestic production increases by larger proportions in the third scenario relative to scenarios one and two; this is because the combined effects of lower trade and transport margins and increased efficiency have a stronger effect on domestic production relative to the separate effects.

Changes in household welfare

Table 10 describes the welfare implication of lower trade and transport margins and improved TFP of activities that produce trade and transport services. Simulation results indicate that expansion of road infrastructure results in welfare improvement among all household groups except non-poor households located in urban areas. However, the amount of welfare gain varies across households. Welfare gains are driven by the increase in the consumption of households in response to lower prices. Households that consume a larger proportion of market non-food commodities are relatively better off than other households are. This is because the cost of margin services accounts for a relatively high proportion of the total expenditure of market non-food commodities. Accordingly, lower trade and transport margins and improved efficiency strongly increase the consumption of market non-food commodities and hence contribute to the well-being of households.

Furthermore, lower transport margins and improved efficiency decrease the cost of production and facilitate domestic production (Table 9) leading to increased factor income to households (Appendix Table 1) and hence positive welfare effects. Only the welfare of non-poor urban households declines in all scenarios because those households pay the largest share of taxes.

Table 10. Simulated changes (percentage) in household welfare (EV/base income).

Households	Scenario one	Scenario two	Scenario three
Household rural zone 1 poor agricultural	0.82	0.73	0.83
Household rural zone 1 poor mixed	0.82	0.73	0.83
Household rural zone 1 poor non-agricultural	0.82	0.73	0.83
Household rural zone 2 poor agricultural	1.31	1.19	1.34
Household rural zone 2 poor mixed	1.31	1.19	1.34
Household rural zone 2 poor non-agricultural	1.31	1.19	1.34
Household rural zone 3 poor agricultural	1.30	1.19	1.32
Household rural zone 3 poor mixed	1.30	1.19	1.32
Household rural zone 3 poor non-agricultural	1.30	1.19	1.32
Household rural zone 4 poor agricultural	1.21	1.12	1.25
Household rural zone 4 poor mixed	1.21	1.12	1.25
Household rural zone 4 poor non-agricultural	1.21	1.12	1.25
Household rural zone 5 poor agricultural	0.74	0.68	0.78
Household rural zone 5 poor mixed	0.74	0.68	0.78
Household rural zone 5 poor non-agricultural	0.74	0.68	0.78
Household rural zone 1 non-poor agricultural	0.96	0.89	1.02
Household rural zone 1 non-poor mixed	0.96	0.89	1.02
Household rural zone 1 non-poor non-agricultural	0.96	0.89	1.02
Household rural zone 2 non-poor agricultural	1.01	0.93	1.10
Household rural zone 2 non-poor mixed	1.01	0.93	1.10
Household rural zone 2 non-poor non-agricultural	1.01	0.93	1.10
Household rural zone 3 non-poor agricultural	1.15	1.09	1.24
Household rural zone 3 non-poor mixed	1.15	1.09	1.24
Household rural zone 3 non-poor non-agricultural	1.15	1.09	1.24
Household rural zone 4 non-poor agricultural	1.07	1.01	1.16
Household rural zone 4 non-poor mixed	1.07	1.01	1.16
Household rural zone 4 non-poor non-agricultural	1.07	1.01	1.16
Household rural zone 5 non-poor agricultural	0.69	0.65	0.77
Household rural zone 5 non-poor mixed	0.69	0.65	0.77
Household rural zone 5 non-poor non-agricultural	0.69	0.65	0.77
Household small urban poor	0.85	0.86	0.90
Household big urban poor	0.42	0.47	0.49
Household small urban non-poor	-3.04	-3.16	-2.83
Household big urban non-poor	-1.23	-1.38	-1.11

Source: Author's computation based on model results.

Macroeconomic effects

Reducing trade and transport margins and increasing the TFP of activities that produce trade and transport services create economy-wide effects and positively affect the entire macroeconomic indicators such as GDP, private consumption, investment consumption, absorption, total domestic production and import demand. Table 11 depicts macroeconomic implications of reducing trade and transport margins and improved efficiency. For instance, in the first scenario GDP increases by 0.3%, private consumption by 0.6%, investment consumption by 1.9%, absorption by 0.7%, total domestic production by 0.5% and import demand by 1.6%. In the second scenario, total domestic production increases by 0.5%, GDP by 0.1%, private consumption by 0.5%, investment consumption by 1.7%, absorption by 0.6% and import demand by 1.5%. Similarly, in the third scenario GDP increases by 0.4%, total domestic production by 0.7%, private consumption by 0.7%, investment consumption by 2.3%, absorption by 0.8% and import demand by 1.8%. Improved road infrastructure facilitates trade and transport activities in the economy that enhance transportation of commodities into the market and results in lower prices of commodities. This leads to an increase in domestic demand and hence more domestic production,

Table 11. Real macroeconomic effects (percentage changes).

Macroeconomic indicators	Scenario one	Scenario two	Scenario three
GDP	0.25	0.14	0.37
Private consumption	0.58	0.49	0.67
Investment consumption	1.96	1.74	2.26
Absorption	0.71	0.61	0.82
Total domestic production	0.45	0.47	0.65
Import demand	1.55	1.47	1.82

Source: Author's computation based on model results.

which accelerates the growth of the economy and increases GDP.

Sensitivity analysis

Sensitivity analysis is conducted to ensure the stability of model results in response to changes in behavioural parameters. Since better access to road infrastructure mostly affects marketed commodities, sensitivity analysis is carried out by changing the income elasticity of demand for these commodities. In other words, because the reduction in margin and increase in TFP of activities that produce trade and transport services is injected to the economy through purchaser prices of marketed commodities, the income elasticity of demand for these commodities is selected for sensitivity analysis. Specifically, the income elasticity of demand for marketed commodities increases and decreases by 50%. The details of the sensitivity of demand for marketed commodities, domestic production, household welfare, and macroeconomic effects in response to a 50% increase and decrease in the income elasticity of demand are reported in Appendix Tables 2 to 6. Household consumption of market commodities is sensitive to the change in the income elasticity of demand for marketed commodities. The higher the income elasticity of demand, the larger the change in consumption of marketed commodities across all scenarios.

Similarly, domestic production is sensitive to the change in the income elasticity of demand for marketed commodities. The higher the income elasticity of demand, the larger the increase of domestic production in all scenarios. Household welfare is also sensitive to the change in income elasticity of demand. The magnitude of welfare gain varies by a small margin in response to the change in the income elasticity of demand. The biggest welfare gain (or the smallest loss) is achieved at the higher income elasticity. Furthermore, macroeconomic indicators such as GDP, absorption, total domestic production and import demand are sensitive to the change in the income elasticity of demand. A lower income elasticity of demand leads to smaller macroeconomic effects across all scenarios. The sensitivity analysis indicates that changes in income elasticity of demand for marketed commodities cause a change in the magnitude of the consumption of commodities, domestic production, household welfare, and real macroeconomic indicators. Although changes in the income elasticity of demand for marketed commodities lead to changes in the size of simulation results, the directions as well as the order of magnitude of changes remain the same in all scenarios.

Conclusions

Ethiopia is heavily dependent on road infrastructure for transportation services. However, access to rural roads is still very low in Ethiopia. Poor road transport is a major constraint of market access and non-agricultural activities in the country. The aim of this paper is to investigate the economy-wide effect of improving road transport infrastructures. Better access to road infrastructure potentially reduces per unit trade and transport margins and increases efficiency of transporting commodities into the market. Three policy scenarios are conducted in this paper. Based on the growth rate of road network density during the GTP period, trade and transport margins are reduced by 1.8 to 2.1% in the first scenario. The TFP of activities that produce trade and transport services is increased by 1.1% in the second scenario. Scenario one and two are combined to form the third scenario with the expectation it might produce a larger effect. The cost of financing road infrastructure is sourced from government savings (government raises funds through income tax replacement) and foreign savings (international aids/loans).

The policy simulations indicate that lower margins and increasing TFP result in a reduction of PQD for marketed commodities across all scenarios. Household consumption and domestic production of agricultural and non-agricultural sectors are positively affected by the policy simulation. Furthermore, the simulation scenarios also indicate that expansion of road infrastructure results in welfare improvement among rural and urban households. The policy simulation also affects real macroeconomic indicators including GDP, investment

consumption, private consumption, absorption, total domestic production, and import demand. All the policy scenarios depict the expected outcome. There is no huge difference between scenario one and two for most simulation results. As expected, the third policy scenario produced a larger effect relative to the separate effects of scenario one and two. As scenario one is carried out based on empirical literature, it seems to be the most realistic policy simulation.

Even though the simulation results are sensitive to the change in the income elasticity of demand for marketed commodities, the direction of changes is unaltered in all scenarios. Improved access to road transport is tremendously important for the promotion of both agricultural and non-agricultural activities. Therefore, improvement of road transport infrastructure should be considered as one of the policy pillars in the design of development policy and strategies of Ethiopia.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDIX

Table 1. Simulated changes (percentage) in factor income.

Factors of production	Scenario one	Scenario two	Scenario three
Agricultural labor male	0.95	0.63	1.12
Agricultural labor female	0.95	0.63	1.12
Administrative labor male	0.23	0.16	0.42
Administrative labor female	0.48	0.35	0.67
Professional labor male	0.27	0.19	0.46
Professional labor female	0.41	0.29	0.59
Unskilled labor male	1.00	0.68	1.17
Unskilled labor female	0.83	0.55	1.01
Skilled labor male	0.28	0.22	0.48
Skilled labor female	0.40	0.30	0.59
Capital land for rural poor in zone 1	1.41	1.13	1.61
Capital land for rural non-poor in zone 1	1.55	1.30	1.78
Capital land for rural poor in zone 2	0.78	0.42	0.92
Capital land for rural non-poor in zone 2	0.48	0.06	0.58
Capital land for rural poor in zone 3	0.78	0.45	0.91
Capital land for rural non-poor in zone 3	0.59	0.21	0.72
Capital land for rural poor in zone 4	0.75	0.42	0.88
Capital land for rural non-poor in zone 4	0.49	0.10	0.59
Capital land for rural poor in zone 5	1.10	0.77	1.24
Capital land for rural non-poor in zone 5	0.96	0.59	1.11
Capital livestock for rural poor in zone 1	1.06	0.72	1.23
Capital livestock for rural non-poor in zone 1	1.06	0.72	1.23
Capital livestock for rural poor in zone 2	0.95	0.60	1.13
Capital livestock for rural non-poor in zone 2	0.95	0.60	1.13
Capital livestock for rural poor in zone 3	0.99	0.65	1.17
Capital livestock for rural non-poor in zone 3	0.99	0.65	1.17
Capital livestock for rural poor in zone 4	1.01	0.67	1.19
Capital livestock for rural non-poor in zone 4	1.01	0.67	1.19
Capital livestock for rural poor in zone 5	0.97	0.62	1.15
Capital livestock for rural non-poor in zone 5	0.97	0.62	1.15
Non-agricultural capital	0.13	0.18	0.25

Source: Author's computation based on model results.

Table 2. Sensitivity of model results to changes in the income elasticity of demand for market commodities.

50% decreases in income elasticity			
Commodities	**Scenario one**	**Scenario two**	**Scenario three**
HPHC food	0.46	0.39	0.54
HPHC non-food	0.64	0.57	0.68
Market food	0.16	0.10	0.21
Market non-food	0.15	0.02	0.28
50% increases in income elasticity			
Commodities	**Scenario one**	**Scenario two**	**Scenario three**
HPHC food	0.19	0.16	0.24
HPHC non-food	0.25	0.13	0.46
Market food	0.38	0.29	0.45
Market non-food	0.47	0.29	0.68

Table 2. Contd.

Original results for comparison			
Commodities	**Scenario one**	**Scenario two**	**Scenario three**
HPHC food	0.26	0.19	0.34
HPHC non-food	0.31	0.15	0.51
Market food	0.29	0.21	0.36
Market non-food	0.33	0.24	0.52

Source: Author's computation based on model results, Sensitivity of demand (percentage) to changes in the income elasticity of demand for market commodities.

Table 3. Sensitivity of production (percentage) to changes in the income elasticity of demand for market commodities.

50% decreases in income elasticity			
Sectors	**Scenario one**	**Scenario two**	**Scenario three**
Agriculture	0.05	0.06	0.10
Service	0.54	0.70	0.80
Industry	0.90	0.15	1.12
50% increases in income elasticity			
Sectors	**Scenario one**	**Scenario two**	**Scenario three**
Agriculture	0.08	0.09	0.21
Service	0.59	0.79	0.88
Industry	1.18	0.81	1.45
Original results for comparison			
Economic sectors	**Scenario one**	**Scenario two**	**Scenario three**
Agriculture	0.07	0.08	0.15
Service	0.57	0.77	0.83
Industry	1.06	0.79	1.36

Source: Author's computation based on model results.

Table 4. Sensitivity of welfare (EV/base income) to changes in the income elasticity of demand for market commodities.

Households	Scenario one	Scenario two	Scenario three
HH-Rural_EZ1Pagr	0.82	0.73	0.82
HH-Rural_EZ1Pmix	0.82	0.73	0.82
HH-Rural_EZ1Pnagr	0.82	0.73	0.82
HH-Rural_EZ2Pagr	1.30	1.18	1.32
HH-Rural_EZ2Pmix	1.30	1.18	1.32
HH-Rural_EZ2nagr	1.30	1.18	1.32
HH-Rural_EZ3Pagr	1.29	1.19	1.30
HH-Rural_EZ3Pmix	1.29	1.19	1.30
HH-Rural_EZ3Pnagr	1.29	1.19	1.30
HH-Rural_EZ4Pagr	1.20	1.11	1.22
HH-Rural_EZ4Pmix	1.20	1.11	1.22
HH-Rural_EZ4Pnagr	1.20	1.11	1.22
HH-Rural_EZ5Pagr	0.73	0.67	0.76
HH-Rural_EZ5Pmix	0.73	0.67	0.76
HH-Rural_EZ5Pnagr	0.73	0.67	0.76

Table 4. Contd.

HH-Rural_EZ1NPagr	0.94	0.88	0.99
HH-Rural_EZ1NPmix	0.94	0.88	0.99
HH-Rural_EZ1NPnagr	0.94	0.88	0.99
HH-Rural_EZ2NPagr	0.98	0.91	1.06
HH-Rural_EZ2NPmix	0.98	0.91	1.06
HH-Rural_EZ2NPnagr	0.98	0.91	1.06
HH-Rural_EZ3NPagr	1.14	1.08	1.20
HH-Rural_EZ3NPmix	1.14	1.08	1.20
HH-Rural_EZ3NPnagr	1.14	1.08	1.20
HH-Rural_EZ4NPagr	1.05	0.99	1.12
HH-Rural_EZ4NPmix	1.05	0.99	1.12
HH-Rural_EZ4NPnagr	1.05	0.99	1.12
HH-Rural_EZ5NPagr	0.67	0.64	0.74
HH-Rural_EZ5NPmix	0.67	0.64	0.74
HH-Rural_EZ5NPnagr	0.67	0.64	0.74
HH-SmallurbanP	0.87	0.88	0.92
HH-BigurbanP	0.39	0.54	0.42
HH-SmallurbanNP	-3.06	-3.18	-2.87
HH-BigurbanNP	-1.26	-1.40	-1.16

Sensitivity of welfare (50% decreases in income elasticity).
Source: Author's computation based on model results.

Table 5. Sensitivity of welfare (50% increases in income elasticity).

Households	Scenario one	Scenario two	Scenario three
HH-Rural_EZ1Pagr	0.82	0.74	0.83
HH-Rural_EZ1Pmix	0.82	0.74	0.83
HH-Rural_EZ1Pnagr	0.82	0.74	0.83
HH-Rural_EZ2Pagr	1.31	1.19	1.34
HH-Rural_EZ2Pmix	1.31	1.19	1.34
HH-Rural_EZ2nagr	1.31	1.19	1.34
HH-Rural_EZ3Pagr	1.30	1.19	1.32
HH-Rural_EZ3Pmix	1.30	1.19	1.32
HH-Rural_EZ3Pnagr	1.30	1.19	1.32
HH-Rural_EZ4Pagr	1.22	1.12	1.25
HH-Rural_EZ4Pmix	1.22	1.12	1.25
HH-Rural_EZ4Pnagr	1.22	1.12	1.25
HH-Rural_EZ5Pagr	0.75	0.69	0.79
HH-Rural_EZ5Pmix	0.75	0.69	0.79
HH-Rural_EZ5Pnagr	0.75	0.69	0.79
HH-Rural_EZ1NPagr	0.97	0.90	1.02
HH-Rural_EZ1NPmix	0.97	0.90	1.02
HH-Rural_EZ1NPnagr	0.97	0.90	1.02
HH-Rural_EZ2NPagr	1.03	0.95	1.11
HH-Rural_EZ2NPmix	1.03	0.95	1.11
HH-Rural_EZ2NPnagr	1.03	0.95	1.11
HH-Rural_EZ3NPagr	1.17	1.10	1.24
HH-Rural_EZ3NPmix	1.17	1.10	1.24
HH-Rural_EZ3NPnagr	1.17	1.10	1.24
HH-Rural_EZ4NPagr	1.09	1.02	1.17

Table 5. Contd.

