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High-Speed Internet, Financial Technology and Banking*

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Abstract

Exploiting the staggered arrival of fibre-optic submarine cables, we show that high-speed internet promotes the role of banks and credit in Africa. Variation within-country and across multi-country bank networks indicates that high-speed internet induced a 22% expansion in credit supply. We investigate the role of plummeting telecommunication costs in promoting the bank adoption of new financial technologies and study a specific technology used in the interbank market, the real-time gross settlement system (RTGS). We find that upon connecting to high-speed internet, banks adopt the RTGS more extensively, reduce inside liquidity and increase interbank transactions and lending. We also observe that high-speed internet particularly strengthens firms in countries with weak pre-existing interbank markets.

JEL: G2, G21, O12, O16
Keywords: FinTech, Banking, Investment, Financial Development

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1 Introduction

High-speed internet induced a political and economic revolution in Africa by emancipating participation (Manacorda and Tesei (2020), Guriev, Melnikov and Zhuravskaya (2019)), promoting mobile money (Jack and Suri (2014), Beck et al. (2018)) and stimulating employment opportunities (Hjort and Poulsen (2019), Bircan and De Haas (2020)). At the same time, local financial markets experienced profound and unprecedented changes due to this technological upgrade. Such disruption was particularly relevant for banks, the largest financial intermediary in the continent (Levine (2005), Beck and Levine (2018)). As McKinsey and Company (2018) reports, African banks reacted to the availability of fast internet by restructuring their business model towards novel financial technology, FinTech, which offered an opportunity to reduce financial frictions (Buera, Kaboski and Shin (2011), Kaboski and Townsend (2012)) and information asymmetries (Hertzberg, Liberti and Paravisini (2010, 2011), Hertzberg, Liberman and Paravisini (2018)).

In this paper, we explore the direct relationship between high-speed internet, financial technology and banking by combining extensive datasets with the staggered installation of fibre-optic submarine cables, which introduced major and long-lasting declines in telecommunication costs. Our evidence indicates that fast internet promoted the role of banks in Africa with sizeable and persistent gains both in lending and deposits. Results from the existing literature (Hjort and Poulsen (2019), Bircan and De Haas (2020)) indicate that high-speed internet stimulated credit demand by boosting employment and business opportunities. Our work adds to this dimension by showing that high-speed internet led to an increase in credit supply through bank adoption of novel financial technologies.

We document a specific mechanism behind the effect of high-speed internet on banking, in line with the work of Bolton, Santos and Scheinkman (2011), Bolton, Li, Wang and Yang (2021) and Denbee, Julliard, Li and Yuan (2021). As faster and more reliable connections become available, banks find it convenient to adopt previously unavailable financial technologies, which decrease their operating costs and promote credit supply. Given the difficulty in tracking several financial technologies across different markets and verifying their effects, we study one specific technology, the real-time gross settlement system (RTGS), and investigate whether bank behaviour changes in response to its adoption.

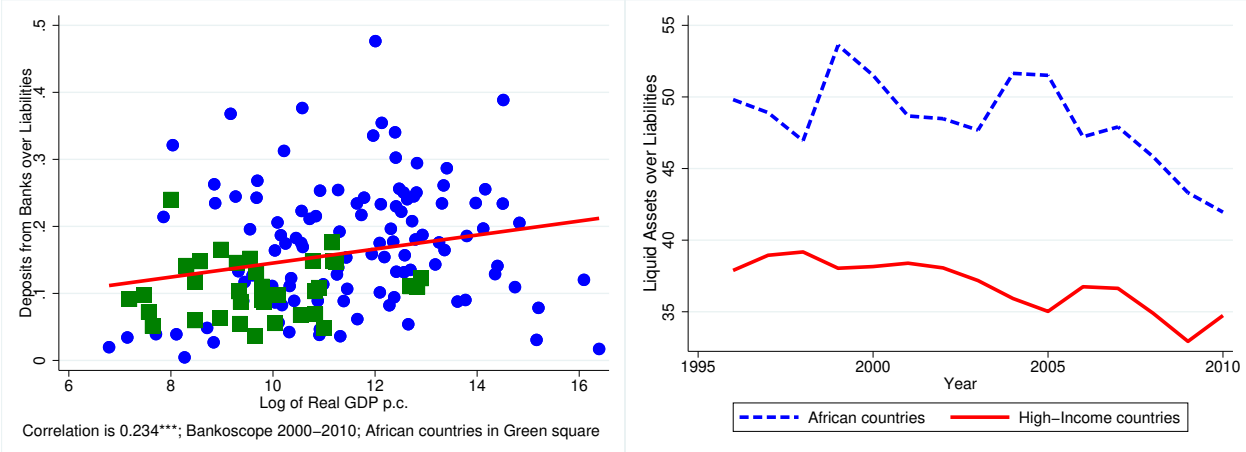
The RTGS lowers a specific set of costs: transaction costs in interbank exchanges (Townsend (1978), Zilibotti (1994), Guerrieri and Lorenzoni (2009)). In line with its stated objective, we observe that after high-speed internet arrives in a country, banks change their liquidity management by reducing inside liquidity (cash and short-term assets) and increasing outside liquidity (use of interbank assets and liabilities). This improvement in liquidity management strengthens lending, resulting in more extensive credit to firms that in turn experience better performance, in line with recent papers on the role of banks and credit in emerging markets (Breza and Liberman (2017), Breza, Kanz and Klapper (2018), Breza and Kinnan (2018), Bustos, Garber and Ponticelli (2020), Bau and Matray (2020), Choudhary and Limodio (2022)).[1]

In this paper, we use four comprehensive datasets. First, following the work of Hjort and Poulsen (2019), we track the exact geography and timing of submarine cable arrival to Africa from the mid-1990s onward. Second, we build a bank-level dataset with balance sheet information following 629 African banks between 1997 and 2018. Third, we introduce a hand-collected dataset containing information on the adoption of the RTGS for all African countries and banks in our sample. Finally, we construct a dataset following 32,761 firms in Africa from the World Bank Enterprise Surveys and observe some indicators of firm credit and performance.

To study how high-speed internet affects banking and FinTech adoption, we face a particularly challenging empirical constraint: the power of the test. Since faster internet connections and novel financial technologies tend to be gradually adopted over time, statistical power is generally low. In this regard, the installation of fibre-optic submarine cables in Africa offers an ideal source of variation for two reasons. First, the magnitude of the effect is large as this novel technology generated a radical improvement in reliability and a 98% decline in the cost of operating fast internet compared to satellite technologies (Detecon (2013)), which were commonly used in the local financial sector (African Development Fund (2002)). Second, African banking systems present considerable frictions in interbank markets, as clarified by Figure 1. The left panel shows that while poorer countries display underdeveloped interbank markets, this is particularly the case in Africa (indicated with a square). The right panel reveals that

[1]Note that the RTGS is one of several financial technologies that banks may adopt. As a result, quantifying the effect of new technologies on credit supply may require more extensive datasets and variation. Our study is intended to offer evidence on the fact that lower telecommunication costs promote the adoption of financial technologies and that the latter shape the behaviour of banks and may alleviate operational frictions.

Figure 1: Interbank Markets and Liquid Assets



Notes: This figure reports information on interbank transactions and the holding of liquid assets by banks in Africa. The left panel uses data from Bankscope on deposits from banks and total liabilities, while data on GDP per capita are extracted from the World Bank's World Development Indicators. Each dot represents a country, while green squares indicate banks operating in sub-Saharan Africa. The right panel uses data from the World Bank Global Financial Development Database. The blue dashed line indicates liquid assets over liabilities for countries belonging to sub-Saharan Africa. The red line refers to the group of high-income countries according to the World Bank classification.

African banks hoard vast amounts of liquid assets, between 45% and 55% of their liabilities, in line with being endowed with dysfunctional interbank markets.