HH-Rural_EZ4NPmix	1.09	1.02	1.17
HH-Rural_EZ4NPnagr	1.09	1.02	1.17
HH-Rural_EZ5NPagr	0.71	0.67	0.79
HH-Rural_EZ5NPmix	0.71	0.67	0.79
HH-Rural_EZ5NPnagr	0.71	0.67	0.79
HH-SmallurbanP	0.84	0.85	0.89
HH-BigurbanP	0.45	0.57	0.53
HH-SmallurbanNP	-3.03	-3.15	-2.82
HH-BigurbanNP	-1.21	-1.36	-1.10

Source: Author's computation based on model results.

Table 6. Sensitivity of macroeconomic effects (percentage) to changes in the income elasticity of demand for market commodities.

50% decreases in income elasticity			
Macroeconomic indicators	**Scenario one**	**Scenario two**	**Scenario three**
GDP	0.25	0.14	0.36
Absorption	0.70	0.60	0.80
Total domestic production	0.45	0.47	0.64
Import demand	1.47	1.39	1.70
50% increases in income elasticity			
Macroeconomic indicators	**Scenario one**	**Scenario two**	**Scenario three**
GDP	0.26	0.14	0.37
Absorption	0.71	0.61	0.81
Total domestic production	0.45	0.48	0.65
Import demand	1.62	1.54	1.88
Original results for comparisons			
Macroeconomic indicators	**Scenario one**	**Scenario two**	**Scenario three**
GDP	0.25	0.14	0.37
Absorption	0.71	0.61	0.82
Total domestic production	0.45	0.47	0.65
Import demand	1.55	1.47	1.82

Source: Author's computation based on model results.

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Moderating effects of social learning on the usage of formal financial services in Kampala, Uganda

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The use of formal financial services has been associated with increased financial wellbeing and overall economic growth. Efforts to increase financial inclusion have emphasized financial literacy provided through formal training and education without due recognition that people's financial behaviors and practices may be motivated by social interactions. The current study examines the moderating effects of social learning on the relationship between financial literacy and formal financial services usage within a developing country context. Survey data collected from a sample of 351 adults in Kampala, Uganda, was analyzed using Pearson correlation coefficients, hierarchical regression, and ModGraph. Findings reveal significant positive relationships between financial literacy, social learning, and usage of formal financial services. Results indicate that social learning moderates the relationship between financial literacy and financial services usage among people in Kampala. The study finds peers and friends to be critical socializing agents with a significant influence on formal financial services usage. Beyond the promotion of financial literacy, financial inclusion initiatives should recognize the effects of social learning to increase the use of formal financial services in countries such as Uganda. The study integrates aspects of the social learning theory into the financial services domain hitherto dominated by finance and economic models.

Key words: Financial literacy, financial inclusion, Uganda

INTRODUCTION

Formal financial services for savings, loans, insurance, and investment have been associated with increased financial wellbeing and overall economic growth (Demirgüç-Kunt et al., 2017a). In this respect, several low-income countries worldwide work toward broadening the financial sector and increasing populations' financial inclusion. However, the increasing diversification and sophistication of financial services requires correspondingly high levels of the masses' financial literacy to ably understand and use them to improve their wellbeing (Peachey and Roe, 2004). However, most government-instituted strategies for financial education aim to improve the financial literacy of their populations through traditional classroom-based training methods. Quite interestingly, consumer behavior literature suggests the prevalence of alternative learning forms that financial

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inclusion proponents may not have been sufficiently explored. For instance, Lehesvirta (2004) posits that adult learners learn not only by themselves as individuals but also with others through collaborative interaction. According to the World Bank, globally, close to one-third of adults – 1.7 billion – are still unbanked (Demirgüç-Kunt et al., 2017b); thus necessitating an inquiry into improved formal financial services utilization approaches.

Two important pillars of the national financial inclusion strategy of Uganda are - the deepening and broadening of formal savings, investment and insurance usage; and, the empowerment and protection of individuals through enhanced financial literacy and capability (BOU, 2017). However, the Finscope (2018) survey on access and usage of financial services in the country revealed that formal financial services usage is still shallow, with about 6 out of every ten adult Ugandans relying on informal financial services. The survey findings attributed the high levels of informal financial service utilization in Uganda, to supply-side institutional challenges and demand-side individual challenges coupled with strong social capital characterized by reciprocal trust among Ugandans. In this regard, our crucial research concern is whether financial education delivered in conventional classroom type and or mass media channels can sufficiently propel the utilization of formal financial services to desirable levels. The current study, therefore, first, examines the extent to which financial literacy promotes the use of formal financial services, and secondly, investigates the moderating influence of social learning on the relationship between financial literacy and the use of formal financial services among people living in developing countries.

Hypothesis development

Financial literacy and the use of formal financial services

Financial literacy is a combination of financial awareness, knowledge, skills, attitude, and behaviors necessary to make sound financial decisions and ultimately achieve financial wellbeing (Atkinson and Messy, 2012). Financial literacy surveys worldwide have revealed low levels of financial literacy in developed and developing countries, but policy and academic responses, especially in developing, are low (Refera et al., 2016). The scholars posit that financial literacy can increase the demand and use of financial services such as savings, microcredit, and insurance to improve people's welfare, increase business for financial service providers, and contribute to the development of stable financial systems and sustain economic growth. Lusardi and Mitchell (2013) concluded that financially literate people could process financial information, make informed decisions, accumulate wealth, manage debt and pensions, and be able to cope with the complex products and services in the financial market. Their assertion builds on earlier observations made in Lusardi and Mitchell (2011), where they stated that individuals would suffer a deficiency of knowledge on critical financial products for saving and retirement when deprived of interaction with formal financial institutions.

In a study conducted in Kenya, Shibia and Kieyah (2016) found that financial literacy scores correspond with increasing levels of formality in the usage of financial products suggesting that the more financially literate people were, the more likely they would use formal financial services. Studies from the developed world, such as Mien and Thao (2015), Hogarth and Hilgert (2002), found that financial literacy was associated with responsible financial behaviors. In agreement, Idris et al. (2013) found that financial literacy accounted for variations in individual behavior and financial outcomes associated with credit, investment, and saving behaviors. Literature is also replete with findings on significant relationships established between financial literacy and the broader concept of financial inclusion (Okello et al., 2016; Grohmann et al., 2017). These studies support Wachira and Kihiu (2012) findings, who established a higher probability for people with lower levels of financial literacy to have a higher likelihood of financial exclusion. Individual-level studies such as Cohen and Nelson (2011) found that effective use of formal financial services was partly constrained by inexperience on the part of customers and sophistication on formal financial products. Their findings suggest that increased financial literacy would demystify seemingly complex financial products and grow their utilization at the individual level.

Therefore, the current study hypothesizes that financial literacy is positively associated with formal financial services usage in Kampala, Uganda.

Social learning, financial literacy, and the use of formal financial services

Social learning theory postulates that people can obtain knowledge from their surroundings, especially from their parents (Pinto et al., 2005). Therefore, adult learners do not always learn in their capacity, but they also learn through interaction with others in a process referred to as social learning. In this context, the use of formal financial services is not always informed by financial literacy acquired through traditional lecture-oriented approaches and informal learning sources among peers within their communities.

The current study uses the term social learning to denote the subset of consumer socialization, which relates to financial services usage. The scope of 'financial social learning' encompasses the many dimensions of money management that can be learned socially, such as saving, borrowing, and investment. The social learning theory (Bandura and Walters, 1963) postulates that individuals are social entities who learn from observing others' actions and behaviors. The theory focuses on

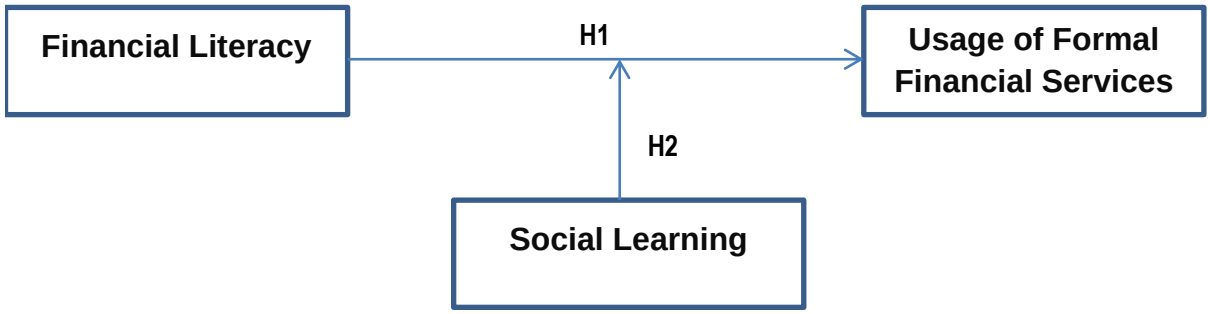

Figure 1. Conceptual model.

three major concepts: observational learning, imitation, and modeling (Ormrod, 1999).

Studies have examined social learning processes in work/formal environments and recognized the shift from traditional lecture-oriented to informal learner-centered approaches, especially in the corporate education (Collin, 2009; Lee and Lee, 2018). These studies have found that collaborative learning occurs through interactions among people within informal learning environments and that corporate personnel gain job-related knowledge and skills through social learning. The application of social learning in the financial services domain has been a subject of scientific inquiry. Lee and Lee (2018) established significant relationships between financial, social learning opportunities, and financial behaviors among college students. Their findings collaborates those of Gutter et al. (2010), which found that people acquire or enhance financial skills from their peers, family members, and parents serving as socializing agents within societies. The latter findings build on earlier studies that found that through imitation and modeling, financial knowledge was likely to increase and have a positive effect on financial attitudes (Campbell, 2006; Grable and Joo, 1999).

There is a dearth of studies on the role played by social learning in the financial education and financial services domain in developing countries such as Uganda. The few extant studies have mostly examined individuals rather than the environmental aspects of social learning. For instance, Mindra and Moya (2017) and Mu'izzuddin et al. (2017) investigated the effects of self-efficacy - an individual-level dimension of social learning. Self-efficacy is the level of confidence in one's ability to deal with financial situations without being overwhelmed (Amatucci and Crawley, 2011). Research attention on the effects of social learning's environmental dimensions, such as interaction and collaborative learning in the financial education and financial services domain, has been insufficient. Studies like Gutter et al. (2010) examined the interactive influences of social learning opportunities of "discussions" and "observations" on consumer decision-making and subsequent practices. They highlight social interactions, including discussions (direct teaching) and observations (modeling) among financial socialization agents such as peers, relatives, and friends. Their findings collaborate with earlier studies that peers can influence consumption-related attitudes and behaviors (Moschis and Churchill, 1978; Moschis and Moore, 1979; Ward, 1974). Other studies have largely dwelt on the direct relationships between social learning, financial literacy, and financial behaviors. For instance, Mahdavi (2012) found that single and educated women who had more social learning opportunities than their married counterparts had lower financial literacy scores. Furthermore, individuals who had educated parents or spouses could learn from their knowledge and experience. Likewise, Lusardi and Mitchell (2011a) found that employed people worldwide had higher financial literacy levels, suggesting that the workplace offers social learning opportunities through which people may acquire financial knowledge, skills, and behaviors from their peers and workmates. The preceding discourse demonstrates that financial services require enhancing financial literacy in terms of financial knowledge, skills, attitudes, and behaviors. However, as further illustrated, the studies have established that learning happens through direct training as well as through social means. This is because, besides the ability to make informed financial decisions, the individuals' decision-making can also be influenced by socializing agents within their environment. The study, therefore, hypothesizes that:

social learning has a moderating effect on the relationship between financial literacy and the use of formal financial services in Kampala, Uganda

Figure 1 illustrates the hypothesized moderating effect of social learning on the relationship between financial literacy and the use of formal financial services. Moderation refers to a situation in which an observed variable strengthens, diminishes, negates, or otherwise alters the association between two other variables. The study sought to test the hypothesis that an individual's levels of exposure to social learning would affect their use of formal financial services even when they were financially literate. This is because, the highlighted studies suggested that individual financial decision making

Table 1. Sample demographic characteristics (percent of the sample).

Variable	Count	Percent	Cumulative percent
Gender			
Male	177	50.4	50.4
Female	174	49.6	100.0
Employment status			
Employed	154	43.9	43.9
Self Employed	197	56.1	100.0
Age Bracket			
18 - 35 yrs.	261	74.4	74.4
36 - 50 yrs.	77	21.9	96.3
Above 50 yrs.	13	3.7	100.0

regarding the use of financial services, is often subject to the observations and discussions with peers and friends, in spite of their levels of financial literacy.

METHODOLOGY

Participants

The target population of this study consisted of economically active users of financial services living in Kampala. This study adopted a proportionate geographical cluster sampling to select study participants. Using the rationale of Krejcie and Morgan (1970), a sample of 384 was randomly sampled from a population of 884,126 adults (aged 18 years and above) living in the five geographical divisions of Kampala, Uganda (UBS, 2014). A survey questionnaire was administered to target all the 384 participants; however, only employed participants were included in the analysis as they were deemed to be the most likely users of financial services. Participation was voluntary, and 351 responses were eligible for analysis representing a response rate of 91%. Out of the valid sample, 177 were male (50.4%) and 174 female (49.6%); 154 employed (43.9%) and 197 self-employed (56.1%). The proportion of participants in each age range was reflective of the national statistics with the greatest number aged between 18 and 35 years (n = 261; 74.4%), followed by 36 to 50 (n = 77; 21.9%), and the rest above 50 (n = 13; 3.7%) (Table 1).

Measurement of variables

A survey questionnaire was used to measure the three variables and their latent constructs: Financial literacy (knowledge, skills, attitudes, and behavior), environmental constructs for social learning (learning community and interaction), and use of financial services (savings, loans, insurance). The social learning measure used focused on participant's exposure to two social learning opportunities, that is, observations and discussions among peers, friends, and family. The measurement items for financial literacy definition that includes non-functional components of knowledge and skills (Lusardi and Mitchell, 2011) as well as functional components of attitudes and behavior (Holzmann, 2010). And, together with the use of financial services, measurement scale used was adapted from the OECD/INFE (2018) toolkit for measuring financial literacy and financial inclusion. The measure used for social learning was measured used an approach proposed and used by Gutter and Garrison (2008) that is based on individual's opportunities for observations and discussions among financial socializing agents. The survey instrument therefore measured financial literacy as an individual's knowledge, skills, attitudes, and behaviors considered as important predictors of use of financial services such as savings, loans, transfers/payments, and digital financial services; as well as to measure social learning based on interaction and community on the relationship between financial literacy and the use of financial services.

All measurement items were anchored onto a five-point Likert scale starting from strongly agree (5), agree (4), not sure (3), disagree (2), and strongly disagree (1). In addition to the variable measurement scales, a section to capture demographic characteristics of age, gender, and educational background was included to constitute the survey questionnaire. The initial version of the questionnaire was pilot-tested with 47 users of financial services working in the central division of Kampala, and the final version constructed by deleting or modifying some original survey items based on participant responses in the pilot study (Table 2).

Reliability and validity assessment

The questionnaire's measurement items were tested for reliability and validity to ensure that the results attained would be credible and have followed the protocol for research instrument use. Reliability was tested using the composite reliability, a measure recommended by Hair et al. *(*2017) as being more advanced and less prone to error than the traditional Cronbach Alpha coefficient. Regarding validity, the instrument was tested for both convergent and discriminant validity. Convergent validity was measured using the Average Variance Extracted (AVE), while the Discriminant validity was tested using the Fornell Larker criterion. The AVE reflects the variance that has been measured by research instrument items for a specific variable relative to the variance that is not measured. AVE values of at least 0.500 indicate that the instrument's Convergent validity is satisfactory, and the items are jointly able to tap more than 50% of the variance of the construct meaning (Henseler et al., 2014; Fornell and Larcker, 1981). The questionnaire items were further tested for collinearity using the Variance Inflation Factor (VIF), a measure of how items could be predicted by others measuring the same variable. If there is a high relationship between these two, then the items could lead to misleading results. VIF values of 5 or higher indicate a problem with the collinearity in the measure used to measure the variable. These they take into account the weaknesses of the traditional approaches

Table 2. Measurement items and sources.