We begin our empirical analysis by studying how the arrival of high-speed internet affects some key banking variables: lending, government bonds, deposits and equity. In this respect, we explore an event study design with a five-year window and a staggered difference-in-difference, in which a bank is treated when its country of operation becomes connected to a fibre-optic submarine cable. Our results show that we cannot reject the existence of parallel trends before the treatment. Conversely, after the cable arrival, treated banks present sizeable gains in lending and deposits, which increase by 36% and 25%, respectively, without differences in the holding of government bonds and equity over liabilities.

Given the current interpretation of these results as due to changes in credit demand, we add a novel dimension to studying this problem by investigating the supply factors behind banking expansion. For this reason, we exploit a source of bank connection to high-speed internet that is unrelated to local demand factors. A bank operating in country c may gain a fast internet connection because its headquarter, located in country g, is connected. As a result, this measure of connectedness does not depend on the cable's arrival in country c, which induces changes in demand. We first verify that both the country and headquarter connection imply similarly sized and positive coefficients, which may be identifying the presence of both demand and supply effects. We then ensure that our key specification focuses on the supply effect by including

country-by-year fixed effects, allowing us to compare banks operating in the same country and year, which only differ in the timing of high-speed internet access due to the heterogeneous headquarter connection. These estimates imply the presence of positive and significant supply effects of fast internet.

To gauge the quantitative component of our study, we develop a back-of-the-envelope calculation and clarify the size of the estimated effect that can be attributed to an enhanced credit supply. For bank loans, our test to isolate supply from demand shows that 62% of the total effect comes from supply-related factors, incorporating changes in RTGS as well as other technologies and bank-induced cost changes. From this exercise, we find that the effect of high-speed internet on credit supply leads to an increase of 22% in lending to the private sector.[2]

After presenting evidence on the effects of high-speed internet on credit supply, we explore a specific mechanism through which this technological progress may lower the marginal cost of bank funding and increase credit supply. We show that cheaper and more reliable internet connections promote the adoption of novel financial technologies, which lower transaction costs in liquidity markets and stimulate interbank activities. Through a set of event studies and staggered difference-in-difference specifications, we document two main results. First, once the fibre-optic submarine cable arrives in a country, the probability of adopting the RTGS, an essential technology to operate interbank transfers, increases by 16 percentage points (p.p.) at the country level and by 5.4 p.p. at the bank level, while it lies on parallel trends before the connection to the cable. Second, local interbank markets grow significantly upon the arrival of the cable and RTGS adoption. Interbank loans and deposits grow by 30% and 63% respectively, and liquidity hoarding declines by 14 p.p. For a limited subset of banks, we also explore a sharper specification, looking at the maturity of interbank transactions, and observe a notable

[2]The magnitudes of our estimates are in line with other studies and are somewhat on the conservative side, in a literature that shows large and long-lasting effects of fast internet. For instance, DeStefano et al. (2018) find that the expansion of broadband in the UK increases the productivity of information and communication technology capital and workers by 85% on output, 87% on employment and more than 100% on firm revenue. Mensah and Traore (2022) show that the arrival of high-speed internet in Africa promoted foreign direct investment (FDI) in financial services, with an 18.4 p.p. increase in the probability of attracting FDI in the financial services sector and a 110% higher amount invested in this field. Houngbonon et al. (2022) find that the arrival of high-speed internet in Africa promotes process innovation by 12%, product innovation by 20% and entrepreneurship by 17%. Bostandzic and Weiss (2021) show that banks with a one standard deviation higher innovation, measured through patents and R&D, experience a 95% higher growth in mortgage lending. Kwan et al. (2021) observe that a one standard deviation higher index of information technology in the United States is associated with a 21% increase in loan volumes generated through the Paycheck Protection Program. Pierri and Timmer (2022) observe that a one standard deviation higher IT adoption before the Global Financial Crisis of 2008 led to a reduction in non-performing loans between 9% and 11% with respect to the mean. Additional studies and considerations on this exciting field of research can be found in the review work of Hjort and Tian (2021).

increase in short-term maturities. This increase offers additional support to the hypothesis that high-speed internet promotes a more extensive and frequent use of the interbank market.

To further investigate our mechanism, we analyse an interesting cross-sectional heterogeneity which allows us to characterise the effect of fast internet in greater detail. We test the assumption that high-speed internet mainly benefits banks with higher ex-ante transaction costs to operate in the interbank market. Such cost difference is established through an interbank 'weak user' dummy, taking a unit value for banks that were below the median usage of the interbank market in a country before being connected to the submarine cable. Our results suggest that a large part of the findings in the previous analysis is driven by these banks becoming more active. The latter remains true even when focusing exclusively on the cross-sectional variation within a country-year unit of observation, hence comparing weak versus strong interbank users by including country by year fixed effects and factoring out the cable's arrival.

Finally, we employ firm-level data to investigate the relationship between high-speed internet and firms. First, we verify that firms in countries experiencing the arrival of the submarine cable exhibit an increase in some of their financial variables (access to finance, loans from banks, and loan maturities), without significant differences in sales and workforce. Second, we note that such an impact is quantitatively relevant for countries presenting weak interbank markets before the cable's arrival. We observe that the arrival of high-speed internet in countries with weak pre-existing interbank markets is associated with a 26 p.p. increase in access to finance, a 20 p.p. higher likelihood of receiving a bank loan, a doubling in loan maturities, a sizeable expansion in yearly sales and a rise in workforce.

To verify the robustness of our results, we devote an extended section and appendix to explore alternative specifications and explanations. We provide empirical evidence on the lack of correlation between the arrival of the fibre-optic cable and economic and financial variables. We then complement the analysis of banking variables through several additional tests. We show the event study and staggered difference-in-difference based on the year in which the headquarter receives high-speed internet. Our results are in line with those that use the cable's arrival in the country of operation. We report a balance table comparing multi- versus single-country banks. We split our sample accordingly and document the complementarity of internet technologies, showing that high-speed internet removes frictions between banks and within bank groups. We

present multiple tests investigating the relationship between fast internet and participation in the RTGS. Furthermore, we implement an additional analysis of the weak interbank setting through a balance table to understand how the latter differ in terms of observables as well as present a scatter plot on their loan/deposits composition. In methodological terms, we check the sensitivity of our graphical results to the choice of different event windows and the presence of heterogeneous treatment effects, and we control for time-varying variables reflecting the country's institutional quality, particularly focusing on financial regulation and contract enforcement. Finally, we offer additional evidence using firm-level data and show that inputs, as well as outputs, increase with the arrival of the submarine cable.

The paper contributes to the literature on financial technology and banking by highlighting how new technologies help to innovate traditional bank functions, as liquidity management,[3] and go beyond the competition-enhancing effects of FinTech (Goldstein et al. (2019)).[4] Lin et al. (2021) study the effect of the telegraph introduction in 19th-century China and find a significantly positive effect on banks' branch network and geographic scope. D'Andrea et al. (2021) study how access to broadband internet affects bank credit to non-financial firms. Using granular micro-data from Italy, they show that branches in locations reached by fast internet increase loan supply and reduce credit price. Mazet-Sonilhac (2021) uses the staggered roll-out of broadband internet in France as a shock to search frictions and document the effect of its reduction on the allocation and price of bank credit to firms. Other interesting papers study related mechanisms affecting individuals and non-financial firms.[5] Overall, the results from this

[3]This paper also brings to the data the predictions of theoretical papers on credit and growth (Townsend (1978), Diamond and Dybvig (1983), Bencivenga and Smith (1991), Saint-Paul (1992), Zilibotti (1994), Acemoglu and Zilibotti (1997), Goldstein and Pauzner (2005), Guerrieri and Lorenzoni (2009)), in line with a growing empirical literature on liquidity risk and credit (Choudhary and Limodio (2017), Limodio and Strobbe (2017)). Regarding the interbank market, the findings of this paper are in line with the recent works of Heider et al. (2015) on equilibrium liquidity hoarding, Allen et al. (2018) on the heterogeneity in interbank access, Craig and Ma (2018) on the structure of interbank networks, Coen and Coen (2019) on risk propagation and Denbee et al. (2021) on the liquidity multiplier induced by the interbank network.