Study variable	No. of Items	References
Financial literacy (functional and non-functional components)		
Knowledge	4	
Skills	2	
Attitudes	3	OECD/INFE (2018)
Behaviors	4	
Social learning opportunities for observation and discussion		
Interaction	5	Gutter et al. (2018)
Community learning	5	
Use of financial services offered by regulated institutions		
Savings	3	
Loans	3	OECD/INFE (2018)
Digital financial services	3	
Payments/transfers	3	

Table 3. Reliability and validity.

Variable	Composite reliability	Average variance	Variance inflation factor (VIF)
Financial literacy	0.832	0.694	1.310
Usage of formal financial services	0.902	0.753	2.304
Social learning	0.914	0.842	1.896

Table 4. Discriminant Validity-Fornell-Larcker Criterion – financial literacy.

Financial literacy	Attitudes	Behavior	Knowledge
Attitudes	0.844		
Behavior	0.526	0.816	
Knowledge	0.404	0.406	0.829

to testing reliability and validity measures (Hair et al., 2017). Table 3 presents the results for the Composite Reliability, AVE, and VIF.

Table 3 shows that the reliability measures were all within the acceptable thresholds for the study variables, that is, Composite Reliability (>.07), Average Variance Extracted (AVE >0.05), and the VIF < 5.000, for all the study variables, which means that the reliability, convergent validity, and the collinearity aspects of the tool, were all acceptable. Furthermore, Table 4 presents the Discriminant validity using the Fornell-Larker criterion. Using the Fornell-Larcker criterion, the AVE's square root for each dimension (these appear in the diagonal) should be higher than each of the correlations that the dimension has with the other dimensions. For instance, the AVE's square-root for the 'Attitudes' dimension is 0.844, which is much higher than the correlations it has with the dimensions of 'behavior' (0.526) and 'knowledge' (0.404). Therefore, the 'Attitudes' dimension had a higher shared variance than the measurement items for 'Behavior' and 'Knowledge.'

The 'financial literacy' measure is, therefore, satisfied the condition for discriminant validity using the Fornell-Larcker Criterion. Similarly, Table 5 presents the results of the Fornell-Larcker criterion for social learning dimensions, that is, 'interaction' and 'community learning.' The Square root of the AVE for the 'interaction' dimension of social learning was .925. It was higher than the value of the interaction with the 'learning community' (.338). The items for this variable indeed also met the conditions for Discriminant Validity. Similarly, as indicated in Table 6, the same approach holds for the variable of 'use of formal financial services.' Furthermore, the Fornell-Larcker Criterion for formal financial services' usage satisfied the condition consistent with Hair et al. (2017). The square root of the AVE for the variable dimension of 'digital services' was .858, which is higher than the correlations this dimension has with the 'loans' (0.163), 'payments' (0.544), and 'savings' (0.712) dimensions.

Hypothesis testing

The study used Pearson (r) correlation coefficient and hierarchical regression analysis (*using the enter method*) to test the

Table 5. Discriminant Validity -Fornell-Larcker Criterion - social learning.

Social learning	Interaction	Learning community
Interaction	0.925	
Learning community	0.338	0.910

Table 6. Discriminant validity-Fornell-Larcker Criterion – Use of formal financial services.

Usage of formal financial services	Digital services	Loans	Payments	Savings
Digital services	0.858			
Loans	0.163	0.913		
Payments	0.544	0.492	0.816	
Savings	0.712	0.458	0.682	0.881

Table 7. Pearson correlation results.

Variable	Mean	SD	1	2	3
Financial Literacy - 1	3.875	0.474	1.000		
Social Learning - 2	3.499	0.566	0.312**	1.000	
Usage of Formal Financial Services - 3	3.704	0.712	0.381**	0.288**	1.000

**Correlation is significant at the 0.01 level (2-tailed).

hypotheses. In the first model, financial literacy, social learning in the second model, and a product of financial literacy and social learning in the third model. Beta coefficients from the resultant Table were captured from this regression model and then entered into the Modgraph tool to present the relationship between the variables in the form of a graph.

RESULTS

Pearson correlation results

The Pearson correlation coefficient was used to test for the relationships between the study's variables. The results are presented in Table 7. The correlation results presented in Table 5 indicate a significant and positive relationship between financial literacy and usage of formal financial services in Kampala ($r = 0.381$, $p<0.01$). This finding implies that the higher the levels of financial literacy, the higher the likelihood that an individual would use formal financial services. Similarly, the findings show that social learning was significantly positively associated with the use of formal financial services ($r = 0.288$, $p<0.01$). Therefore, the results imply that individuals who demonstrate higher levels of social learning through observations and discussions with their peers and friends were more likely to have a higher incidence of using formal financial services. Nonetheless, the relationship between financial literacy and formal services usage is stronger than the relationship between social learning and formal financial services usage.

Regression

Table 8 presents a hierarchical regression to test for the moderating effect. First, the control variables are input into Model-1, and after that, study constructs added into the subsequent regression models until the final model where the interaction term, that is, a product of the financial literacy and social learning.

In both Models 2 and 3, the addition of financial literacy and social learning, it was noted that both variables are significant predictors of the use of formal financial services in Uganda ($p <0.01$). The Adjusted R Square value for financial literacy increases from .149 ($p < 0.05$) in model 2 to .175 in model 3 with the introduction of social learning into the equation. It was noted that the variance explained increases by a magnitude of 2.9%. The Adjusted R square was preferred in this study since it allows the researcher to generalize the broader population's findings. It was also noted that when the interaction term in Model 4 was included, a significant change in the value of formal financial services usage was gotten. The findings suggest that social learning plays a moderating role in the relationship between financial literacy and formal financial services usage. Furthermore, to explore the moderating effect, a graphical illustration is generated using the following section's

Table 8. Hierarchical regression model.

	Model-1	Model-2	Model-3	Model-4
(Constant)	3.907**	1.716**	1.175**	1.227
Gender	0.098	0.150	0.120	0.125
Highest level of education	0.011	0.005	0.019	0.023
Age Group	0.029	0.032	0.027	0.036
Region of Origin	0.051	0.038	0.041	0.043
Financial Literacy		0.582**	0.493**	1.151**
Social Learning			0.227**	1.053**
Interaction Term				-.224*
Dependent variable: Usage of formal financial services				
R	0.113	0.401	0.435	0.452
R Square	0.013	0.161	0.190	0.205
Adjusted R Square	0.001	0.149	0.175	0.188
Std. Error of the Estimate	0.711	0.656	0.646	0.641
R Square Change	0.013	0.148	0.029	0.015
F Change	1.121	6.931	12.159	6.447
Sig.	0.346	0.000	0.001	0.012

** p <0.01 and * p <0 .05. Interaction Term: Financial Litearcy*Social Learning.

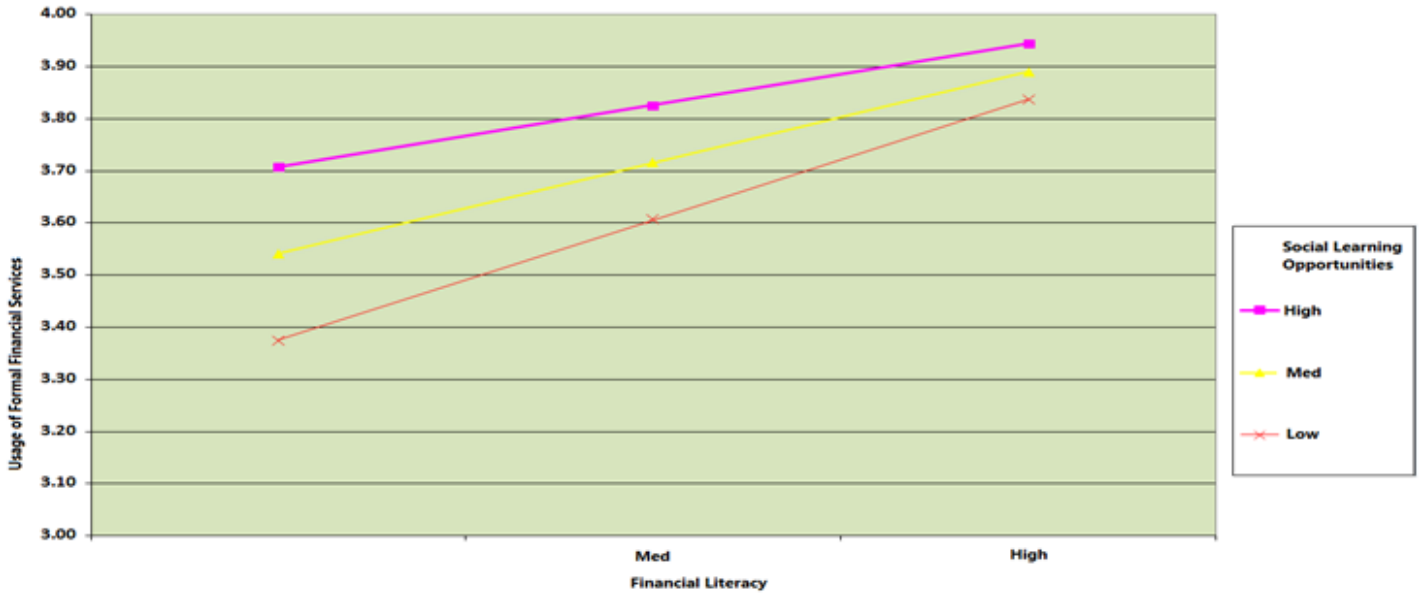

Figure 2. Moderation model.

mod-graph tool.

Moderation

Further analysis to test for the moderating effects of social learning on the relationship between financial literacy and formal financial services usage is presented in Figure 2. The results in Figure 2 show that the weakest association between financial literacy and usage of formal financial services occurs when individuals have the highest incidence of social learning through interactions with peers and friends. Therefore, the study finds support for Hypothesis 2 that "*Social learning has a moderating effect on the relationship between financial literacy and the use of formal financial services in Kampala, Uganda."* The implication of this is that financially literate individuals are less likely to use formal

financial services when their social interactions provide an alternative social, financial learning. It is highly likely that individuals adopt particular perspectives that do not typically encourage the use of formal financial services through observations and discussions. On the contrary, individuals with higher financial literacy levels are very likely to use formal financial services when they exhibit minimum social, financial learning.

DISCUSSION

Consistent with this study's objectives, three findings emerged: First, the study established a significant positive relationship between financial literacy and usage of formal financial services in Kampala, Uganda. The implication is that the higher the level of financial literacy, measured as being more knowledgeable and better skilled in financial matters, the greater their likelihood of using especially savings, credit, and transfer/payment services offered by regulated institutions. This finding is consistent with mainstream thinking shaped by previous studies that have justified the application of financial literacy as a tool for improved uptake and use of financial services in many countries. In Uganda, for instance, the national strategy for financial literacy has been designed to deliver financial education programs targeting people at all levels: the youth in schools, the employed at the workplaces, community outreach programs (BOU, 2017).

Secondly, the study established a significant positive relationship between social learning and formal financial services usage in Kampala, Uganda. The implication is that people with a higher level of social interactions involving observation and discussions among their friends and peers were more likely to use regulated institutions' financial services. In other words, friends and peers play an important role as financial socialization agents among users of formal financial services in Kampala. This finding is consistent with Gutter et al. (2010), who found a significant relationship between social learning opportunities and financial behaviors. Their study found higher financial behaviors of saving and budgeting among students who had a higher level of exposure to social learning opportunities of observation and discussion among peers.

The two findings have important implications for policymakers, financial educators, and financial institutions. First, financial literacy is a vital tool to equip users and potential users of financial services, with knowledge, skills, and attitudes necessary to utilize formal financial services. Second, peers and friends are essential financial socialization agents through which individuals, through interaction and discussion, become aware and may develop favorable perspectives towards the use of certain financial services. Therefore, financial inclusion and education efforts would be more effective if they targeted individual users as social entities whose financial decisions are subject to social influences.

This study's third finding was that social learning was a significant moderator in the relationship between financial literacy and usage of formal financial services. Notably, the study found that higher levels of social learning weakened the relationship between financial literacy and formal financial services usage. In comparison, lower levels of social learning strengthened the relationship. In other words, financially literate respondents in Kampala Uganda reported a lower incidence of formal financial services usage in instances where they had higher exposure to financial, social learning. On the contrary, respondents with lower social interaction levels were more likely to have higher usage of formal financial services. Therefore social interactions (observations and discussions) were found to discourage formal financial services usage even among financially literate people in Kampala, Uganda. Policymakers, service providers, and financial educators ought to take cognizance of social influences to promote financial inclusion in countries like Uganda. This recommendation supports Okello et al. (2016), who found that financial literacy alone had no significant impact on financial inclusion but rather that social capital's introduction fully mediated the relationship between financial literacy and financial inclusion in rural Uganda. Bandura (1986) postulates that learning also occurs when people, through interactions, observe others, imitate them, and seek to model specific behaviors, our results highlight the importance of social interactions in synthesizing knowledge on formal financial products, before actual product uptake. In support of this presumption, the study recommends further empirical investigations into the comparative efficiency of using person-to-person delivery channels for financial education generally and financial products specifically through peer networks that are critical financial socialization agents within specific communities.

Conclusion

This study examined the extent to which social learning may moderate the relationship between an individual's level of financial literacy and their use of formal financial services. By focusing on the user perspective, the study established the prevalence of financial social learning opportunities through discussion and observations among peers had a significant influence on consumers' financial services usage. This finding is consistent with Ramsden and Moses (1992), who found that individuals acquired financial knowledge and skills, attitudes, and behaviors to handle their financial problems. The study's contribution to knowledge is embedded in developing a theoretical model that explains FI in Uganda from a demand-side perspective. The study also contributes to the body of knowledge through the moderating role of social learning in the relationship between financial

literacy and the use of financial services in Kampala, Uganda. This study contributes to the behavioral finance discourse by adopting behavioral theory, that is, the social learning theory, to compliment the economic models of demand and supply that are often used. This provides a better theoretical and empirical understanding of financial services usage in the population's urban segment in the Ugandan context.

Recommendations

Specifically, the study findings suggest that the design of national strategies for financial literacy should consider the different economic and social conditions and the varying levels of financial market development. However, a caveat to the findings' applicability is that the current study adopted a cross-sectional design, which captures the status-quo in terms of social learning exposure and the ongoing use of financial services. Therefore, a fundamental limitation is that the analysis is unable to provide observations over a long time. Future research could use longitudinal approaches. Furthermore, the sample size is limited to Kampala, Uganda. Therefore, to allow for generalizations of findings, future studies should utilize larger samples in other social-economic contexts.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Two qualified models of learning by doing

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Learning by doing (or learning curves) is a well-known law in economics and psychology, but no consensus has been achieved on the "qualified" models for more than a century. This article explores the expression of learning by doing in a way where the expression is not involved with changing the prime factors of a learning process. If one prime factor changes dramatically during the course of a learning process, the result of the regression is actually an approach to link two different learning curves. If the two curves are distinguishable, they each obey the law of learning by doing, which will progress rapidly at the initial phase and gradually slow down to a flat end. This article presents two functions as the law of learning by doing: The general exponential model is 0.79:0.21 better than the exponential delay model, whereas the later has the ability to investigate the change of loading factors. This ability makes the models a powerful tool for entrepreneurs and managers in investment and production planning.

Key words: Learning by doing, function expression, single equation models, firm behavior, empirical analysis.

INTRODUCTION

The law of the learning curves has become ubiquitous since its introduction in an 1885 study of individuals in psychology, and has been found in the manufacturing process of industrial organizations, called "learning by doing" or "organizational learning" in the field of economics and management (Wright, 1936). Empirical evidence of more than thousands of industries such as aircraft assembly, ship building by big firms, as well as cigar making by small firms have shown this law being used in industries broadly (Yelle, 1979; Thompson, 2010; Anzanello and Fogliatto, 2011; Jaber, 2016). The core idea of the law of the learning curves is negative acceleration: as one practices and learns more in a specific domain, the amount of unknown material decreases and, thus, the amount of newly learned information declines. Therefore, it is natural to anticipate progress being essentially null at the end of the learning process, which Bryan and Harter (1897, 1899) termed the "plateau."

However, this explanation is assumed to be insufficient, as the learning process has long been reported as continuing infinitely with no convincing evidence of an end in progress (Wright, 1936; Jaber, 2016; Hirschmann, 1964; Dar-El et al., 1995; Asher, 1956). For example, Arrow (1962) seminal work was based on the log-linear function $y = px^r$ of Wright (1936), who found that when the output doubled, the cost of airplane declined along the power sequence infinitely to 0. Although this finding was and is counterintuitive, that the cost of airplane should be much higher than 0, a vast body of empirical evidence supports that the end of learning process is ambiguous. Recently, this phenomenon was partly attributed to the

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Table 1. Models.