[4]Part of this literature highlights that the rise of FinTech changed the competitive landscape in many sectors, for example, Buchak et al. (2018) and Fuster et al. (2019) for lending, Bartlett et al. (2018) and Tang (2019) for consumer and peer-to-peer lending, Berg et al. (2018) for credit scoring; Hertzberg et al. (2018) for screening, D'Acunto et al. (2019) and Abis (2017) for investment management, Benetton et al. (2019) for cryptocurrencies and Beck et al. (2018) for mobile payment systems. Recently, D'Acunto et al. (2020) observe that novel financial technologies, like robo-advising, lower cultural biases and reduce discrimination in financial decisions.

[5]Higgins (2019) exploits a natural experiment in debit card adoption and shows that financial technology changes individual transaction costs and affects consumption. On a similar ground, Crouzet et al. (2019) verify that the temporary shock of the Indian demonetisation induced the persistent adoption of novel payment technologies, in line with a dynamic adoption model with network complementarities. Recently, Saka et al. (2021) find that the epidemic exposure induced a sizeable advancement in the adoption of financial technology using a global dataset, with demand being a central driver and preexisting telecommunication infrastructure playing a critical role.

literature are in line with our mechanism but focus on banks and liquidity management instead of firms and individuals. At the same time, two papers show that high-speed internet promotes the adoption of information and communication technologies (Augereau and Greenstein (2001)) and that this fosters the country-level adoption of the RTGS and other novel practices in central banking (Bech and Hobijn (2006)).

In addition, our results shed light on the mechanisms through which high-speed internet can affect the economy. Other papers have contributed in this direction. Eichengreen et al. (2016) study the effect of submarine cables on the foreign exchange market and show results compatible with ours; i.e., as submarine cables arrive, local banks respond with their forex trades. Hjort and Poulsen (2019) show that submarine cables improve business opportunities and productivity, especially for high-skill sectors and workers. Bircan and De Haas (2020) show that historical credit access affects innovation and technology adoption across Russian firms and generates economic growth. Finally, Mensah and Traore (2022) document the positive effect of accessing high-speed internet on FDIs into the financial and technology sector.

The rest of the paper is organised as follows. Section 2 introduces the empirical framework and data. Section 3 presents our main results. Section 4 reports some robustness checks. Finally, Section 5 concludes.

2 Empirical framework and data

2.1 Fibre-optic submarine cables and banking

Submarine cables in the oceans have a long history, starting in 1842 when Samuel Morse demonstrated the feasibility of transmitting telegraphic signals over long distances. In 1850–1851, the first telegraphic cable under the sea connected England and France, while in 1866 the first long-term successful transatlantic cable was laid between Canada and Ireland. Despite their rapid diffusion, early submarine cables suffered from reliability and capacity problems. In the absence of repeater amplifiers, they required high voltages to transmit signals over long distances, creating distortion, limiting carrying capacity and heightening the risk of short-circuiting.

At the turn of the 19th and 20th century, the new science of transmitting higher frequencies was established through the introduction of coaxial cables.[6] Nevertheless, commercialisation was delayed by the two World Wars and the Great Depression. The first modern submarine cable, TAT-1 (Transatlantic No. 1), a coaxial cable that had polyethylene insulation and vacuum tubes used as repeaters, was only laid in 1955. In the 1980s, coaxial cables were replaced by modern fibre-optic cables—glass fibres conveying signals by light rather than by electric current. The advantages of these new cables were several, from greater reliability to higher capacity and a faster speed of transmission. The first submarine fibre-optic cable was laid in 1986 between England and Belgium, while the first transatlantic cable connected France, the United Kingdom and the United States in 1988. At that time, the internet was beginning to take shape, and the development of the global fibre-optic network and the internet proceeded simultaneously.

Over the last 30 years, more than one million kilometres of fibre-optic submarine cables have been constructed. This extraordinary network provides the communication infrastructure at the base of the modern internet (Carter (2010)). The path of construction has been fairly irregular. After a great burst from 2000 to 2002, in conjunction with the dot-com bubble, the cable-laying industry has contracted severely, eventually reverting to its previous growth rates after the 2008 and the great financial crisis.

Nowadays, it is estimated that more than 95% of information and communications technology data are carried on low-cost, modern fibre-optic submarine cables.[7] The transmission of data through cables has several advantages: it increases the reliability of connection, increases the speed of the signal and overall capacity and reduces transmission costs. Appendix Figure A1 shows the average unit cost per Mb/s transported capacity, based on 2008 prices. The price was about 740,000 US$ for satellite transmission compared with 14,500 US$ for submarine fibre-optic transmission (Detecon (2013)).

The submarine cable network is a core infrastructure of the modern financial system. Each day, the Society for Worldwide Interbank Financial Telecommunications (SWIFT) transmits more than 15 million messages over cables to over 8,300 banking organisations, securities in-

[6] In coaxial cables, the copper- or copper-plated steel wire is surrounded by an insulating layer which is in turn enclosed by a metallic shield.

[7] These data refer to the testimony of D. Burnett before the Senate Foreign Relations Committee on the United Nations Law of the Sea Convention, 4 October 2007.

stitutions and corporate customers in 208 countries all over the world (Burnett et al. (2013)). Referring to the fibre-optic submarine network, the previous staff director for management of the Federal Reserve, Steve Malphrus, observed that *'when the communication networks go down, the financial sector does not grind to a halt, it snaps to a halt'* (Burnett et al. (2013)).[8]

High-speed connections improve the functioning of the banking system along several dimensions. First, banks benefit from better screening and scoring algorithms, as well as from enhanced information processes and human resource management, which can result in greater ability to interact with firms, households and other banks (D'Andrea et al. (2021)). Second, the internal liquidity management of the banks is highly affected by faster connectivity, mostly through the access and use of the interbank market, where sizeable monetary transactions occur with intense frequency. Being connected to the fibre-optic line determines whether a bank can operate in real time with a long list of counterparties, with effects on bank networks, interbank operations and the speed of transactions.

The staggered arrival of fibre-optic submarine cables in Africa at the turn of the 20th and 21st century is key to understanding the development of the banking sector in the continent. In this paper, we provide evidence that high-speed internet improves banking and facilitates access to credit. In particular, we show that the advent of fast internet in Africa has been paralleled by the development of domestic interbank markets, with a sensible increase in interbank liquidity. We propose this channel to explain part of the effects of high-speed internet on banking.

In this process, we take the arrival of fibre-optic submarine cables as an exogenous technological shock since it was mostly due to the need to increase connectivity between America, Europe and Asia. Our empirical analysis capitalises on three main aspects. First, before the arrival of submarine cables, the interconnection of national banking networks in Africa was based on satellites (African Development Fund (2002)). In that regard, the fibre-optic technology represents a major shock to banks as they transition from a more expensive/less reliable technology to a cheaper/reliable system. Second, geography matters for the timing of the cables' arrival. The distance from Europe was crucial for earlier cable receivers, whereas

[8] On December 26 of 2006, the Hengchun earthquakes occurred off the southwest coast of Taiwan, in a zone which connects the South China Sea with the Philippine Sea. The earthquakes not only caused casualties and building damage, but several submarine communications cables were also cut, disrupting telecommunication services in various parts of Asia. The earthquakes catastrophically disrupted internet services in Asia, affecting many Asian countries as China and Hong Kong. The earthquake also impacted financial transactions, with the foreign exchange market being seriously affected. It was only the capillary presence of other submarine cables that avoided the instant halt of foreign exchange transactions.

being on the route between America, Europe and Asia was key for more recent connections. Third, endogeneity issues coming from the fact that submarine cables had the explicit purpose to improve the banking sector are of second order. Indeed, the first submarine cable laid for the express purpose to foster electronic trading in financial markets was tested in September 2015 (Eichengreen et al. (2016)), only at the end of our sample, and it is not included in our analysis.[9] Before that time, fibre-optic cables had the broader aim to accommodate general telecommunication needs as long-distance telegraphic communication, telephone calls, fax and internet transmission.

2.2 Liquidity markets in Africa

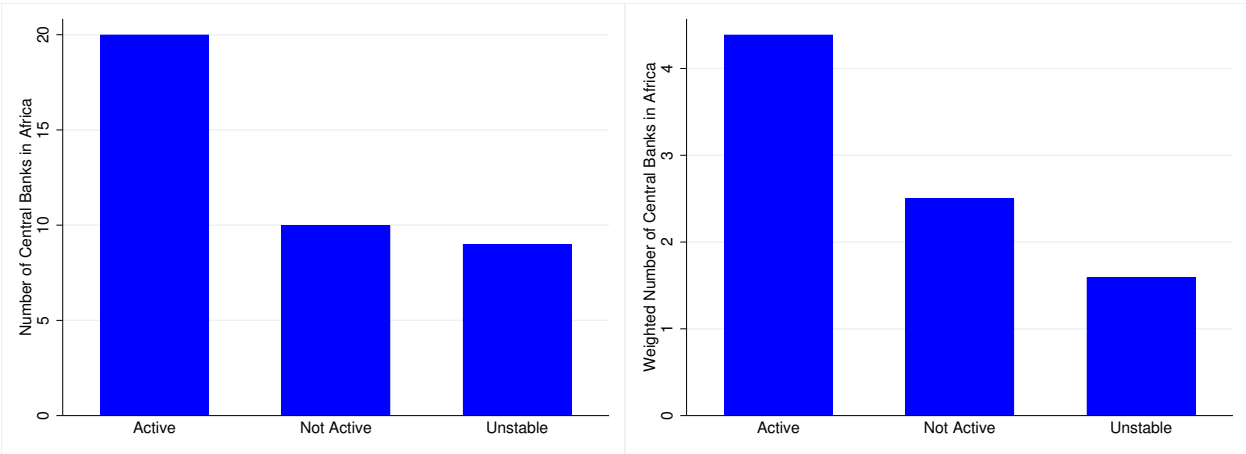
Africa constitutes the best laboratory to explore our research question. On the one hand, banks in Africa experience substantial liquidity risk due to imperfect risk sharing and a high volatility of deposits. On the other, African countries are characterised by a limited functioning of local liquidity markets, which exacerbates deposit shocks. Furthermore, the staggered arrival of submarine cables provides the ideal setting for econometric investigation. We think that the statistical power in our analysis is high and that, among the reasons behind the positive effects of high-speed internet on banking, there is a critical impact caused by the reduction of interbank transaction costs.

Banks in Africa are severely impaired in their access to international capital markets because of local regulation or, even more importantly, because of low international reputation. At the same time, most of the central banks in Africa are either legally unable or *de facto* unwilling to provide liquidity on a predictable basis. Figure 2 shows data on the status of discount window facilities for all countries in Africa, as described by Choudhary and Limodio (2022). Based on documentation published by either local sources or by the International Monetary Fund and the World Bank, this figure confirms that more than 50% of African central banks are not actively engaged in discount window operations, with this number being reflected in absolute terms (left panel of the figure) and weighted by the size of the financial system (right panel). Similarly, local interbank markets are very small or non-existent, forcing African banks to rely on the hoarding of reserves and liquid assets to cushion themselves from liquidity shocks.

[9] Our analysis explicitly focuses on the first fibre-optic cable landed in a country. The last cable in our sample was brought to Africa in December 2012 (see Appendix A).

A major reduction in the cost of interbank transactions, as the one caused by the arrival of fast internet and the introduction of RTGSs, can dramatically affect the activity of banks and generate cascade effects on credit supply and firms.

Figure 2: The Status of Discount Window Facilities in Africa



Notes: This figure shows the status of discount window facilities in Africa. Data are from local sources, the International Monetary Fund and World Bank documentation. The y-axis reports the number of central banks in Africa (left panel), or the weighted number of central banks, weighted by the relevance of the banking sector (banking/GDP from the GFDD) (right panel). The x-axis reports a classification of ventral banks based on how active they are in providing discount window facilities: active, not active and unstable. Active implies that access to the discount window is available given the policy rate. Not active means there is no facility dedicated to providing loans to commercial banks. Unstable indicates that the facility does not necessarily provide funds given a policy rate; see Choudhary and Limodio (2022) for more details.

The recent orientation of policymakers also acknowledges that lack of credit is mostly a supply problem, where banks and liquidity risk play a major role. For example, World Bank (2015) presents a survey of financial development among financial sector practitioners (bankers, central bankers, regulators, academics), from which two important messages emerge: 1) domestic banks are core institutions determining how firms and households have access to finance (61% of respondents agree); 2) access to finance is a supply problem (75% of respondents agree).

Our paper contributes to this literature by showing that new technologies, through the channel of bank liquidity management, can generate positive effects on risk sharing, bank efficiency, credit supply and economic growth.

2.2.1 Real-time gross settlement systems

The arrival of high-speed internet in Africa through fibre-optic submarine cables led to a profound transformation of the banking system. Among the critical changes that modernised local banking networks, RTGSs have played a role.

The RTGS is a special interbank transfer system where the transfer of money and securities occurs on a 'real-time' and 'gross' basis. RTGSs are typically used for low-volume, high-value transactions, and their purpose is to reduce credit risks due to settlement lags. These systems exhibit an inherent trade-off. On the one hand, they reduce information asymmetries by providing an accurate picture of an institution's account at any point in time, thus lowering settlement risk. On the other, they require large amounts of liquidity in the system to work properly, which may be a major shortcoming in markets facing liquidity shocks.

One potential alternative to the RTGS is the Automated Clearing House (ACH), an electronic system for processing transactions between participating financial institutions. Different from the RTGS, this system may require longer settlement periods and can entail significant credit and systemic risk, for example, when a party cannot settle its debt. Its advantage is that banks still benefit from having the 'float' while payments are clearing. ACHs are widespread in high-income countries, but their adoption is low and less frequent than the RTGSs in sub-Saharan Africa. Following the statistics in the Global Payment Systems Survey 2010 of the World Bank, ACHs are used in 38% of surveyed countries, whereas the RTGS is used in more than 71% of the countries (World Bank (2013)).

The prevalence of RTGSs in Africa is motivated by the importance of settlement risk in interbank markets, which the real-time component of the system helps to alleviate. Another advantage of the RTGS, compared to alternative settlement methods, is that it promotes a more liquid and deeper banking system. As World Bank (2013) (p. 23) indicates, 'in 80 out of 94 systems, participants can mobilise their reserve requirements either fully or partially during the operating day as an important source of liquidity'. Furthermore, central banks also take action through the RTGS by using the platform together with their traditional tools (discount window facilities, for instance). Indeed, 'the vast majority of RTGSs rely on the central bank providing some form of credit, either in the form of a loan or repo (76%), or collateralized account overdrafts (22%)' (p. 25).

RTGSs are seen in favourable light by institutions and practitioners in Africa. The adoption of real-time interbank systems is considered a necessary condition for the development of fast and instant payment networks (Bank for International Settlements (2021)) as well as being

related to more advanced and efficient interbank markets.[10] [11] For these reasons, RTGSs have often been promoted by transnationals economic unions like the Southern African Development Community, the West African Economic and Monetary Union, and the Economic Community of Central African States. At the same time, individual countries and national central banks have invested in RTGSs to reduce credit risk and deepen the access of domestic banks to liquidity markets.

There are multiple channels through which fast internet has affected the supply of credit by African banks in the last 20 years.[12] In Section 3, when characterising our main results, we concentrate on the adoption of RTGSs and the resulting change in individual banks' liquidity management. While we acknowledge that this is only one of the possible mechanisms, we provide robust evidence on the relevance of this channel and show that reduced transactions costs in the interbank market positively affect credit supply.

2.3 Data and descriptive statistics

In the first part of our analysis, we focus on the effects of high-speed internet on banking. The main data sources are Bankscope and BankFocus from Bureau van Dijk. These databases contain financial variables and finance reports for about 30,000 public and private banks across the globe. We employ data from Bankscope until 2013, its last year of operations, integrated with data from BankFocus, which allow us to extend the sample up to 2018. We use Bankscope and BankFocus to construct the main dependent variables and some of the control variables that we use in the robustness section.[13]

We complement bank-level data with hand-collected country-level data for fibre-optic submarine cables. Our main source is TeleGeography maps, a telecommunications market research and consulting firm providing data on the telecom industry since 1989. TeleGeography provides

[10] Note that the 24 principles for financial market infrastructures published in April 2012 by the Committee on Payment and Settlement System and the Technical Committee of the International Organisation of Securities Commission emphasise final settlement in central bank money, in real time, as the new global standard.