Name	Function expression	Value range of parameter	Monotonicity
Exp-Gen[1]	$y = k + pr^{x-1}$	$k > 0, p > 0, 0 < r < 1$	Decrease
Exp-Delay	$y = k + p(t+1)/(t+e^{xr})$	$k > 0, p > 0, t \geq 0, r > 0$	Decrease
Stanford-B	$y = p(x+t)^r$	$p > 0, t \geq 0, -1 < r < 0$	Decrease
S-curve	$y = c_1[M + (1-M)(x+t)^r]$	$c_1 > 0, 0 \leq m \leq 1, t \geq 0, -1 < r < 0$	Decrease
Log-Linear	$y = px^r$	$p > 0, -1 < r < 0$	Decrease
DeJong	$y = c_1[M + (1-M)x^r]$	$c_1 > 0, 0 \leq m \leq 1, -1 < r < 0$	Decrease
Power-Delay	$y = k + p(t+1)/(t+x^r)$	$k > 0, p > 0, t \geq 0, r > 0$	Decrease
Power-Gen	$y = k + px^r$	$k > 0, p > 0, -1 < r < 0$	Decrease
Hyp2	$y = k[x/(x+r)]$	$k > 0, r > 0$	Increase
Exp2	$y = k(1-e^{-x/r})$	$k > 0, r > 0$	Increase
Exp3	$y = k(1-e^{-(x+p)/r})$	$k > 0, p > 0, r > 0$	Increase
Hyp3	$y = k(x+p)/(x+p+r)$	$k > 0, p > 0, r > 0$	Increase

[1] The originators of models are listed as follows: Exp-Gen (Pegels, 1969; Towill, 1990); Exp-Delay (Evans et al. 2018); Stanford-B (Asher, 1956); S-curve (Carr, 1946); Log-liner (Wright 1936); DeJong (De Jong, 1957); Power-Delay (Evans et al., 2018); Power-Gen (Newell and Rosenbloom 1981); the rest four models Hyp2, Exp2, Hyp3, Exp3 originated by Mazur and Hastie (1978) and Nembhard and Uzumeri (2000).

"leaps" (Gray, 2017; Gray and Lindstedt, 2017). Slow progress followed by rapid learning in the initial phase has also been long discussed, and was termed as "initial delay" (Carr, 1946; Evans et al., 2018). To achieve a better fit with all of the divergent empirical datasets, scholars have introduced more than a dozen learning curve models (Table 1), and constant efforts have been made to determine which is best (Crossman, 1959; Nembhard and Uzumeri, 2000; Newell and Rosenbloom, 1981; Badiru, 1992; Heathcote et al., 2000; Anzanello and Fogliatto, 2011; Evans et al., 2018). However, different models better fit different datasets, and no consensus has been achieved on "qualified" models.

This study aims to identify reasonable and qualified models of "learning by doing" by illuminating the mechanism of the learning process. The key idea in this study is that the process of learning is compounded by different factors and that performance improvement is actually the improvement of loading factors, meaning there are two methods for learning to progress: improve the performance of loading factors and reload more efficient factors. A learning model can be applied only under the condition that the prime factors of a learning process do not change dramatically. The law of the learning curve should be discussed apart from how to significantly change the prime factors of current manufacturing processes. If one prime factor changes dramatically during the course of a learning process, the result of the regression is actually an approach to link two different learning curves. If the two curves are distinguishable, they each obey the law of learning by doing, which will progress rapidly at the initial phase and gradually slow down to achieve plateau (Bryan and Harter, 1897, 1899). The plateau indicates a time when the prime factors of a learning process have approached their limits until a change of prime factors occurs.

To illustrate this idea, this article uses empirical evidence of organizational learning in railway industry, which also illustrates that the controversial phenomena of the "leap" (Teplitz, 2014; Gray, 2017; Gray and Lindstedt, 2017) and "initial delay" (Evans et al., 2018) are both the result of the change in prime factors.

For any theory, nothing is more important than determining the accurate function expression because it not only articulates the relationship between variables but also unveils the mechanism behind this relationship, and thus, explains that why a microeconomic law can be used in macroeconomics. For the empirical evidence of the Shenzhen railway industry, the general exponential model (presented by Pegels 1969; Towill 1990 in different forms[1]) is the best, at 0.79:0.21; it performs better than the exponential delay model (Evans et al., 2018), although the exponential delay model has some ability to detect changes in loading factors. The two functions can

[1] According to Towill (1990), $y = y_c + y_f(1-e^{-x/t}) \Leftrightarrow y = (y_c + y_f) - y_f \cdot e^{-x/t}$, denote $k = (y_c + y_f)$, $p = -y_f \cdot e^{-1/t}$, $r = e^{-1/t}$, then, $y = k + pr^{x-1}$.

not only predict the future performance of an organization but also distinguish eligible datasets from ineligible ones. This ability makes the models a powerful tool for entrepreneurs and managers in investment and production planning, as well as researchers.

Background and models

When an individual learns a skill, he or she usually experiences a period of rapid improvement in performance followed by a period without obvious progress and then more improvement. This period with no obvious progress is called a plateau on the learning curve. Bryan and Harter (1897, 1899) were the first to describe the limit of learning as a “plateau” after studying individuals’ skills in receiving Morse code and finding a steady state without obvious progress between one rapid period of improvement and another period of improvement. They believed this plateau was because learning involves a hierarchy of habits, in which (using Morse code as an example) letters must be learned first, followed by the sequences of letters forming syllables and words, and finally phrases and sentences. A plateau is a point of transition, when lower-order habits are not sufficiently learned to advance to the next level of habits in the hierarchy; thus, the pace of progress slows until this lower-order learning is completed. This notion prevailed until the Second World War. Half a century after Bryan and Harter, the speed of sending and receiving Morse code improved greatly and researchers found little difference between receiving sentences, unrelated words, nonsense material, and random letters—unexpected from the hypothesis of a hierarchy of habits. Most importantly, the anticipated plateaus did not appear (Keller, 1958).

Wright's (1936) log-linear model is another example of the “phantom” plateau. Asher (1956) assumed this was because the period of observation was not long enough and, thus, presented the Stanford-B model. In this model, despite that cost of aircraft declining significantly toward 0 with no observable signs of plateau, Asher insisted that the learning progress would slow down in the long run while it remains infinite and ends ambiguously. De Jong (1957) is perhaps the only writer to outline why the learning curve should have a limit, explaining that because learning was a characteristic of human beings and machines could not learn, manufacturing had an “incompressibility” factor. Soon after, Crossman (1959) provided cases demonstrating these incompressibility factors, most notably the cycle time of a cigar-making firm. During the startup phase, cycle time declined along the Log-Linear curve, but two years later, the Log-Linear curve bent to a lower limit. Crossman (1959) believed this lower limit demonstrated the machinery’s incompressibility factor. However, subsequent studies (Hirschmann, 1964) implied the “machine factor” should not lead to a plateau because if the machine is the incompressibility factor, then operations paced by people should have steeper slopes than those paced by machines-that is, the less human involvement, the less capacity for learning. As an example, the petroleum industry was characterized by large investments in heavy equipment and so highly automated that learning was thought to be either non-existent or of insignificant value. However, the empirical evidence found the progress ratio in cost per barrel of capacity from 1942 to 1958 was almost the same as many other industries fitting the assumption that the limit is 0, as well as the average direct person-hours per barrel from 1888 to 1962, and that this also held true in the electric power and steel industries, and so on. Dar-El et al. (1995) stated frankly that even in the long run, there is no scientific work supporting the assumption of DeJong and Crossman.

The mainstream of contemporary studies on the law of learning curve is to test the hierarchy hypothesis (Gray, 2017; Gray and Lindstedt, 2017; Evans et al., 2018). However, as Jaber (2016) states, there is no tangible consensus among researchers as to what causes a plateau in the learning curve.

This article investigates 12 models that are most often cited in the literature (Table 1). Some letters of the variables differ from the original literature, they are unified here according to the meaning of the variables. For all models listed in Table 1, parameter k is the asymptote for performance after an infinite amount of practice without random impact by external variables, p concerns the working group’s experience before manufacturing, (which is usually defined as the person-hours needed for the first product), and r is the learning rate in functions. Although parameters k, p, and r roughly mean the same thing in all models, they are different in their range of value.

These 12 models can be divided into two types: the first involves y decreasing continuously with the increase of x (eight models), and the second involves y increasing with the increase of x (four models), and actually, they mean the same. For example, in the general exponential model (Towill, 1990; Pegels, 1969), y is the person-hours needed to produce a product, which declines with the increase in production number; that is, more products x being produced means fewer person-hours are needed for the x-th unit. By contrast, in the Hyp2 model (Mazur and Hastie, 1978; Nembhard and Uzumeri, 2000), y is the number of products produced in one unit of time, which increases with the increase in time x spent on production.

The essential divergence among these models lies in two questions: First, which does it assume, plateau or leap? Second, does it allow for a slow start-up phase? As a reflection of the controversy, the most popular models among scholars (Log-Linear, Stanford-B) simply do not have asymptote because they sometimes fit even better. Moreover, asymptote is allowed to be 0 in decreasing models or can be quite large in the increasing models. To provide a reasonable explanation of the plateau, the

special parameter M (DeJong, S-curve) was created to incorporate the influence of machinery. In terms of the start-up phrase, four models (Exp-Delay, Power-Delay, Stanford-B, S-curve) indicate the degree of delay for the start-up phrase with parameter t; in the initial delay models, the learning process is not rapid at the beginning but progress is instead rapid after a period of learning initiation, when t does not equal 0. K, p, r and M, t are the parameters employed in this study.

Theory

When we observe organizational learning in manufacturing, we can easily divide the production process into numerous small factors. For example, Asher (1956) divided the total person-hours in aircraft assembly into 10 major procedures (e.g., final assembly, fuselage major assembly, and miscellaneous sub-assembly); the cost of these procedures could be improved independently or further divided, with the total cost of the product being the sum of the costs of its factors. Along with the improvement of every loading factor, this presents another method to accelerate the learning curve: load more efficient factors by replacing, or without replacing, the original factors. For example, when the numerically controlled machines in a flat-screen television manufacturing procedure were replaced by a “smarter” computer numerically controlled machine, the product cost per unit reduced considerably, which is a “leap” (Teplitz, 2014; Gray, 2017; Gray and Lindstedt, 2017). Thus, academics have intuitively accepted these two methods for the learning curve to progress.

The key difference that separates this study from previous ones is that the studies allowed for these two progression methods to converge and did not distinguish between them. By contrast, this study emphasizes that a learning model should be used strictly under the condition that all factors remain unchanged in theory or, in practice, the prime factor(s) should at least not change dramatically. The reason to hold all factors of a learning process unchanged is that when factors change, they could also turn the learning process into an entirely different procedure, thus making the regression meaningless. For example, one feature of the pre-2012 railway industry in Shenzhen was that it mainly used traditional diesel locomotives; however, in January 2012, the new high-speed railway came into service with electric locomotives. Using the industry transition of two learning processes would be unsuitable, as it involves two types of trains belonging to many different railway companies on two types of railways using two different techniques.

However, if this requirement of factors remaining unchanged is followed strictly, no eligible datasets would be found as factors constantly change in every learning process. Furthermore, the train system is an aggregation of all trains and stations; train service using one electric locomotive between two stations does not change the prime factor of the large system, and it is hard to draw a rigid theoretical line as to how many added electric locomotives and stations exactly brings about the change in prime factors. Arguing that prime factors should not change dramatically is a compromise, but that does not mean “dramatically” is ambiguous. In this case, a dramatic change means heavy investment in new infrastructure and facilities in comparison to previous investments, as well as hard work that differs from previous efforts by entrepreneurs and managers. It should not be hard for entrepreneurs and managers to distinguish the prime factors because they cause a dramatic change of prime factors to occur.

The process of forgetting (Benkard, 2000; Jaber, 2006) should be excluded for the same reason, as it is a process of constantly losing loading factors and not of “learning.” The desired condition of a learning process is that one should deliberately practice (Ericsson et al., 1993) to improve ability with the exclusion of dramatic changes to prime loading factors.

The general exponential model (Pegels, 1969; Towill, 1990) and the exponential delay model (Evans et al., 2018) fit the data well and predict the plateau in performance, and the fact that they fit so well in difficult conditions means the need for a new model is not urgent. The two models are presented together because they substantively have the same meaning when t=0:

$$y = k' + p'(t+1)/(t+e^{xr'}) = k' + p'e^{-xr'},$$

Denote $k' = k$, $p' = p \cdot r^{-1}$, $r' = -\ln r$,

Then

$$y = k + pr^{x-1}$$

The relative learning rates (RLR) of the two are theoretically equal as well because $r' = -\ln r$.

$$\frac{\partial(y_{\exp-gen})}{\partial x} = \frac{\partial(k + pr^{(x-1)})}{\partial x} = \ln r \cdot (y_{\exp-gen} - k),\ 0<r<1;$$

$$\frac{\partial[y_{\exp-delay}]}{\partial x} = \frac{\partial[k' + p'(t+1)/(t+e^{xr'})]}{\partial x} = -r'(y_{\exp-delay} - k'),\ r' > 0.$$

Thus, for a given dataset with t=0, the general exponential model and the exponential delay model should theoretically progress at a constant RLR ratio along the regression curves.

METHODOLOGY

To refine the qualified models, the factor analysis method was applied to distinguish eligible datasets from ineligible ones in the Shenzhen railway industry database; then, nonlinear regression method was employed (Bates and Watts, 1988) to obtain the value

of parameters (k, p, r, t, M), the determination coefficient (R^2), and the residual sum of squares (RSS). This was followed by an estimation of the reasonable limits of plateaus for the datasets; each was compared with the regressed result of asymptotes (parameter *k*), and only two models (Exp-Delay, Power-Delay) do not have unreasonable asymptotes across all datasets. Finally, the two models were compared using the Akaike Information Criterion Test (AIC, Akaike 1974), the Bayesian Information Criterion Test (BIC, Schwarz, 1978), and F-test. For calculation, the software Origin 9.1 by OriginLab was used.

The most important task, which missed in previous literature, was to find datasets in the Shenzhen railway transportation industry that met the requirement of prime factors not changing dramatically with the knowledge that factors in transportation change rapidly. On the demand side, every trip is an individual decision triggered by different reasons (an accident in a distant hometown, for example, could necessitate an emergency trip); the most significant regular reason for changes in demand side are the Spring Festival of the Chinese New Year and the peak summer season. The Spring Festival sometimes comes in January and sometimes in February, and it causes a surge in passenger volume before this number drops dramatically; the summer peak comes in June, July, and August as the result of summer vacations. On the supply side, a train can add or cancel a stop without explanation, and arbitrary decisions on the frequency of trains at stations make the data of many stations change substantially. Competition from other modes of transportation (that is by airplane or by automobile) is one of the external factors that significantly influence the number of railway trips, as well as the number and type of residents in Shenzhen. Thus, regression on the railway system is set to be in difficult conditions because different kinds of factors cannot be controlled simultaneously.

Factor analysis focuses on using the supply side to identify different prime factors in a learning process. For example, the two modes of railway transportation (the traditional diesel railway system and the high-speed electric railway system) should be regressed separately; one can also apply regression together beginning with the day the two modes were both in service but not from the beginning of the traditional railway system and over the change to the two modes together. For data involving no change in the railway system type, I observed the yearly increasing rate of trips in every month to identify the prime factors to avoid the seasonal influence on the demand side. The yearly increasing rate in number of trips is assumed to be high at the start-up phase and gradually approach 0, and a significant increase would indicate that a new prime factor has been loaded.

The criterion between eligible and ineligible datasets in this study depends on four requirements, and if one of them was not met, the dataset is ineligible. First, the station or a group of stations should be in service in December 2018. Second, they should have remained in service for at least 12 successive months from the first month of operation to December 2018, and null datum during this period was not allowed. Third, the data demonstrates general growth and not decline. Finally, if the Exp-Delay model fits, the delay parameter t should equal 0. It must be noted that as long as t did not equal 0, the dataset was excluded despite the goodness of fit because it indicated a change in prime factors (which the next section explains; also see Evans et al. (2018), for the connotation of t).

The work of nonlinear curve fitting follows the doctrine articulated by Bates and Watts (1988). According to the Gauss-Newton method, for equation $y = f(x,\theta)+\varepsilon$, the aim is to find the expectation value $\hat{\theta}$ of θ with the minimum least square value in $S(\theta)=\sum_{i=1}^{n}\varepsilon_i^2=\sum_{i=1}^{n}[y_i - f(x_i,\theta)]^2$. With the expansion in a first-order Taylor series about θ, an iterative equation can be deduced, and the convergence of $\hat{\theta}$ can be obtained until the increment of θ is small to the point there is no useful change in the elements of the parameter vector. The convergence criterion in this study is less than 1E-9.