[11] RTGS systems have become crucial infrastructures in the modern financial system. In 2014, during the Second Libyan Civil War, the Government of National Accord, through the central bank based in Tripoli, disconnected its two eastern branches from its automated clearing system, the RTGS. The eastern branches were under the competing faction's control, the Libyan National Army of General Khalīfa Belqāsim Haftar, and this move had the specific aim to prevent eastern-based authorities from accessing government accounts and funds and to limit their access to finance.

[12] As suggested by an anonymous referee, another important role of fast internet has been to lower the cost of servicing deposit accounts.

[13] Our data have been homogenised following the routine by Duprey et al. (2016).

general information about the fibre cables—name, total length, owners (generally a consortium of public and private companies), list of landing points (country and landing location) and year from which the cable is ready to serve (RTS). Moreover, it supplies the shapefiles of the worldwide submarine cable network, which we use to generate our maps.

To construct the main predictor at the headquarter level, we extract information from the CvH database on bank ownership (Claessens and Van Horen (2015)) and complement it with information from individual bank's reports. The CvH database contains full ownership information for the period 1995–2013 for most of the commercial banks included in our sample. We extend the panel until 2018 by hand-collecting the remaining information.

As a last step, we combine our main dataset with two ancillary sources from the World Bank—the World Bank Global Financial Development Database (WB GFDD) and the World Bank Worldwide Governance Indicators (WB WGI). The WB GFDD is an extensive dataset of financial system characteristics for 214 economies, capturing various aspects of financial institutions and markets. The WB WGI contains aggregate and individual governance indicators for over 200 countries and territories over the period 1996–2018, for six dimensions of governance. We use both the datasets to retrieve control variables at the country level.

In the second part of our analysis, we focus on a specific mechanism that can partly explain the effect of high-speed internet on bank credit supply: an improvement in the functioning of interbank markets due to the adoption of real-time technologies. In addition to the datasets already mentioned, and to show the positive relationship between fast internet and the adoption of RTGS at the country and bank level, we extract information from central banks websites and individual bank reports. The RTGS adoption year at the country level is generally public information, released by central banks and telecommunication authorities. In building our bank-level dataset, we join this country-level information with specific information on banks from their annual reports. Unless otherwise stated, banks are assumed to join the RTGS upon connectivity at the country level; however, this involves a minor share of banks in our sample. In most cases, the annual reports specify that banks adopt the RTGS either in the following year or after a couple of years.

In the third part of our analysis, we focus on the real effects of having access to high-speed internet. We use part of the data collected for the banking analysis, combined with

information on firm's characteristics, business activity, and funding, from the World Bank Enterprise Survey (WB ES). The WB ES offers an array of economic data for 164,000 firms in 144 countries gathered through different surveys. For the purpose of this paper, we focus on surveys conducted in African coastal countries during the period 2002–2018.

Our final dataset includes 629 banks, located in more than 90 cities, distributed among 37 coastal countries in Africa, during the period 1997–2018.[14] Our firm dataset includes 32,761 firms in 31 African countries. The countries are all coastal, and the amount of firms participating in the surveys is well distributed.[15]

For each country, we use the arrival of the first fibre-optic submarine cable to proxy for the positive technological shock generated by access to high-speed internet. Then, when narrowing the analysis to interbank markets, we interpret the connection to high-speed internet as a negative shock on interbank transaction costs. We assume that once the cable lands in a country, banks in the sample are automatically connected. This assumption is motivated by two facts. First, banks in our sample are typically located in capital cities, which are usually the places receiving high-speed internet first. Second, among companies, banks are likely to be early adopters since new technologies are generally associated with sizeable profits, as discussed by Hannan and McDowell (1984) and Frame et al. (2014).

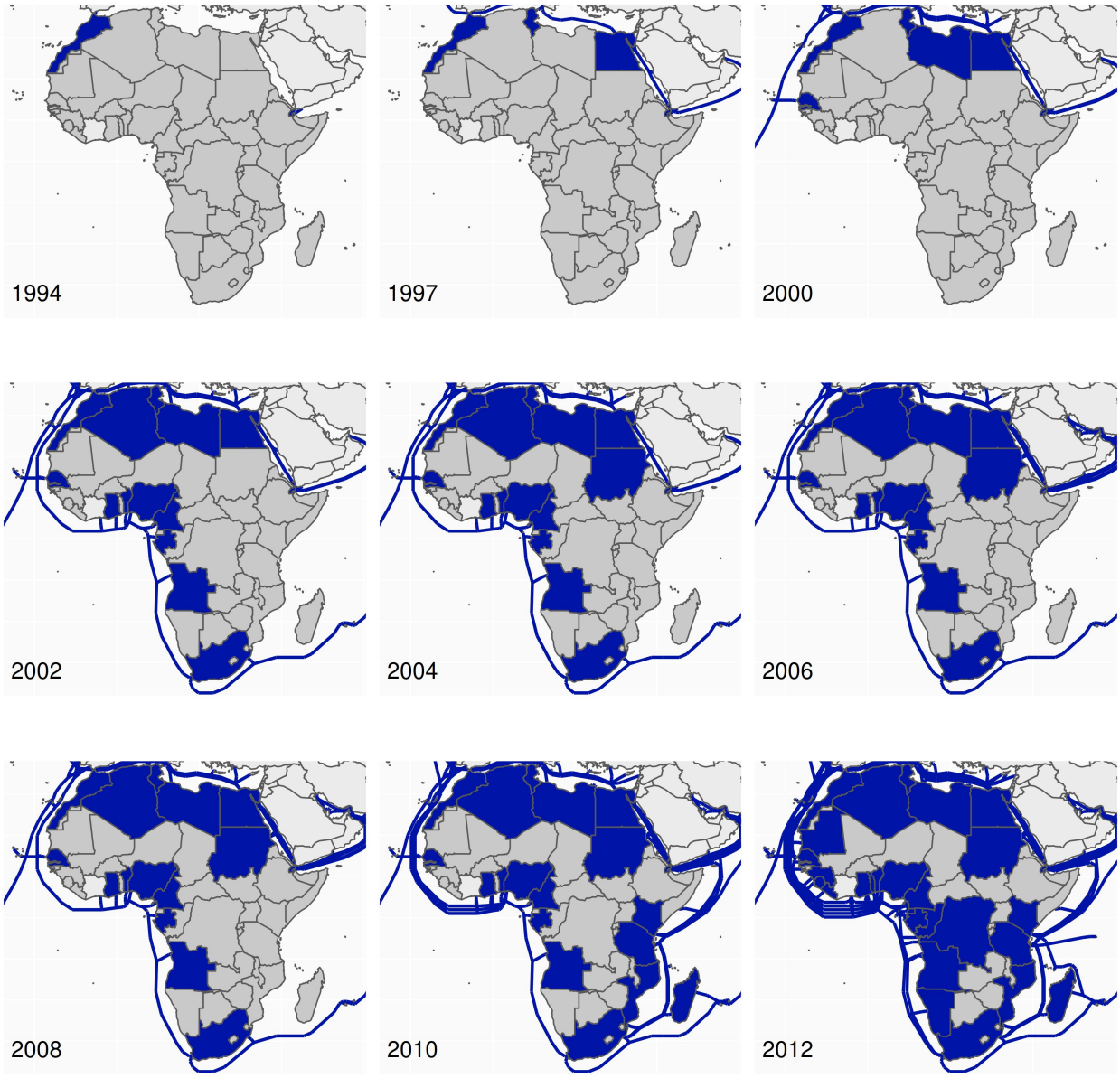
The arrival of fibre-optic submarine cables in Africa has been staggered over time, with years of arrival spanning from 1994 to 2013.[16] Figure 3 provides a graphical representation.