The idea behind plateau estimation is that a given amount of investment in railway system cannot achieve infinite passenger handling capability. The criterion of current plateau presented in this study is less than three times that of the passenger departure volume (PDV) in the highest month of 2018, the regressed asymptote of a model higher than this volume will be unreasonable. Because, the triple PDV by train in a month will be much higher than the number of residents in Shenzhen. The reason for holding the same plateau criterion as Shenzhen's total volume for the remainder of the eligible datasets is that these datasets are subsets of the total volume and their volume distribution reflects a balanced response to all types of demand for different destinations. No more or less models can be presented in spite of the change of plateau criterion.

To compare the goodness of fit of the two models, I used the AIC (Akaike, 1974), BIC (Schwarz, 1978), and F-test, with the results being the same for the three methods. The reason that only the AIC result is presented is that it tells not only which model is better but also how much the better as a percentage with the information of Akaike's weight.

Datasets

Railway system data were deliberately selected for this article for two key reasons: They quantify factors and sub-factors in the learning process, and there are two obvious types of learning processes. The data were extracted from two financial settlement system databases of a listed company on the Hong Kong Stock Exchange and the New York Stock Exchange covering January 2007 to December 2018 (so, no data in 2019 are used). They exclude the ticket price and only concern the PDV of railway stations in Shenzhen, a city located in South China that is adjacent to Hong Kong that has the country's highest per capita gross domestic product. The search found 21 datasets, two being ineligible but illustrated for the phenomenon of leap and initial delay and the remaining 19 being eligible to find the most suitable models. Table 2 provides information from the datasets and the regressed result of mean R^2 of the 12 models for every eligible datasets.

The most notable characteristic of the datasets is that the prime factors of learning processes can be precisely divided and evaluated, meaning it is essential to know the relationships among the datasets. This is evident from their names, dataset which comprise two or three parts: the first part is an abbreviation of a company and the final part is the initial month of the duration of the dataset, which indicates the PDV of railway station(s) this company charges for in the period under review. For example, China Railway Guangzhou Group (CRGG) is the parent company of all railway station companies in Shenzhen, so the dataset name "CRGG2007" means the PDV of all stations in Shenzhen from January 2007 to December 2018. GuangShen Railway (GSR) is the largest traditional railway company, and "GSR2007" means the monthly PDV from January 2007 to December 2018 in traditional service. "PH2016oct" means the PDV of PH station (a small traditional railway station) from October 2016 to December 2018.

Shenzhen North Station (SNS) is one of the high-speed railway stations and the largest station of CRGG. To investigate the learning phenomenon for the high-speed railway service in detail, an abbreviation of destination station is added as the middle part of

Table 2. Datasets and the result of determinant coefficient.

Datasets	N	Unit	Mean	Variance	R^2
CRGG2007	144	Million	3.4602	3.5560	---
SNS2012	84	Million	2.2478	1.6232	---
GSR2007	144	Million	1.7509	0.0870	0.3368
CRGG2014	60	Million	6.3425	1.0862	0.5408
SNS2014	60	Million	2.9107	0.6174	0.7785
PH2016oct	27	10 thousand	7.2059	1.4739	0.5331
SNS-north-2012	84	Million	1.3092	0.3840	0.8207
SNS-east-2014	60	Million	1.3141	0.1356	0.7899
SNS-FJ-2014	60	100 thousand	5.4646	1.3233	0.4506
SNS-GX-2014dec	49	100 thousand	1.0725	0.1720	0.6791
SNS-HN-2012sep	76	10 thousand	3.3337	2.1454	0.7182
SNS-east-GD-2014	60	100 thousand	11.9838	43.0249	0.8819
SNS-qs-2012	84	Thousand	10.6594	49.0885	0.6126
SNS-ydx-2012apr	81	Thousand	4.8709	4.3452	0.6236
SNS-cs-2014	60	10 thousand	14.3862	19.3061	0.7597
SNS-cy-2014	60	10 thousand	5.3060	3.2241	0.7831
SNS-hm-2014	60	Thousand	9.0724	22.3320	0.8582
SNS-hd-2014	60	Thousand	20.3145	123.9908	0.6770
SNS-hzn-2014	60	10 thousand	9.4233	23.1925	0.7377
SNS-pn-2014	60	10 thousand	9.8543	10.6039	0.7927
SNS-sw-2014	60	10 thousand	6.2335	5.4849	0.8972

the name beginning with SNS concern the monthly PDV from SNS to different destinations. That is, the -north- and -east- means the two high-speed railway systems respectively, the uppercase letters mean a group of stations in a province out of Guangdong, the lowercase letters mean a certain station inside Guangdong province, the province Shenzhen located in.

Data were deleted in these 21 datasets under two conditions: the deleted datum must be the first number of a dataset's sequence, and it must be significantly smaller than the second month. When the two conditions were met, I checked the first operational day of this railway line and found, without exception, that the PDV in that month was in the trial operation stage and not fully operational for the entire month. In all, 12 numbers in the 21 datasets (1493 numbers in total) are deleted.

RESULTS AND DISCUSSION

The influence of newly added factors: Leap and initial delay

Findings show that the change of prime factors causes a systematic leap in the learning process, the intuitive impression that the learning process can go infinitely without plateau overlooks the significant changes in prime factors; this can be illustrated either intuitively by figure or numerically by quantity.

Seeing the PDV of CRGG in Figure 1, an intuitive impression is drawn where CRGG increases from 2007 to 2018 infinitely with no sign of plateau, which is a very similar pattern to the findings of Wright (1936) or Keller (1958). However, when examining the prime factors (GSR, SNS), the curves show that GSR had plateaued before 2012, whereas SNS, which came into service in 2012, increases infinitely and has a similar pattern like Wright (1936) or Keller (1958) as well. When investigating the prime factors of SNS using the north and east railway lines both came into service for different provinces in 2012 and 2014 respectively the curves show that these two factors also plateaued. As Figure 1 demonstrates, the three railway lines (GSR2007, SNS-north-2012, SNS-east-2014) plateau at a similar volume under the premise that their respective prime factors will not change further. In other words, every learning process will plateau, and the aggregation of the different prime factors that came into service at different times makes the curve rise infinitely.

The conclusion also can be drawn in a numerical way. The asymptote regression results of all models to CRGG2007 are infinite, and the asymptote of SNS2012 is either non-existent or extremely huge (Table 3), which indicates the need to proceed carefully to the existence of a plateau.

However, in the Shenzhen railway system, it is clear that the irregular addition of new prime factors causes the continual leap of PDV as old prime factors plateaued one by one. First of all, for the solo prime factor of CRGG before 2012 (with the market share at 82.7%), GSR has a limited asymptote value in all models, except the two without asymptote (Table 3). Also, the high-speed railway

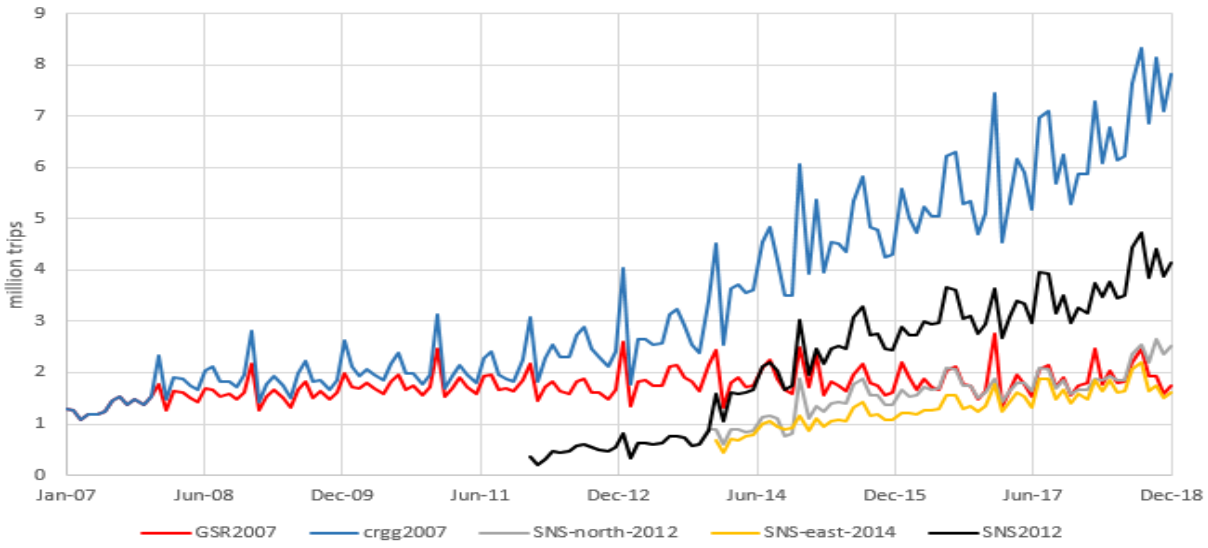

Figure 1. Leaps versus plateaus.

is the factor for the leap of CRGG, for two reasons: first, the increment quantity of CRGG is roughly equal to the PDV of high-speed railway (2.50 million trips versus 2.55 million trips in monthly average); second, the two are highly correlated with a correlation coefficient of 98.1%. As a result, the high-speed railway became a new prime factor of CRGG and of its market share, which rose from 0 to 75.3% along with the decline of GSR from 82.7 to 22.5% from December 2011 to December 2018.

Similar situation is found with the high-speed railway when it is divided into two railway systems. SNS-north-2012 and SNS-east-2014 connect Shenzhen with different provinces by different rail tracks and trains, and are like two lines intersecting at a point, and the two railway lines played an almost equal role in mean PDV from 2014 to 2018 (0.45: 0.55). It can be seen that the majority of models with asymptotes have limited value for the two lines (Table 3).

Changing prime factors causes not only the leap phenomenon but also the initial delay phenomenon simultaneously. When the factor of the high-speed railway was added to GSR in 2012, CRGG2007 experienced a leap; this brought about an initial delay effect (Evans et al., 2018), and the delay parameter (t) in the Exp-Delay model is greater than 0 (t=1.4416). When the factor of the east-direction railway was added to north-direction of SNS in January 2014, there must have been a delay effect for SNS2012 as well, and t=0.2697 is seen. From these figures, it is deduced that when the initial delay parameter t>0, the prime factors must have changed, and thus the dataset is ineligible (Evans et al., 2018).

It should be highlighted that the Exp-Delay model does not have the ability to investigate the change of prime factor at the end of a learning curve. For example, when a new destination (Hong Kong station) came into service in September 2018 with PDV up to 1.29 million trips, the increasing rate of CRGG deviated from a declining trajectory and leaped higher than 20% for the last four months. Hence, it is a better approach to treat the monthly PDV to Hong Kong as a new prime factor for the significant change of learning rate, in spite of t=0. As a result, the mean value R^2 of CRGG2014 for the twelve models improved from 0.4620 to 0.5408.

The results of eligible datasets

Eligible data require the prime factors of a learning process to remain unchanged and the initial delay parameter (t) to equal 0. Under this requirement, datasets such as CRGG2014 are eligible because beginning January 2014; the three prime factors (GSR2007, SNS-north-2012, SNS-east-2014) remained unchanged. The dataset SNS2014 is also eligible because the main factors of the two high-speed railways remained unchanged. Conducting analysis in this way, 19 eligible datasets are found along with a mean value R^2=0.6985, which is a fair result (Table 2), particularly considering the difficult conditions of regression. The best fitting dataset is SNS-east-GD-2014 with mean value of R^2=0.8819 for 12 models; and R^2 of the two best-fitting models both equaled 0.913. The worst dataset is GSR2007 (mean value of R^2=0.3368), which is expected as the PDV of GSR is nearly horizontal. In fact, it is the only dataset that fit not so good. The mean value of R^2 of remaining 18 datasets is 0.7186, which is pretty good considering that this is not an experiment and so many arbitrary

Table 3. The predicted asymptote of 2 ineligible datasets and 19 eligible datasets comparing with their plateau (ov: over parameterized).

Data sets	MAX*3	Unit(trips)	Exp-Gen	Exp-Delay	Stanford-B	S-curve	Log-Linear	DeJong	Power-Delay	Power-Gen	Hyp2	Exp2	Exp3	Hyp3
CRGG2007	-	Million	+∝	+∝	-	+∝	-	+∝	+∝	+∝	OV	OV	OV	OV
SNS2012	-	Million	5.009	4.604	-	+∝	-	+∝	+∝	+∝	19.598	10.546	10.546	14.806
GSR2007	7.408	Million	1.822	1.828	-	1.950	-	13.031	1.950	13.045	1.860	1.786	1.879	1.998
CRGG2014	24.952	Million	7.645	7.597	-	+∝	-	5.88E+14	22.321	+∝	6.455	5.836	30.242	27.507
SNS2014	14.204	Million	3.625	3.618	-	5.634	-	2.29E+16	5.633	+∝	4.194	3.543	4.686	6.202
PH2016oct	27.326	10 thousand	8.195	8.181	-	32.015	-	9.67E+14	11.989	+∝	8.200	7.583	10.085	10.688
SNS-north-2012	7.945	Million	2.141	2.132	-	+∝	-	7.04E+15	+∝	+∝	4.775	2.996	4.423	7.794
sns-east-2014	6.603	Million	1.638	1.631	-	5.299	-	+∝	2.684	+∝	1.955	1.644	2.437	3.478
SNS-FJ-2014	26.085	100 thousand	5.828	5.811	-	7.560	-	20.969	6.913	20.969	6.192	5.721	6.658	7.387
SNS-GX-2014dec	6.220	100 thousand	1.575	1.579	-	+∝	-	+∝	+∝	+∝	2.465	1.819	OV	OV
SNS-HN-2012sep	23.450	10 thousand	3.124	3.133	-	3.718	-	5.315	4.203	3.561	4.727	3.977	4.051	4.727
SNS-east-GD-2014	28.592	100 thousand	7.249	7.248	-	16.744	-	2.91E+16	16.750	+∝	12.000	8.922	17.500	28.267
SNS-qs-2012	101.049	Thousand	41.545	41.254	-	+∝	-	+∝	+∝	+∝	OV	OV	2.81E+12	OV
SNS-ydx-2012apr	27.495	Thousand	7.915	7.935	-	+∝	-	+∝	+∝	+∝	11.281	8.008	10.071	16.225
SNS-cs-2014	79.508	10 thousand	16.554	16.554	-	23.675	-	+∝	22.002	+∝	20.902	17.547	21.783	27.330
SNS-cy-2014	26.006	10 thousand	6.628	6.648	-	13.958	-	+∝	12.858	+∝	9.187	7.237	8.681	11.882
SNS-hm-2014	49.374	10 thousand	12.992	12.974	-	+∝	-	+∝	+∝	+∝	73.195	40.523	63.080	121.190
SNS-hd-2014	136.977	Thousand	24.091	24.033	-	+∝	-	+∝	OV	+∝	315.511	170.066	OV	OV
SNS-hzn-2014	54.197	10 thousand	13.358	13.277	-	+∝	-	+∝	+∝	+∝	84.470	47.607	OV	OV
SNS-pn-2014	50.832	10 thousand	11.593	11.569	-	+∝	-	+∝	19.231	+∝	17.058	13.671	45.947	73.672
SNS-sw-2014	30.615	10 thousand	7.752	7.751	-	17.661	-	+∝	17.668	+∝	13.888	10.145	15.571	24.083

factors are not controlled, and so many different models.

Table 4 provides the regression results of parameters of the general exponential model (k, p, r) and the exponential delay model (k', p', t, r') to all datasets. It can be seen that lnr is roughly equal to–r' in every dataset. The two models have the best R^2 as well, which is only lower than that of Stanford-B (0.7754 and 0.7704 respectively in average of 19 datasets).

Two notes are needed on eligible datasets: First, concepts like (the efficiency of) a production, or (the performance of) a company or a workgroup does not guarantee a dataset's eligibility. Every learning process can be further divided endlessly, even beyond the individual human. This was first noticed by Thorndike and Woodworth (1901), who found that even the factor of an individual's "attention" was a vast group of sub-factors, and that even a slight variation in the nature of the data would affect the efficiency of the group. Second, despite the difficulty of developing a strict definition of "prime factor" or "dramatic change," it is not difficult to distinguish them in practice. GSR was the sole primary company in Shenzhen before 2012, a fact that the residents in this city should know; they also should be aware of the change of prime factors with the two high-speed railways.

Comparing to the residents, entrepreneurs and managers would be much easier to identify the prime factors, who propel the learning curve processing.

Table 4. Regression results for parameters in exp-gen and exp-delay.