[14] We focus on coastal countries because for those that are landlocked it is not clear whether (and when) terrestrial connections have made available the access to the fibre-optic technology.

[15] There are only a few exceptions such as Egypt-2013 and Nigeria-2014. Together, those two surveys account for 20% of our observations.

[16] Appendix A provides a table in which, for all coastal countries in Africa, we show the name of the first submarine cable landed and the month and year from which that cable was RTS.

Figure 3: The Arrival of High-Speed Internet in Africa



Notes: This figure shows the gradual arrival of submarine fibre-optic cables in Africa. In our analysis, we focus on first connections. Data are from Telegeography maps, available online. The top panel refers to cables ready to serve during the 90s, from 1994, when the first cables connected Morocco and Djibouti, to 2000. The middle panel shows the progressive connection to high-speed internet at the beginning of the 21st century. The left panel shows the cables ready to serve in 2002. In the centre are those ready to serve in 2004. Finally, on the right are cables ready to serve in 2006. The bottom panel refers to the last stage of first connections. On the left are cables ready to serve in 2008, and in the middle are cables ready to serve in 2010. Finally, on the right are cables ready to serve in 2012, which is also the last year in which countries in our sample receive connection. The group of treated African coastal countries is reported in dark blue.

To evaluate the effects of the new technology on banking, we focus on the following dependent variables: *Loans*, which proxies for credit to the private sector; *Government*, which indicates how much is invested in government securities; *Deposits*, which indicates customer deposits; and *Equity/Deposits and short-term funding*,[17] which shows the share of equity over

[17]We trim the bottom 2% of *Loans* and 1% of *Government* securities and *Deposits* to mitigate the effects of outliers. Similarly, we trim *Equity/Deposits and short-term funding* at the first and last percentile.

deposits. To highlight that more efficient interbank markets can potentially explain the positive effect of fast internet on banking, we study *RTGS* country (bank), which indicates whether the country (bank) adopts a RTGS; *Loans to banks* and *Deposits from banks*,[18] which proxy for the liquidity of the interbank market; and *Liquid Assets/Deposits and short-term funding*, which proxies for the bank holding of liquid assets. Finally, to assess the effects of high-speed internet on firms' credit and business activity, we define *Access to Finance*, a dummy variable that shows whether the firm considers access to finance to be an issue; *Loans from Banks*, which is whether the firm has issued at least one loan with a commercial bank in the last fiscal year; *Loan Maturity*, the term, in months, of loans from banks; *Sales*, the amount of total annual sales; and *Workforce*, the number of permanent and temporary full-time employees.[19]

As the main predictor in our analyses, we use a dummy, *Submarine*, that is a binary variable for the arrival of the fibre-optic submarine cable in the country (in the country of the headquarter when we isolate the effect on supply). This dummy takes a value of 0 before the cable arrived and 1 from the time of its arrival onward. In some of our specifications, we also refine this variable to check for bank and country heterogeneity. In the analysis at the bank level, we concentrate on $Submarine \times Weak\ User$, namely the interaction between *Submarine* and a dummy variable that specifies whether the bank was below the median of interbank volumes in the country before the cable's arrival. In the analysis of firm outcomes, we concentrate on $Submarine \times Weak\ Interbank$, where the latter represents the interaction between *Submarine* and a dummy that specifies whether the country was below the median of interbank volumes before the cable's arrival.

Table 1 provides summary statistics for both dependent (banks' and firm's) and independent variables. Column 1 refers to the number of observations. Columns 2 and 3 refer to mean and standard deviation. Finally, columns 4 to 6 show the 50th, 5th and 95th percentile.

[18] *Deposits from banks* are trimmed at the first percentile.

[19] *Sales* and *Workforce* are trimmed to remove the bottom 1% and the top 5%–1%, respectively. We trim the latter to avoid outliers that could drive the results. Moreover, *Workforce* only considers firms with at least five employees.

Table 1: Summary Statistics

Variables	(1) Obs.	(2) Mean	(3) Std. Dev.	(4) Median	(5) 5th P.tile	(6) 95th P.tile
	Panel A. Dependent variables: Banks (1997-2018)					
Loans	6,519	5.12	1.90	4.99	2.16	8.37
Government	3,680	3.89	2.33	3.90	0.24	7.57
Deposits	6,501	5.54	1.90	5.43	2.58	8.80
Equity/Dep. & ST	6,552	0.20	0.23	0.14	0.05	0.54
RTGS Bank	10,569	0.53	0.50	1	0	1
Loans to Banks	6,344	3.77	2.05	3.84	0.50	7.19
Deposits from Banks	4,931	2.99	2.36	3.09	-1.13	6.74
Liquid Assets/dep. & ST	6,674	0.46	0.46	0.37	0.09	0.99
	Panel B. Dependent variables: Firms (2002-2018)					
Access to Finance	25389	0.64	0.48	1	0	1
Loans from Banks	27863	0.19	0.39	0	0	1
Loan Maturity	2694	3.25	1.07	3.58	1.10	4.68
Sales	22,856	-2.00	2.29	-2.14	-5.64	2.05
Workforce	26,981	3.11	1.28	2.83	1.61	5.66
	Panel C. Independent variables					
Sample of Banks:	6,776					
Submarine	6,776	0.72	0.45	1	0	1
Submarine × Weak User	4,170	0.25	0.43	0	0	1
Sample of Firms:	32,761					
Submarine	32,761	0.84	0.36	1	0	1
Submarine × Weak Interbank	32,495	0.26	0.44	0	0	1

Notes: This table reports the summary statistics for our main dependent and independent variables. Panel A shows statistics for the dependent variables related to banks indicators: *Loans* (natural logarithm of net loans (in millions of US dollars)), *Government* (natural logarithm of government securities (in millions of US dollars)), *Deposits* (natural logarithm of customer deposits (in millions of US dollars)), *Equity* (share of total equity over deposits and short-term funding) and *RTGS bank* (dummy variable, where 1 indicates the bank's participation to the RTGS). The higher number of observations is explained by the fact that we consider a balanced panel 1997–2018; *Loans to Banks* (natural logarithm of loans to banks (in millions of US dollars)), *Deposits from Banks* (natural logarithm of loans to banks (in millions of US dollars)) and *Liquid Assets over DST* (share of liquid assets over deposits and short-term funding). Panel B shows statistics for the dependent variables related to firms indicators: *Access to Finance* (dummy variable, where 1 indicates easy access to finance), *Loans from Banks* (dummy variable, where 1 indicates at least one loan from a commercial bank), *Loan Maturity* (natural logarithm of the term, in months, of loans from banks), *Sales* (natural logarithm of total annual sales) and *Workforce* (natural logarithm of the number of permanent and temporary full-time employees). Panel C focuses on the main predictors. In both the analysis, on banks and firms, we have *Submarine*, a binary variable for the arrival of the fibre-optic submarine cable in a country. This dummy takes a value of zero before the cable's arrival and 1 from the time of its arrival onward. In the banking analysis, we also have *Submarine* × *Weak User*, the interaction between the dummy submarine and a dummy that specifies whether the bank was below the median of interbank volumes in the country before the cable's arrival. Finally, in the firm's analysis, we have *Submarine* × *Weak Interbank*, the interaction between the dummy submarine and a dummy that specifies whether the country was below the median of interbank value of transactions before the cable's arrival. Column 1 refers to the number of observations. Columns 2 and 3 refer to the mean and the standard deviation. Columns 4, 5 and 6, refer to the 50th, 5th and 95th percentiles, respectively.

2.4 Empirical methodology

Our empirical strategy relies on four different specifications. First, we develop an event study design meant to test for pre-trends and to investigate the dynamics of the treatment effect. Second, we implement a staggered difference-in-difference specification using two-way fixed effects regressions. The staggered difference-in-difference provides compact estimates of the average treatment effect under the assumptions of no pre-trends. Third, we offer a specific test to identify the existence of a distinct supply effect by focusing on multi-country banks. Fourth, we refine our analysis with the inclusion of a bank-specific (or country-specific, in the case of firm analysis) heterogeneity, being a (pre-) weak user of the interbank market. In the last cases, we also augment our specifications with the inclusion of country-by-year fixed effects, which factor out the confounding effects associated with domestic unobservable variables. The next paragraphs provide a detailed description of each of the aforementioned approaches.

The first specification that we propose is an event study based on the fibre-optic submarine cable's year of arrival. The event study allows us to check for pre-trends and, to a lesser extent, to provide evidence on the dynamics of the treatment effect. The empirical specification is as follows:

$$Y_{ict} = \alpha_i + \beta_t + \gamma_{-5} I\left\{K_{ct} \leq -5\right\} + \sum_{k=-4}^{4} \gamma_K I\left\{K_{ct} = k\right\} + \gamma_{5+} I\left\{K_{ct} \geq 5\right\} + \varepsilon_{ict}, \qquad (1)$$

where Y_{ict} represents the dependent variable[20] for bank i in country c at time t; α_i and β_t are bank and year fixed effects; K_{ct} is the relative year from the activation of the cable (ACT_c), $K_{ct} = t - ACT_c$; γ_{-5} is the single coefficient for far leads; and γ_{5+} is the single coefficient for longer-run effects.

[20]For the first part of the analysis, the dependent variables are the following: *Loans* (natural logarithm of net loans (in millions of US dollars)), *Government* (natural logarithm of government securities (in millions of US dollars)), *Deposits* (natural logarithm of customer deposits (in millions of US dollars)) and *Equity* (share of total equity over deposits and short-term funding). For the second part of the analysis, the dependent variables are *RTGS* (dummy variable for the presence of a RTGS in the interbank market), *Liquid Assets over DST* (share of liquid assets over deposits and short-term funding), *Loans to Banks* (natural logarithm of loans to banks (in millions of US dollars)) and *Deposits from Banks* (natural logarithm of loans to banks (in million of US dollars)).

We use the event study only for banking variables. The observation window is 1997–2018, while we restrict the event window to be the interval [-5;+5] from the year of the cable's arrival.[21] We assign a value of 1 to the dummies that are at the extremes of the event window, where $-5 \geq K_{ct} \geq 5$, and set the year before the cable's arrival as the baseline category, as is standard in the literature.

The second specification is a canonical (two-way fixed effects) staggered difference-in-difference regression. We use this specification to study the effects of fast internet on banking and firm outcomes. Compared to the dynamic specification, it imposes no pre-trends. The staggered difference-in-difference provides a compact measure of the average causal effect of fibre-optic technology on our dependent variables. The empirical specification is as follows:

$$Y_{ict} = \alpha_{i(c)} + \beta_t + \gamma D_{ct} + \varepsilon_{ict}, \tag{2}$$

where Y_{ict} represents the dependent variable, for bank (firm) i in country c at time t; $\alpha_{i(c)}$ and β_t are bank (country) and year fixed effects; and D_{ct} is a dummy variable that equals one after the arrival of the first submarine cable in country c and zero before.[22]

The third specification that we propose is meant to isolate the effect of supply from that of demand (where the former is partly induced by lower marginal costs in the interbank market). To identify the supply effect, we exploit the presence of multi-country banks and define high-speed internet connectedness at the level of the bank headquarter, moving from D_{ct} to D_{gt}. The advantage of this specification is that banks can be connected to fast internet because the group to which they belong is connected independently from their country being reached by the fibre-optic cable. The empirical specification is as follows:

$$Y_{igct} = \alpha_i + \beta_t + \sigma_{ct} + \gamma D_{gt} + \varepsilon_{igct}, \tag{3}$$

where Y_{igct} represents the dependent variable for bank i belonging to group g in country c at time t; α_i and β_t are bank and year fixed effects; and D_{gt} is a dummy variable equal to one after the arrival of the first submarine cable in the headquarters' country. In this setting, γ captures

[21] We try this with different specifications of the event window, and the results are particularly stable (see Appendix Figures C1a and C1b for the three-year window).

[22] Firm-level regressions also controls for firm sector and size. Furthermore, these regressions use probability weights based on the WB ES re-scaled weights.

the average effect of fast internet on bank i, when the headquarter of group g, regardless of the country, receives high-speed internet. To specifically account for country time-varying unobservables, we also include country-by-year fixed effects, σ_{ct}.

Finally, the fourth specification is a modified version of the staggered difference-in-difference regression in equation (2), which allows for the inclusion of a specific heterogeneity. We test the basic idea that the magnitude of the effect of the technology shock depends on the bank's relative decline of transaction costs in interbank transactions. In particular, banks that had higher transaction costs before the arrival of high-speed internet were the ones most exposed to the shock. With that purpose in mind, we define an indicator of (pre-) weak users that takes a value of 1 if the bank was below the median of interbank volumes in the country before the arrival of high-speed internet and zero otherwise.[23] Similarly, when dealing with the firm analysis, we define an indicator of weak interbank markets that takes a value of 1 if the country amount of interbank transactions before the arrival of high-speed internet was below the median and zero otherwise. Then, we implement the following empirical specification:

$$Y_{ict} = \alpha_{i(c)} + \beta_t + \gamma_1 D_{ct} \times X_{i(c)} + \gamma_2 D_{ct} + \varepsilon_{ict}, \tag{4}$$

where Y_{ict} represents the dependent variable for bank (firm) i in country c at time t; $\alpha_{i(c)}$ and β_t are bank (country) and year fixed effects; D_{ct} is a dummy variable equal to one after the arrival of the first submarine cable in country c; and $X_{i(c)}$ is the bank (country) specific heterogeneity. Notice that the presence of the dummy D_{ct} and its interaction with $X_{i(c)}$ is not coupled by the inclusion of $X_{i(c)}$ alone since the latter is absorbed by bank (or country) fixed effects. We also strengthen our findings for banking outcomes by augmenting equation (4) with the inclusion of country-by-year fixed effects, σ_{ct}.

3 Results

Following the structure of the paper, this section is divided into three subsections. In the first subsection, we study the effect of high-speed internet on banking and isolate its supply-driven

[23] Following this definition, the subsample of banks considered in equation (4) excludes those for which data previous to the cable arrival are not available. Additionally, our measure of weak user only considers data in the five years before the cable's arrival.

component. The second subsection identifies a specific mechanism whereby the effect of fast internet on banking is partly due to more liquid interbank markets. In the third and final subsection, we study the real effects on firms' outcomes.