Dataset	k	p	r	k'	p'	t	r'
CRGG2007	0.0000	0.7665	0.9889	0.0000	0.7245	1.4416	0.0173
SNS2012	0.1996	3.1095	0.9425	0.2172	3.1940	0.2697	0.0665
GSR2007	0.5488	0.2687	0.9508	0.5469	0.2871	0	0.0423
CRGG2014	0.1308	0.1567	0.9658	0.1316	0.1618	0	0.0352
SNS2014	0.2726	0.4677	0.9250	0.2732	0.5066	0	0.0785
PH2016oct	0.1220	0.0746	0.8720	0.1222	0.0858	0	0.1386
SNS-north-2012	0.4603	2.6675	0.9477	0.4623	2.8179	0	0.0539
SNS-east-2014	0.6106	1.0554	0.9227	0.6131	1.1482	0	0.0815
SNS-FJ-2014	0.1716	0.1422	0.8844	0.1721	0.1632	0	0.1269
SNS-GX-2014dec	0.6348	1.6859	0.9275	0.6334	1.8272	0	0.0740
SNS-HN-2012sep	0.3201	4.1819	0.5233	0.3192	8.2326	0	0.6179
SNS-east-GD-2014	0.1380	0.4347	0.9044	0.1380	0.4837	0	0.0998
SNS-qs-2012	0.0241	0.3688	0.9661	0.0242	0.3818	0	0.0346
SNS-ydx-2012apr	0.1264	0.4804	0.9580	0.1260	0.5016	0	0.0427
SNS-cs-2014	0.0604	0.1187	0.8864	0.0604	0.1346	0	0.1195
SNS-cy-2014	0.1509	0.4300	0.8999	0.1504	0.4810	0	0.1028
SNS-hm-2014	0.0770	0.6964	0.8874	0.0771	0.7852	0	0.1196
SNS-hd-2014	0.0415	0.4450	0.8331	0.0416	0.5354	0	0.1832
SNS-hzn-2014	0.0749	0.4404	0.9072	0.0753	0.4869	0	0.0980
SNS-pn-2014	0.0863	0.2238	0.8812	0.0864	0.2548	0	0.1275
SNS-sw-2014	0.1290	0.4832	0.8837	0.1290	0.5491	0	0.1228

The plateau

The criterion of capability limit is set as triple the PDV of the highest month in 2018 of every dataset, and higher volume of asymptote of a model is unreasonable. Despite being the best-fitting model among the 19 eligible datasets according to R^2, the Stanford-B model had to be excluded because it assumes infinite growth. It is impossible that current prime factors will allow a station or a group of stations to achieve infinite capability, and there are other limits to external variables, such as the city's population and competition from other modes of transportation. Only two models are free from this unreasonable plateau across the 19 datasets: the general exponential model and the exponential delay model (Table 3).

To avoid the subjectivity and inaccuracy of the triple criterion, four additional criteria were tested. Additionally, several managers in Shenzhen railway industry consulted during the preparation of this study, asserted that a strict criterion that is higher than the maximum and lower than double PDV of the highest month in 2018 would be more accurate because of the clear shortage of transportation capability in Shenzhen's railway industry. When a more rigorous criterion, double the PDV of the highest month, was employed, the two models remained the only ones to qualify; only when the capability limit was reduced to the maximum PDV in 2018 did the result change to the point that no model could be suggested. This is unsurprising as the two models have 34 of the 38 lowest two asymptotes for the 19 datasets (the Exp2 model has three of the 38 lowest, and Hyp2 has one of the 38 lowest). Hence, these two models could not be outperformed when using a significantly more rigorous criterion across the 19 datasets.

However, could more models be presented as qualified models when a less restrictive criterion is employed? The answer is no. When the capability limit is enlarged to quadruple or quintuple the PDV, the two models remained the only ones to qualify; however, even so, five times the maximum PVD in 2018 is nearly double Shenzhen's population, a figure going too far.

Due to the lack of knowledge on the mechanism of the plateau, previous studies reveal no asymptote for eligible datasets however, the regression result is analogous. For example, Mazur and Hastie (1978) compared four models (Exp2, Exp3, Hyp2, and Hyp3) and confirmed that the asymptotes of exponential models were much lower than the hyperbolic models in every case as well (for 89 datasets in 23 experiments). Newell and Rosenbloom (1981) fit three models (Exp-Gen, Power-Gen, and Hyp2) to 18 datasets in 15 experiments, finding

Table 5. Akaike's information criterion (aic) test weight.

AIC weight	Exp-Gen	Exp-Delay
GSR2007	0.8951	0.1049
CRGG2014	0.7672	0.2328
SNS2014	0.767	0.233
PH2016oct	0.8204	0.1796
SNS-north-2012	0.756	0.244
SNS-east-2014	0.7667	0.2333
SNS-FJ-2014	0.7667	0.2333
SNS-GX-2014dec	0.7852	0.2148
SNS-HN-2012sep	0.9871	0.0129
SNS-east-GD-2014	0.7744	0.2256
SNS-qs-2012	0.7562	0.2439
SNS-ydx-2012apr	0.7571	0.2429
SNS-cs-2014	0.7722	0.2278
SNS-cy-2014	0.7849	0.2151
SNS-hm-2014	0.7671	0.2329
SNS-hd-2014	0.767	0.233
SNS-hzn-2014	0.767	0.233
SNS-pn-2014	0.7668	0.2332
SNS-sw-2014	0.7737	0.2263
Mean	0.7894	0.2106
Variance	0.0033	0.0033

that Exp-Gen was the most conservative prediction model in 16 datasets and ranked second in the remaining two, the same conclusion.

Heathcote et al. (2000) compared four models (Exp-Gen, Power-Gen, and two other models) across 17 datasets, furthermore, they even set a criterion of plateau, as in this study, and found that the Exp-Gen had the least implausible rate (18.3% on average, ranging from 1.4 to 45.8% among all datasets, while their presented model ranked second at a rate of 30.7% on average and the Power-Gen model had an implausible rate of 65.4%). Their dataset contained ineligible data; thus, the Exp-Gen would have been the only remaining model if only eligible datasets had been included.

Furthermore, Mazur and Hastie (1978), Newell and Rosenbloom (1981), and et al. (2000) demonstrate that hyperbolic functions imply a process in which incorrect response factors are replaced with correct ones, as well as that power functions imply a learning process in which some mechanism slows the rate of learning, whereas the exponential functions imply a constant learning rate relative to the amount remaining to be learned. Thus, we can see that many scholars intuitively hold that as one practice and learn more in a specific domain; the amount of unknown material decreases and the progress is essentially null at the end of the learning process.

Comparing the two presented models

The general exponential model is 0.79:0.21 better than the exponential delay model in average across the 19 eligible datasets, with a variance of 0.003 in the AIC weight criterion (Table 5). The models' difference in AIC weight criterion is fairly significant, primarily because that the general exponential model only has three parameters whereas the exponential delay model has four and the RSS of the general exponential model is even smaller than the exponential delay model in seven datasets (the same in eight datasets and larger in four).

The AIC weight criterion balances the number of parameters and goodness of fit with the RSS value: if the same number of parameters is employed, the smaller RSS value is better; if the RSS value is the same, fewer parameters is better. Considering that a description of a learning curve should have at least three parameters (the asymptote, prior experience, and learning rate[2]), and the Exp-Gen model fit the data fairly well in difficult conditions, the ability to find a better model is likely minimal. Thus, the Exp-Gen model by Pegels (1969) and Towill (1990) and the exponential delay model by Evans et al. (2018) are presented in this study without any suggested modifications. The fitted lines of the two models concerning the two most divergent datasets in AIC weight (SNS-HN-2012sep and SNS-north-2012) are shown in Figures 2 and 3. The difference between the two models

[2]For any learning process of firms, the prior experience is supposed not to be null.

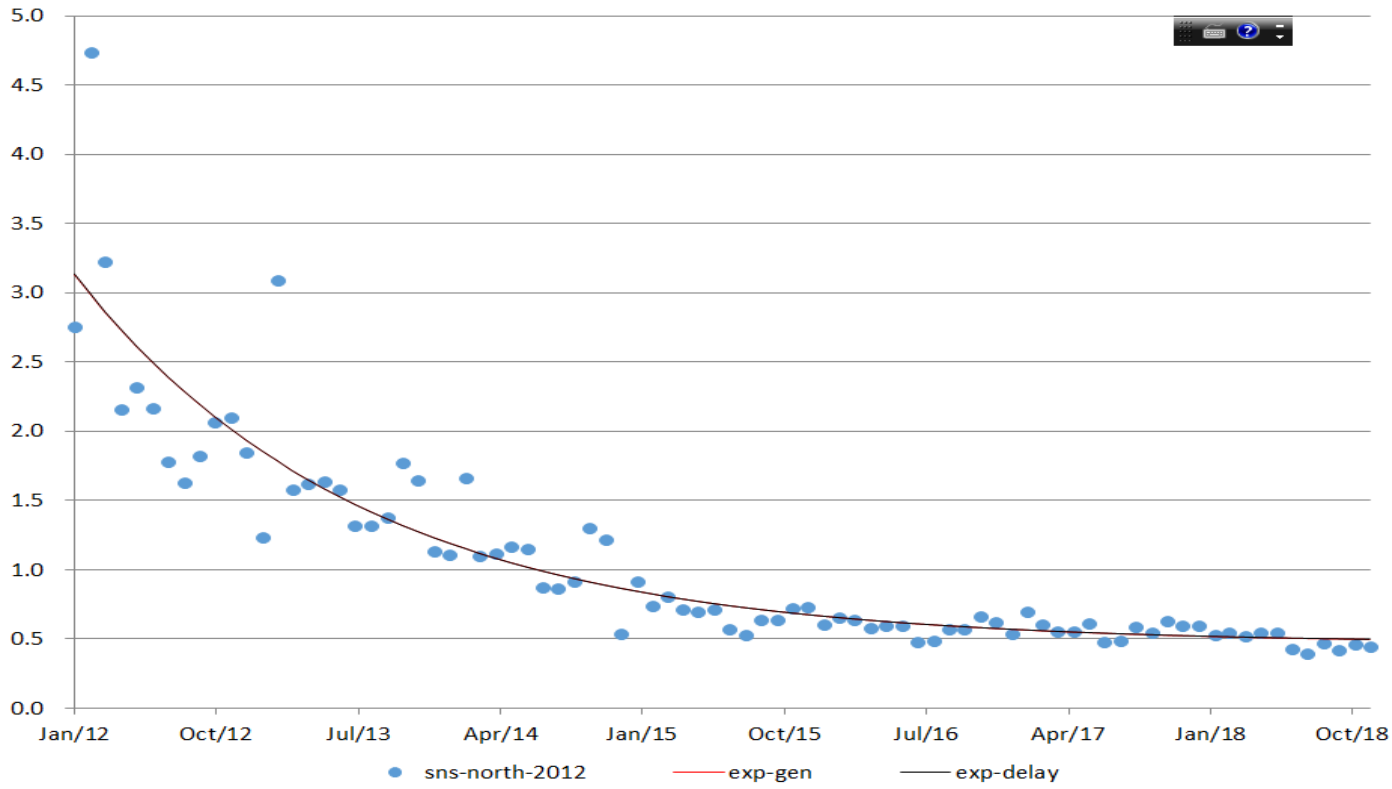

Figure 2. SNS-NORTH-2012.

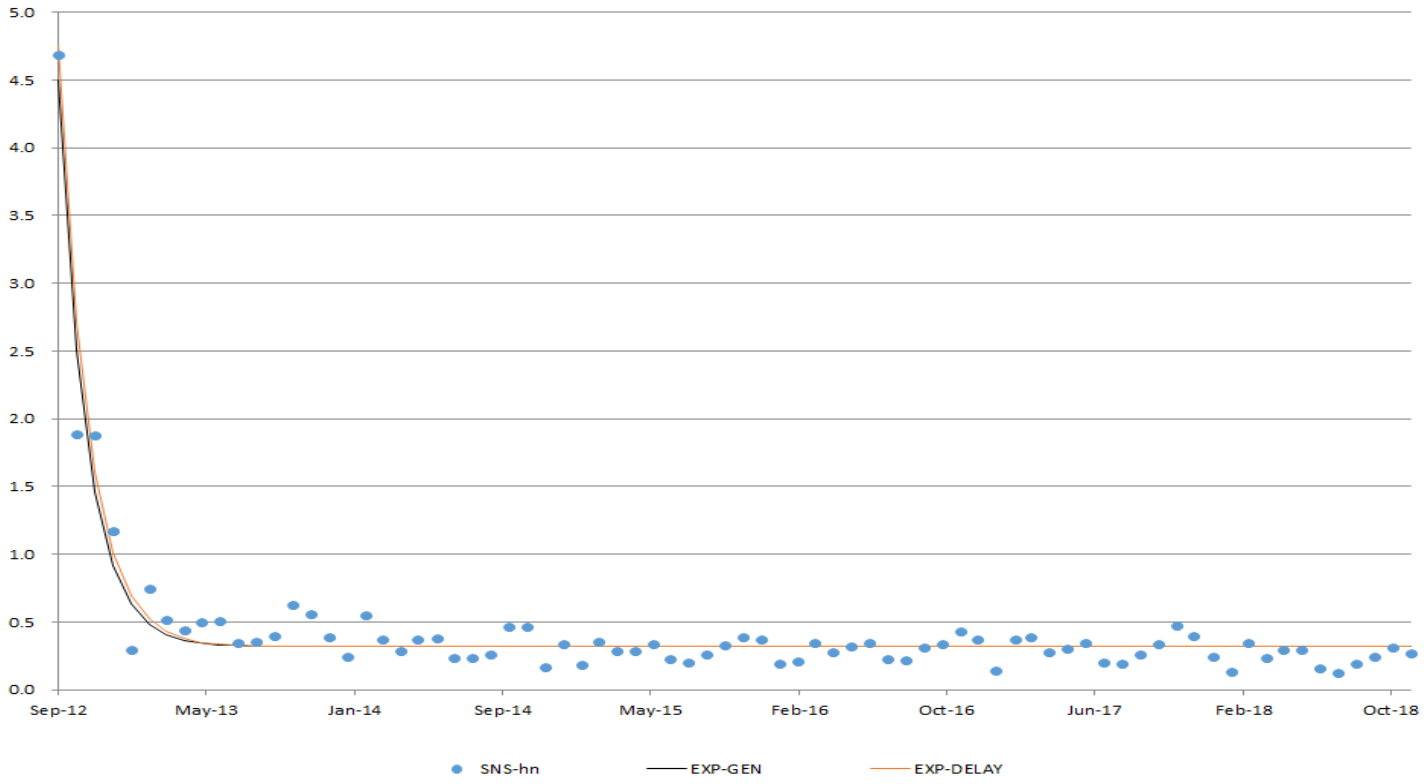

Figure 3. SNS-HN-2012.

is small and difficult to distinguish as the RSS value of them is almost identical.

Conclusion

This study describes the mechanism of the plateau and the reason why previous studies could not locate a plateau. Two exponential models are presented as the function expressions of the law of learning by doing, both of which can provide entrepreneurs and managers with a powerful tool to predict future performance of their investment. This study also specifies that the law of learning by doing can be applied not only in individual learning but also in organizational learning.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Elasticity and buoyancy of tax system in Cote d'Ivoire

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This paper examines the productivity of revenue from the Ivorian tax system over the period 1984 to 2016. To do this, it estimates the buoyancy and elasticity of tax revenues over this period. It uses the Ordinary Least Squares (OLS) method to estimate the buoyancy and elasticity. The results show a buoyancy and elasticity less than one, reflecting the inelasticity of tax system. Furthermore, they reveal tax reforms undertaken have failed to improve the productivity of the tax system in Cote d'Ivoire.

Key words: Elasticity, buoyancy, tax system, tax reforms, tax revenue, Cote d'Ivoire.

INTRODUCTION

A good tax system is characterized by higher revenue productivity. This revenue productivity depends on the responsiveness of the tax system to changes in economic activity and/or on tax decisions made by the policy makers. The question of the responsiveness of taxes to changes in economic activity or to discretionary changes in tax policy is a subject of interest among economists. Since then, they have been developing models to determine how taxes react to changes in economic activity or to discretionary changes by the authorities. This responsiveness of taxes is commonly assessed through the concepts of elasticity and buoyancy. Elasticity measures the automatic response of revenue to changes in income less discretionary changes in tax policy while buoyancy measures the total response of tax revenue to changes in income and discretionary changes in tax policy.

The Ivorian tax system has been the subject of several tax reforms aimed at improving the productivity of tax revenue and meeting the country's needs for economic and social development. Although a series of tax reforms have been undertaken, the country has failed to generate enough tax revenue to meet financing needs. This inability of the tax system to generate enough revenue has led the government to run large budget deficits. Consequently, bank loans and external financing are requested to finance public expenditure. Since these sources of deficit financing are unsuitable for the medium and long term, efforts must be done to design an efficient tax system capable of supporting public services without resorting to the search for external funds.

Making a tax policy decision without knowing the magnitude of the percentage change in tax revenue at its base can distort the expectations of decision-makers regarding the economy's ability to generate tax revenue and this could lead to a fiscal imbalance. The way taxes are raised and used influences the legitimacy of government and its accountability to taxpayers and encourages good management of public finances. In this regard, the concept of elasticity is a crucial factor in

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assessing the effectiveness of the tax system. Elasticity measures, in economics, the variation of a quantity caused by the variation of another quantity. Conversely, inelasticity characterizes the absence of a link or the independence of the variations of the two variables concerned.

However, to measure the productivity of the tax system, a distinction is made between the elasticity of revenue and the buoyancy. Elasticity and buoyancy have the advantage that they can both result in increased tax revenues. However, this growth in tax revenue can come either from an automatic response or from discretionary changes which are the result of action by the authorities. Indeed, the growth in tax revenue resulting when the rules, the tax base, tax rates, etc. (discretionary changes) are held constant is the automatic response. However, the growth in tax revenue resulting from the combined effect of automatic response and discretionary changes is buoyancy.

In general, it is desirable that the growth in revenue from a tax corresponds to that of the Gross Domestic Product (GDP), without frequent discretionary modifications being necessary for its rates and structure. This requires that the tax elasticity coefficient be equal to or greater than one. This property ensures that revenue growth increases with that of income (GDP) without frequent discretionary changes. Also, the study of elasticity and buoyancy is very useful for forecasting revenue.

However, very few studies have focused on studying the buoyancy and elasticity of the Ivorian tax system. Furthermore, the empirical results of these studies are inconclusive. Indeed, the studies of Leuthold and Tchetche (1985), and Keho (2013) show that the Ivorian tax system is not dynamic while that of Den Tuinder (1978) shows that the tax system is dynamic. These contradictory results can be explained by the different methods and the size of the data sample used in each of the studies.

The objective of this paper was to examine the implications of tax reforms on the productivity of tax revenues in Côte d'Ivoire. To do this, the approach of Prest (1962) was used to eliminate discretionary effects on tax revenue series. Then, using the ordinary least squares method, we empirically estimated the buoyancy and elasticities of tax revenues in the Ivorian tax system. The first step was to analyze the productivity of tax revenues and major individual taxes. Then, it was a question of assessing the impact of tax reforms on the productivity of the tax system.

The rest of the paper is structured as follows. Section 2 examines the theory of tax reform and the empirical work on tax elasticities. Section 3 defines buoyancy and elasticity and presents techniques for estimating buoyancy and elasticity. Section 4 is devoted to the presentation of the results while Section 5 concludes the paper.

LITERATURE REVIEW

Theory of tax reform

Tax reforms should be used to stimulate economic growth, including by changing the way the tax burden is distributed between work and consumption and by broadening the tax base rather than increasing tax rates (Remeur, 2015). According to Osoro (1993), a tax reform raises four fundamental questions: why do it? When should it be done? In which direction should it go? how should it be implemented? These questions indicate how tax reform should be examined before it is undertaken in a tax system.

The goal of tax reform is geared towards increasing resources, equity, simplicity and economic efficiency. According to Wilson et al. (2018), the goal of most tax reforms is to make tax revenue levels more progressive and sustainable, to promote independence from tax revenue from natural resources and foreign aid, to elevate the role taxation in building the state and creating a better understanding of its impact on growth and inequality. The need for tax reform stems from the inadequacy of the existing tax system to achieve the objectives set. Tax reforms have therefore moved from the desired task to a necessary task in developing countries. According to Osoro (1993), tax reform is a change from the status quo and has become one of the main concerns of the tax systems of most developing countries. Tax reforms are sometimes difficult to achieve because they create winners and losers but sometimes overcome prejudices about the status quo.

Tax reform is an implicit recognition of the failure of the existing tax system. Reform is now necessary to remedy the faulty, deficient and ineffective system. It is a conceptual fiscal policy strategy designed to improve tax administration. Tax reform measures are mainly aimed at boosting tax revenues, strengthening modern taxes and significantly reducing the complexity and lack of transparency of the tax system (Omondi et al., 2014). According to Wilson et al. (2018), good governance also plays an important role in influencing the level of civic mindedness of citizens through the provision of efficient public services and infrastructure such as schools, health care services and social security programs. Also, for Addison and Osei (2001), investing in democratic institutions is also important for tax reform. Indeed, for these authors, taxpayers will be willing to comply with tax legislation if there are mechanisms guaranteeing them that their money will be used legitimately. Tax reform are therefore a fundamental strategy for fiscal consolidation and governance designed to improve the efficiency of the tax administration. According to Wilson et al. (2018), it is a two-way process that requires changing the way taxes are collected and managed by the government. The fact that tax administration does not work optimally in many countries, distorting the intent of tax laws, is an implicit

recognition of the organizational failure of the tax administration systems in these countries. The common thread of tax reform strategies is to improve tax administration by addressing the shortcomings observed in the tax collection system. This involves simplifying the process of collecting and paying taxes, promoting voluntary compliance by taxpayers, and adopting a logical sequence of procedures to effectively identify and manage non-compliance (Pellechio and Tanzi, 1995).

For Pereira et al. (2013), tax reform is the process of reviewing and modifying the administration and collection of taxes by the government in order to boost state revenues on the one hand, and provide more socio-economic benefits important and better, on the other hand. Thus, Silvani and Baer (1997) have listed a number of reasons why tax reforms are justified: a) when there is a need to modernize tax administration as part of a broad tax reform strategy in response to the observed weakness and ineffectiveness of the tax system; (b) in response to the demands of a growing economy, in which an expansion of the tax base is necessary to integrate taxpayers not yet captured, for example, the growing number of actors in the informal sector; and c) when the imperatives of modern information and communication technologies (ICTs) as well as changes in macroeconomic policies and legislation force fiscal reforms, for example, to complement economic, trade and investment policies.

To improve the impact of tax reform efforts in developing countries, Rao (2014) recommends a number of points: (1) support local leadership in reform efforts; (2) incorporate political economy analysis into the design and implementation of programs; (3) design tax reform programs to foster broader links between taxation, state-building and governance; (4) pay attention to the complexity of the relationship between foreign aid and tax effort; (5) improve the design of fiscal conditionality and performance indicators; (6) more effectively coordinate donor interventions; and (7) pay more attention to the international political context and its impact on local tax systems.

Successful tax reform involves several steps because it is a major process of fiscal consolidation. First, having recognized that there is a problem with and in the country's tax system, it is important to size the problem. This implies a diagnosis of the problems of the existing budgetary structure. This is followed by an assessment of the role of taxation as a macroeconomic tool (Islam, 2001). The literature on tax reforms has evolved over the past decade, justifying their theoretical and practical importance. However, much of the literature is more descriptive than analytical, and the techniques applied to assess the success or failure of tax reforms are not well documented (Osoro, 1993). However, Osoro (1993) points out that the success of tax reforms in increasing the revenue-raising capacity of the tax system can be assessed by examining the elasticity and buoyancy of the tax system.

The existing budget deficits in many developing countries suggest that the tax systems are not producing enough revenue. Some may ignore this and attribute the cause of the deficits to excessive spending or temporary adverse economic conditions. If budget deficits persist for a long time, it is questionable whether increasing tax revenue should not be the main objective of tax reform. The answer will necessarily depend on the situation in each country. No developing country can afford tax reforms as desirable as they are for other reasons unless these reforms result in substantial tax revenue gains.

Review of empirical studies about buoyancy and elasticity

Several empirical studies have been conducted to assess the performance of tax systems. However, the countries and the methodologies used differ from one study to another. For example, Leuthold and Tchetche (1985) estimated, by logarithmic regression linking tax revenues to GDP, the buoyancy for each of the main Ivorian taxes using annual data from the period 1965 to 1975. They found, unlike Den Tuinder's study (1978), that the Ivorian tax system is less dynamic. In another article, Leuthold and Tchetche (1986) estimated the elasticity and buoyancy of the main taxes of the Ivorian economy over the period 1970-1979. Using alternately the estimation techniques of Prest (1962) and Singer (1968), they conclude that tax revenue in Côte d'Ivoire tends to be slightly inelastic while specific taxes such as value-added tax and the import tax are very elastic.

Keho (2013) was interested in the buoyancy of the UEMOA countries by calculating the buoyancy of individual taxes in each of the member countries of this economic space over the period 1996-2008. The results show that the overall tax system is not dynamic in Côte d'Ivoire. And, the poor performance of indirect taxes negatively affects the overall performance of the tax system. On the other hand, the small fluctuations in trade and indirect taxes are attributable to the low tax elasticities at the base, which indicates that, despite the increase in imports and GDP, import taxes are not collected accordingly.

Akbar and Ahmed (1997) examined the elasticity and buoyancy of various taxes and expenditures of the federal government of Pakistan during the period 1973-1990 using the methodology of Prest (1962). They found that the buoyancy and elasticity of taxes were low due to the low elasticity and buoyancy of tariffs and excise duties. Elasticity and buoyancy were found to be relatively higher for sales tax followed by income taxes. Jeetun (1978) found that Pakistan's direct and indirect taxes were very inelastic over the periods from 1960 to 61 and from 1975 to 1976. Among indirect taxes, tariffs appeared to be more elastic, followed respectively by tariffs import, excise and sales taxes. The main reason

for the low elasticity was the low elasticity of the tax relative to the base.

Other studies have estimated short-term and long-term buoyancy of the tax system using time series. Upender (2008) examines the degree of buoyancy in India by fitting a logarithmic regression model with an interaction variable. It considers the period after 1992 as the period of tax reform to examine the forecasts of tax reforms initiated by the government of India. These results show that buoyancy is positively significant and greater than unity during the pre-reform period. However, the coefficient on the interaction variable is significantly negative, showing a downward change in the degree of buoyancy during the post-reform period. The buoyancy estimate, which was just above unity during the pre-reform period, is lower than unity during the post-reform period, which shows that overall taxation is relatively inelastic. Thus, it concludes that the buoyancy during the periods before and after tax reform is not stable.

Barrack and Olukuru (2016) estimated in a comparative study the buoyancy of income tax, value-added tax, import tax, excise tax and total tax revenue in using annual data from 1972 to 2014 for Kenya and South Africa. They applied the error correction model for the short and long-term estimation of buoyancy and the level of convergence between the short-term estimation and the long-term estimation. The results suggest that the tax systems for both countries are dynamic in the long and short term with an average speed of adjustment between the long term and short-term estimates.

Osoro (1993) examined the relationship between tax reforms and the productivity of Tanzania's tax system. These estimates of global and individual tax elasticities show that the tax reforms undertaken in Tanzania have been ineffective in improving the productivity of the tax system. In fact, all taxes, except corporate taxes, had elasticities less than one. He believes that the expected impact of tax reforms seems to have been thwarted by the many exemptions and the efficiency of Tanzania's tax administration. Furthermore, Kusi (1998) assessed the link between tax reforms and the productivity of the tax system using data from Ghana to demonstrate the long-term and medium-term effects of tax policies. His study showed that tax reforms had a significant impact on individual taxes than on the overall tax system. Indeed, he found that all individual taxes except export taxes and excise duties had buoyancy and elasticities greater than unity during the reform period (1983-1993). He concluded that this improvement in tax elasticities and buoyancy can be attributed to the effects of the tax reforms carried out in this country.

Kargbo and Egwaikhide (2012) examined the elasticity of the tax system in Sierra Leone using annual data covering the period 1977-2009. They use the dummy variables method of Singer (1968) to adjust the effect of discretionary tax measures and then compare the measures of buoyancy and elasticity. Their empirical results indicated that the estimates of buoyancy were higher than the estimates of elasticity, and the short-term elasticities were lower than the long-term elasticities. The results of the estimate also showed that discretionary tax measures were effective in raising additional tax revenue and that the tax system was inelastic during the 1977-2009 period.

Mansfield (1972) analyzed the elasticity and buoyancy of the Paraguayan tax system during the period from 1962 to 1970 in which judicious tax reforms were carried out. The results show that the tax system was dynamic with buoyancy greater than elasticity. Thus, for the author, the difference between buoyancy and elasticity indicates that discretionary changes have improved the performance of the Paraguayan tax system by generating additional revenue and increasing the tax burden**.** All the studies as a whole show that the results obtained largely depend on the estimation techniques or methodologies used, the estimation periods covered by the data, the estimation data itself and the tax reforms were undertaken in the system tax.

ECONOMETRIC METHODOLOGY AND DATA

Definition of buoyancy and elasticity

Buoyancy

The buoyancy of a tax system is measured by the proportional change in total tax revenue relative to the proportional change in national income. The buoyancy is expressed as follows:

$$B_{T_t^y} = \frac{\Delta T_t}{\Delta Y} \times \frac{Y}{T_t} \quad (1)$$

Where T_t is the total tax revenue and Y is the income (GDP), are actually observed figures (taxes and bases). Total tax revenue can be replaced by any tax from the tax system and the base, income (GDP), by other bases (consumption, import or export values). Thus, buoyancy can be broken down into individual fiscal buoyancy as follows:

$$B_{T_t^y} = \frac{T_1}{T_t} B_{T_1^y} + \frac{T_2}{T_t} B_{T_2^y} + \ldots + \frac{T_n}{T_t} B_{T_n^y} = \sum_{i=1}^{n} \frac{T_{it}}{T_t} x \frac{\Delta T_{it}}{\Delta Y_t} x \frac{Y_t}{T_{it}} \quad (2)$$

Where, $T_t = T_1 + T_2 + \ldots + T_n$ and n is the number of taxes. Hence, buoyancy is a weighted sum of individual fiscal buoyancy.

Elasticity

The elasticity of a tax system is measured by the proportional change in total tax revenue relative to the proportional change in national income less discretionary changes in tax policy over time. The elasticity is expressed as follows:

$$E_{T_t^y} = \frac{\Delta T_t}{\Delta Y} \times \frac{Y}{T_t} \quad (3)$$

Where, T_t is total tax revenue, Y is income GDP) and $E_{T_t^y}$ is

income elasticity.

Although it looks like buoyancy, there is still a crucial difference. In fact, tax revenue is calculated here as it would have been if there had been no change in tax laws, including rates or tax bases. Tax elasticity is therefore a hypothetical construction. It is trying to reconstruct what would have happened if there had been no change in the tax rules, that is, what would be the tax revenue if the laws of the reference year had continued to apply during other years of the study.

It is conventional to give elasticity in global models as a simple number. However, it is generally expressed as the weighted average of the elasticities of individual taxes which differ widely with changes in income. Thus, overall tax elasticities should be measured by analyzing the elasticities of individual taxes separately. Analytically, it is important to decompose the income elasticity of each separate tax into two elements: the tax elasticity to the tax base and the income tax base. Symbolically, these elasticities are defined according to Mansfield (1972) as follows:

Elasticity of total tax revenue to income: $E_{T_t^y} = \frac{\Delta T_t}{\Delta Y} \times \frac{Y}{T_t}$ (4)

Elasticity of k[th] individual tax to income: $E_{T_t^y} = \frac{\Delta T_k}{\Delta Y} \times \frac{Y}{T_k}$ (5)

Elasticity of the k[th] individual tax to base: $E_{T_k B_k} = \frac{\Delta T_k}{\Delta B_k} \times \frac{B_k}{T_k}$ (6)

Elasticity of k[th] individual base to income: $E_{B_k^y} = \frac{\Delta B_k}{\Delta Y} \times \frac{Y}{B_k}$ (7)

Where, T_t is the total tax revenue, T_k is the tax revenue from the k[th] tax, Y is the income, B_k is the basis of the k[th] tax and Δ the discrete change in the variable associated with it. Given these definitions of elasticity, we can write the expression of elasticity in a system of n taxes as follows:

$$E_{T_t^y} = \frac{T_1}{T_t}\left(\frac{\Delta T_1}{\Delta Y} \times \frac{Y}{T_1}\right) + \cdots + \frac{T_k}{T_t}\left(\frac{\Delta T_k}{\Delta Y} \times \frac{Y}{T_k}\right) + \cdots + \frac{T_n}{T_t}\left(\frac{\Delta T_n}{\Delta Y} \times \frac{Y}{T_n}\right) \quad (8)$$

The expression (8) indicates that the elasticity of total tax revenue with respect to income is equal to the weighted sum of individual tax elasticities with respect to income (where the weights represent the share of each individual tax in the total of tax revenues). In addition, as shown in expression (9), the elasticity of any tax taken in isolation can be broken down into the product of tax elasticity to its tax base and the elasticity of the income base.

$$E_{T_n^y} = \left(\frac{\Delta T_k}{\Delta B_k} \times \frac{B_k}{T_k}\right)\left(\frac{\Delta B_k}{\Delta Y} \times \frac{Y}{B_k}\right) \quad (9)$$

Ultimately, the combination of equations (8) and (9) shows that the elasticity of total tax revenue to income in a system of n taxes depends on the product of the elasticity of the tax on its base and the elasticity to the income base for each individual tax, weighted by the importance of that tax in the total tax system. This gives Equation (10):

$$E_{T_t^y} = \frac{T_1}{T_t}\left[\left(\frac{\Delta T_1}{\Delta B_1} \times \frac{B_1}{T_1}\right)\left(\frac{\Delta B_1}{\Delta Y} \times \frac{Y}{B_1}\right)\right] + \cdots + \frac{T_k}{T_t}\left[\left(\frac{\Delta T_k}{\Delta B_k} \times \frac{B_k}{T_k}\right)\left(\frac{\Delta B_k}{\Delta Y} \times \frac{Y}{B_k}\right)\right] + \cdots + \frac{T_n}{T_t}\left[\left(\frac{\Delta T_n}{\Delta B_n} \times \frac{B_n}{T_n}\right)\left(\frac{\Delta B_n}{\Delta Y} \times \frac{Y}{B_n}\right)\right] \quad (10)$$

This presentation of the income elasticity of the total tax system has two advantages. First, it identifies sources of rapid income growth and, conversely, sources of slow income growth. For example, a high elasticity value (greater than unity) would reflect rapid income growth while a low elasticity value (less than unity) would imply slow income growth. Second, it identifies the part of the growth that policy makers can control.

Buoyancy estimation technique

Buoyancy measures the responsiveness of tax revenue to changes in income without seeking to control discretionary changes in tax policy. The difference between elasticity and buoyancy shows the importance of discretionary changes while a tax-by-tax comparison of the two measures indicates the taxes for which the discretionary changes are more significant. The method to estimate the buoyancy of a tax k consists in using the following model:

$$T_t = \delta_t Y^{\lambda_t}\, \theta_t \quad (11)$$

By putting in logarithmic form, equation (11) becomes:

$$lnT_t = ln\,\delta_t + \lambda_t lnY + ln\theta_t \quad (12)$$

Equation (12) can be rewritten simply as follows:

$$lnT_t = ln\,\delta_t + \lambda_t lnY + v_t \quad (13)$$

Where, T is the tax revenue, t is the time index, Y is the gross domestic product and v is the stochastic perturbation term with $v = ln\theta$. The ordinary least squares method is used to estimate the coefficients δ and λ. The equation being in double logarithmic form, it provides an estimate of buoyancy because it determines the percentage response of the fiscal variable to GDP.

Elasticity estimation technique

Elasticity is quite difficult to measure because it requires an estimate of what would have happened if the changes related to the tax structure had not been made. Thus, estimating elasticity involves modifying equation (13) to account for discretionary changes in tax policy. However, various factors can lead to a change in tax revenue: changes in the tax base and tax rates, the efficiency of the tax administration, the introduction of new taxes and collection methods, the abolition of other taxes and fees, etc. In order to estimate elasticity, the time series of tax revenue must be adjusted to eliminate the effects on tax revenue of all factors other than GDP. To eliminate these effects on the tax revenue series, several techniques exist, notably that of Prest (1962) and that of Singer (1968).

However, it is difficult to use the technique of Prest (1962) in the absence of effective monitoring by the tax administration of the estimated amounts of the variations in revenue induced by the tax reform measures. Also, the administrative methods used to estimate the anticipated effects of tax reforms on revenue can be marred by many significant biases. In addition, the method of Prest (1962) is useful when data on the legal tax bases are available and the rate structure is not complex. The technique assumes the existence of statistical data on the legal bases of taxation and tax rates, which is difficult to apply in developing countries because statistics on bases and rates are lacking and the structures of taxation are often very complex.

For these different reasons, we adopt the technique of dummy variables developed by Singer (1968). This approach allows the introduction of a dummy variable into the model of equation (13) presented above in order to capture changes in discretionary fiscal policy. Thus, to isolate the effects of discretionary fiscal policy on tax k and estimate the elasticity of this tax, equation (13) was estimated by increasing it by the indicator variable considering the

Table 1. Different taxes and their respective tax base.

Tax	Proxy for tax base
Total Taxes	Current GDP at market price
Directs Taxes	Non-agricultural GDP at current prices
Taxes on income, profits and capital gains of individuals	Tax Payroll
Taxes on corporate income, profits and capital gains	Corporate profits
Indirects Taxes	Final private consumption at market price
Value added taxes	Total final consumption
Excise duties	Industrial sector GDP
Customs duties and import duties	Value of imports
Export taxes	Value of exports

years of application of the discretionary tax policy reforms affecting the tax series. The revised model takes the following form:

$$lnT_t = ln\,\delta_{0t} + \lambda_{1t} lnY + \sum \beta_{2i}\, D_i + \varepsilon_t \quad (14)$$

Where, the dummy variable D_i takes the value 1 when a discretionary change has taken place in the tax series and 0 everywhere else. The sum Σ indicates the possibility of multiple changes over the period. In equation (14) the coefficient λ_{1t} estimates the elasticity. A series of tax reforms took place in Côte d'Ivoire during the study period. For this reason, the dummy variable method is used to estimate the elasticities of different taxes.

Decomposition of elasticity

The elasticity of a tax can be broken down as the product of two elasticities, that is, elasticity of the tax in relation to the tax base and elasticity of the base in relation to the GDP, which indicates to what extent each tax contributes to increasing or reducing the elasticity of the overall tax system in relation to GDP. This decomposition thus makes it possible to determine the taxes which, in the tax system, have a higher or lower elasticity with respect to GDP, to indicate the causes of this high or low elasticity and to estimate to what extent the discretionary changes have helped increase tax revenue. The estimation formula is as follows:

$$lnT_t = \beta_0 + \beta_1 ln\, B_t + v_{1t} \quad (15)$$
$$lnB_t = \gamma_0 + \gamma_1 ln\, Y_t + v_{2t} \quad (16)$$

Where, B is the tax base, v_1 and v_2 are random error terms. The coefficients β_1 and γ_1 respectively provide the elasticity of the tax to the base and the elasticity of the base to the GDP.

Data

The study uses annual time series covering the period 1984-2016. The data come from the databases of the Central Bank of West African States (CBWAS) and the database of the Organization for Economic Cooperation and Development (OECD). Data on nominal GDP, non-agricultural GDP, wage bill, industrial GDP, current GDP at market price, value of imports and exports, total final consumption and final private consumption come from the CBWAS data while total tax revenue, direct and indirect taxes, corporate profits come from the OECD database. The variables are transformed in logarithmic form in order to attenuate the fluctuations of the series. Also, the logarithmic transformation will allow us to interpret the estimates of the coefficients in terms of elasticities and growth rates. The data on tax reforms come from our compilations, based on various sources including official reports of tax administrations, versions of the General Tax Code and the Customs Code, versions of the book of tax procedures and IMF country reports. For the estimation of the decomposition of the elasticity, the bases of the different taxes and charges summarized in Table 1 will be used.

RESULTS AND DISCUSSION

The results of the estimates are summarized in Table 2. It was noted that the Ivorian tax system is less dynamic. Indeed, the buoyancy estimate shows that tax revenue is inelastic, which translates into low productivity in the tax system. The buoyancy coefficient of 0.78 is less than the unit. This indicates that a 1% change in GDP results in a less than proportional change of 0.78% in tax revenue. These results are consistent with those obtained by Leuthold and Tchetche (1985) and by Keho (2013) for the Cote d'Ivoire. These authors found that the Ivorian tax system was less dynamic with coefficients of buoyancy lower than unity, unlike Den Tuinder (1978) who found that the tax system was dynamic with a coefficient of buoyancy greater than unity.

Like the buoyancy results, the elasticity estimation results show that the tax system is inelastic with an elasticity coefficient of 0.79. In short, this low elasticity does not allow enough tax revenue to be mobilized to finance public spending. By taking tax revenue by major categories, we make the same observation. Indeed, we realize that direct taxes and indirect taxes are inelastic with a respective buoyancy of 0.90 and 0.76 on the one hand and an elasticity of 0.98 and 0.77 respectively on the other.

However, taken individually, it can be seen at the level of buoyancy that the taxes on income, profits and capital gains of companies as well as export taxes are elastic with an elasticity of 1.09 and 1.42 respectively. However, at the elasticity level, the taxes that have proven to be the most dynamic in the tax system are personal income

Table 2. Estimates of tax Buoyancy and Elasticity, 1984-2016.

Dependent variables	Buoyancy		Elasticity		Gap
	Coef. λ(t-Stat)	R^2	Coef. λ_1(t-Stat)	R^2	
Total Taxes	0.78*(19.18)	0.92	0.79*(17.33)	0.92	-0.01
Directs Taxes	0.90*(10.53)	0.78	0.98*(10.10)	0.79	-0.20
Taxes on income, profits and capital gains of individuals	0.96*(9.82)	0.75	1.04*(9.46)	0.77	-0.08
Taxes on corporate income, profits and capital gains	1.09*(8.79)	0.71	1.17*(8.09)	0.72	-0.08
Other directs taxes	0.00(0.03)	0.00	0.18(1.08)	0.12	-0.18
Indirects Taxes	0.76*(19.54)	0.92	0.77*(19.67)	0.92	-0.01
Value added taxes	0.73*(21.28)	0.93	0.74*(22.07)	0.94	-0.01
Excise duties	0.38*(3.66)	0.30	0.40*(4.02)	0.37	-0.02
Customs duties and import duties	0.72*(13.49)	0.85	0.73*(15.11)	0.88	-0.01
Export taxes	1.42*(6.07)	0.54	1.37*(5.94)	0.57	+0.05
Other indirects taxes	0.95*(9.39)	0.74	0.96*(9.62)	0.75	-0.01

*, (**) respectively indicates significance at the 1%, (5%) level. Figures in parentheses are t-statistics. "Gap" is the difference between the buoyancy coefficient and the elasticity coefficient for each type of tax revenue.

taxes, profits and capital gains (1.04), income taxes, corporate profits and capital gains (1.17) and export taxes (1.37). This means that a 1% increase in GDP causes a more than proportional increase in these individual taxes. Moreover, the other individual headings indicate an inelasticity of these taxes. This reflects a less than proportional increase in these taxes relative to GDP.

The difference between buoyancy and elasticity shows the importance of discretionary changes. To estimate the importance of the tax reforms undertaken by the Ivorian government on the yield of tax revenues, the buoyancies of the same revenue categories were compared to those of the elasticities. As noted, the tax system has a buoyancy of 0.78 versus an elasticity of 0.79; a difference of -0.01. It is safe to say, therefore, that the impact of discretionary changes has been negligible on the mobilization of tax revenue from the tax system. This result is consistent with that of Osoro (1993) for Tanzania but contrary to that of Kusi (1998) for Ghana. It is the same observation that is made for all taxes taken individually, except for the tax on export taxes.

Indeed, the gap between the buoyancy and the elasticity of income tax, profits and capital gains of individuals, income tax, profits and capital gains of companies, of other direct taxes, value-added tax, excise duties, customs and import duties, other indirect taxes is negative and varies between -0.01 and -0.20. This implies that the tax reforms had rather negative effects on these different revenue categories. This is understandable if one considers the reductions or abolition of VAT and the economic liberalization policies that led to the UEMOA Common External Tariff. However, the estimate shows that export taxes have been increased following discretionary changes. Indeed, the difference between buoyancy and the elasticity of export tax revenue is 0.05. The main cause of the growth in export taxes can be the discretionary changes, in particular the gradual reduction of the single exit duty (DUS) on coffee and cocoa in order to promote exports and of import substitution operated in 1995.

In addition, Table 3 shows the results of decomposing the tax elasticity to the base and the elasticity of the base to GDP. As noted above, the elasticity of the Ivorian tax system is low (0.78). This can be explained by the upward rigidity of revenues in relation to tax bases (0.93) and tax bases in relation to GDP (0.60). For direct taxes, their overall elasticity is only 0.90. This relative inelasticity is explained by the combined effects of the inelasticity of indirect taxes which evolve more slowly than the change in their base (0.80) and the slight elasticity of the base in relation to changes in GDP (1.12). As for indirect taxes, with an overall elasticity of (0.76), they also proved to be inelastic due to their rigidity to variations in their base (0.76) even if the base proved to be insensitive to changes in the GDP (0.99).

In the category of direct taxes, we can see that the overall elasticity of income, profits and capital gains tax for individual's amounts to 0.96 and it results from the product between this inelastic tax variation in the base (0.84) and its base even less sensitive to variations in GDP (0.69). The low sensitivity of this tax to changes in its base undoubtedly means that job creation has taken place in sectors that are not very profitable from a tax point of view. As for the low reactivity of the base to changes in GDP, it reflects the fact that the country's economic growth has not translated into equivalent creation of jobs whose income is taxable. For corporate income, profit and capital gains taxes, an overall elasticity of 1.09 can be observed. This elasticity results from the combination of the inelasticity of this tax to changes in the base (0.95) and the elasticity of its base to changes in GDP (1.09). Consequently, if it had not been for the

Table 3. Decomposition of elasticity, 1984-2016.

Dependent variables	Elasticity			
	Tax % base		Base % GDP	
	Coef. β_1(t-Stat)	R^2	Coef. γ_1(t-Stat)	R^2
Total Taxes	0.93*(9.44)	0.74	0.60*(7.28)	0.63
Directs Taxes	0.80*(10.19)	0.77	1.12*(98.57)	0.99
Taxes on income, profits and capital gains of individuals	0.84*(9.42)	0.74	0.69*(15.37)	0.88
Taxes on corporate income, profits and capital gains	0.95*(8.37)	0.69	1.09*(8.78)	0.71
Indirects Taxes	0.76*(16.46)	0.90	0.99*(71.98)	0.99
Value added taxes	0.73*(18.51)	0.92	0.96*(78.20)	0.99
Excise duties	0.37*(3.59)	0.29	1.09*(65.80)	0.99
Customs duties and import duties	0.56*(15.29)	0.88	1.29*(30.22)	0.97
Export taxes	1.28*(7.29)	0.63	1.17*(28.74)	0.96

*, (**) respectively indicates significance at the 1%, (5%) level. Figures in parentheses are t-statistics. "Gap" is the difference between the buoyancy coefficient and the elasticity coefficient for each type of tax revenue.

sensitivity of the base relative to income (1.09), the overall elasticity of the recipe, which amounted to 1.09, would be much less. The elasticity of the base of this tax to changes in GDP is no doubt explained by the transformation of the economy, which results in the creation of formal businesses and productive salaried employment. In the category of indirect taxes, one could justify the quasi-elasticity (0.99) noted by the elasticity of the base with respect to GDP of excise duties (1.09), import duties and taxes (1.29) and export taxes (1.17). However, except for export taxes, which are a 1.28 elasticity of tax relative to the base, the elasticities of the revenue bases, of duties and taxes on imports and exports are inelastic in relation to the base by the inelastic nature of their respective base.

Analysis of the components of the income elasticities revealed that the modesty of the elasticity of the tax system results, first of all, from the inelasticity of the tax bases, in particular the tax bases of indirect taxes, namely the Tax on value-added, excise duties and customs and import duties. To improve the yield on indirect taxes, structural actions going beyond fiscal policy are necessary and should be combined with reforms aimed at improving the efficiency of collection procedures or adjusting the rates of certain indirect taxes. Second, the inelasticity of the tax system results from the inelasticity of the bases in relation to the GDP of direct tax items. Indeed, the elasticity coefficients of the base relative to the GDP of these tax items have been shown to be low. In order to improve the return on this type of tax, measures to broaden the base can range from facilitation to setting up large companies to detecting new tax loopholes.

Conclusions

This paper examined the productivity of revenue from the Ivorian tax system. The results show that the most elastic taxes are export taxes, followed by taxes on income, profits and corporate capital gains. This results in buoyancies greater than the unity of these tax headings. However, the least elastic taxes are value added tax, customs and import duties followed by excise duties. This results in buoyancies below the unit of these taxes. We have seen the low productivity of the tax system because the buoyancy is less than the unit, reflecting the inelasticity of the tax system.

In addition, estimates of the buoyancy and elasticity of total tax revenue and individual tax revenue show that tax reforms have failed to increase revenue productivity. Indeed, all the different tax headings (including the total tax system), except for the export tax, have a coefficient of buoyancy lower than that of elasticity, which shows that discretionary modifications have not been significant in increasing tax revenues.

Analysis of the components of the income elasticities revealed that the modesty of the elasticity of the tax system results, first of all, from the inelasticity of the tax bases, in particular the tax bases of indirect taxes, namely the Tax on value-added, excise duties and customs and import duties. Second, the inelasticity of the tax system results from the inelasticity of the bases in relation to the GDP of direct tax items. Indeed, the elasticity coefficients of the base relative to the GDP of these tax items have been shown to be low. To improve the return on indirect taxes, reforms to improve the efficiency of collection procedures or adjust the rates of certain indirect taxes are needed. As for direct taxes, measures to broaden the base and detect new tax loopholes will be necessary.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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