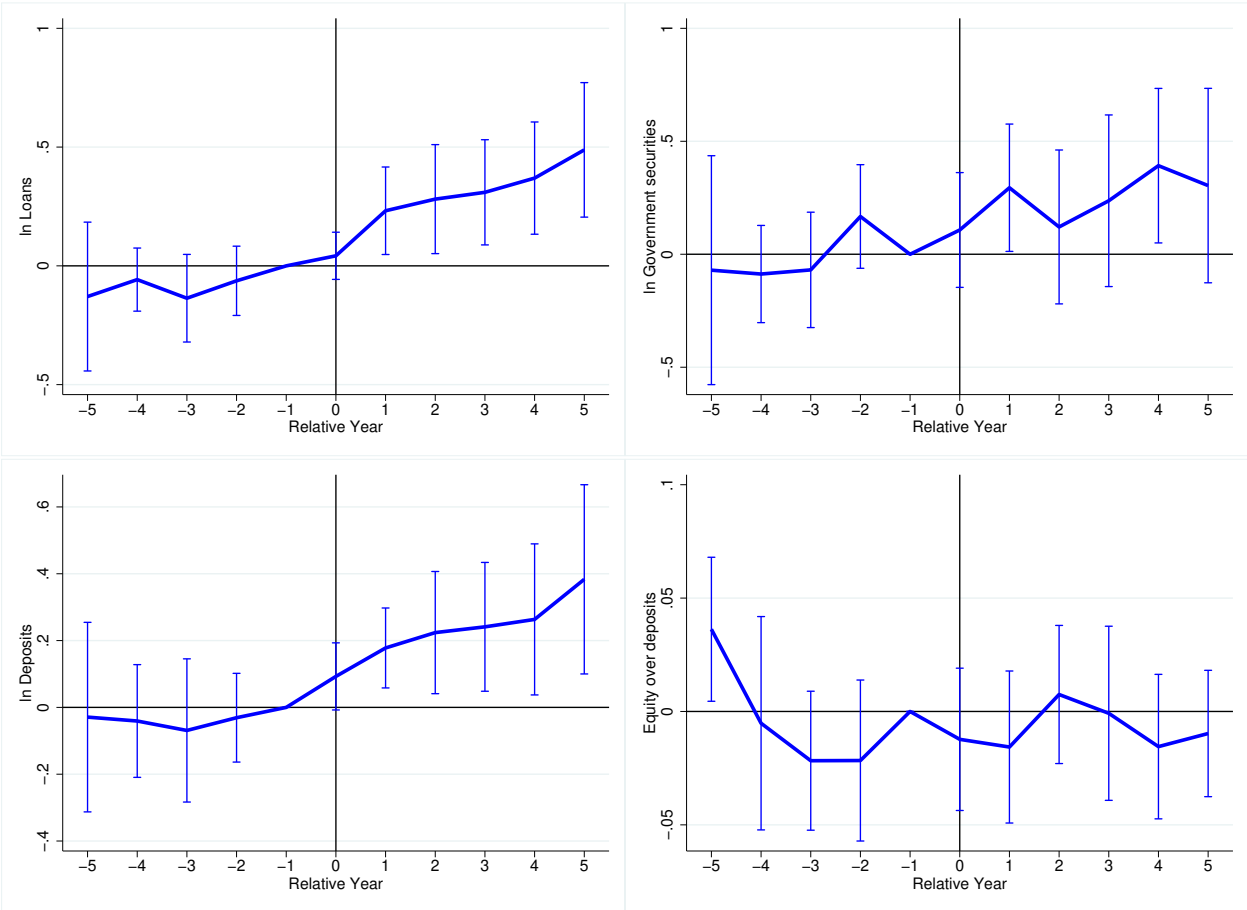
3.1 Banking

We exploit the staggered arrival of fibre-optic submarine cables on the African coast to show the effect of high-speed internet on four dependent variables: *Loans*, the natural logarithm of net loans, which proxies for bank credit to the private sector; *Government*, the natural logarithm of government securities, which quantifies the investments of banks in government bonds; *Deposits*, the natural logarithm of bank customer deposits; and *Equity/Deposits and short-term funding*, which measures the amount of shareholder equity over bank deposits.

The first exercise that we propose is the event study as defined in equation (1). The results are reported in Figure 4. The top-left panel refers to bank loans and shows no pre-trends; i.e., before the cable's arrival, the point estimates are close to zero, and none of them are statistically significant. However, the coefficients become positive and statistically significant after the arrival. In particular, we observe a small jump at year zero, followed by a sizeable and gradual increase after year one. The top-right panel refers to the investments in government securities. Similar to before, no pre-trends can be detected and the coefficients are positive and stable after year one, even though none of them are statistically different from zero.[24] The bottom-left panel refers to deposits. The pattern is very similar to that of loans—no pre-trends and a gradual increase after the arrival of the fibre-optic cable but with lower magnitudes. Finally, the bottom-right panel refers to the share of equity over deposits. Interestingly, the increase in deposits is perfectly paralleled by an equivalent increase in total equity.

[24]The analysis of these coefficients may be informative of the fact that part of the new credit granted by banks is directed to profitable (riskier) investments.

Figure 4: Event Study: High-Speed Internet and Banking



Notes: This figure shows the event study for the period five years before to five years after the arrival of the first submarine cable in country c. The y-axis reports the coefficients for the dependent variables: *ln Loans* (the natural logarithm of net loans (in millions of US dollars)), *ln Government securities* (the natural logarithm of government securities (in millions of US dollars)), *ln Deposits* (the natural logarithm of customer deposits (in millions of US dollars)) and *Equity over DST* (the share of total equity over deposits and short-term funding). The x-axis reports the relative time from the cable's arrival. The blue (solid) line connects point estimates relative to the base year (-1). Standard errors are clustered at country level, and 95% confidence intervals are reported.

Table 2 reports the estimates from the staggered difference-in-difference specification as defined in equation (2). This two-way fixed effects regression provides a compact measure of the average causal effect of high-speed internet on our four banking outcomes. It imposes no pre-trends[25] and assumes constant treatment effects. The results from Table 2 confirm those from the event studies. Connection to the fibre-optic cable is associated with a significant increase in loans and deposits, while the coefficients associated with government securities and the share of equity over deposits are not statistically different from zero. The estimates for loans and deposits are also large in magnitude: having access to high-speed internet increases the amount of loans issued by 36% and deposits and short-term funding collected by 25%.[26]

[25] This justifies the order of our results. We present the event study before the staggered difference-in-difference to graphically show the lack of pre-trends.

[26] As already mentioned, our coefficients are on the conservative side among those presented in the literature on the economic effects of fast internet.

Table 2: High-Speed Internet and Banking

Variables	(1) Loans ln	(2) Government ln	(3) Deposits ln	(4) Equity over DST
$Submarine_{ct}$	0.312**	0.234	0.223**	-0.007
	(0.117)	(0.145)	(0.087)	(0.012)
Bank FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs.	6,483	3,593	6,469	6,518
Adj. R sq.	0.898	0.822	0.909	0.575
MDV	5.131	4.001	5.551	0.196
SDDV	1.891	2.167	1.897	0.225

Notes: This table reports estimates from the staggered difference-in-difference design presented in equation (2). The dependent variables are as follows: *Loans* (natural logarithm of net loans (in millions of US dollars)), *Government* (natural logarithm of government securities (in millions of US dollars)), *Deposits* (natural logarithm of customer deposits (in millions of US dollars)) and *Equity* (share of total equity over deposits and short-term funding). The main predictor is $Submarine_{ct}$, a binary variable for the arrival of the first fibre-optic submarine cable in the country. This dummy takes a value of zero before the cable's arrival and 1 from the time of the arrival onward. Obs. refers to the number of observations, Adj.R^2 is the adjusted R^2, MDV refers to the dependent variable's mean and SDDV refers to its standard deviation. Fixed effects are at the bank and year level. Standard errors are in parentheses, clustered at country level. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

The results from Figure 4 and Table 2 are among the key findings of this paper. They show the effect of high-speed internet on banking in Africa, emphasising the increase in credit associated with the technological shock. However, these specifications do not help to distinguish between the demand- and supply-driven component of the aggregate effect. As well as providing direct benefits to banks along several dimensions, high-speed internet helps to increase firms' productivity and production efficiency (Akerman et al. (2015), Hjort and Poulsen (2019)), thus boosting their demand for credit. To go a step forward, we next present a tailored exercise that aims to isolate the supply channel.

We exploit information on the multi-national bank-group composition of banks in our sample to construct a proxy of the cable connection at the headquarter level. For banks belonging to multi-country groups, high-speed internet may be directly available for the headquarter but not for the subsidiary located in a different country. In this way, we make use of a source of exogenous variation, the arrival of fast internet in the headquarters' country, immune from domestic demand factors. Using bank headquarters to identify effects on foreign branches is in line with Detragiache et al. (2008) and Cetorelli and Goldberg (2012), and in particular with Xu (2022), who offers evidence on the ability of multi-national bank networks to transmit shocks across countries.

Multi-country banks are common in our sample. Of the 629 banks, 37% have their headquarter located in another country, and 88% get connected in a year different from that of the headquarter. Multi-country banks have also similar characteristics with respect to single-country banks. We show this in Appendix Table A3, where we report a balanced table for single- versus multi-country banks, with values referring to the year before the arrival of high-speed internet.

Appendix Figure B1 and Table B3 report the results from the event study and the staggered difference-in-difference as in equation (3). Here, the connection of the headquarter, $Submarine_{gt}$, is used as the main predictor. This variable is a dummy that takes a value of 1 when the country of the headquarter is connected and zero otherwise.[27] The estimates are in line with those in Figure 4 and Table 2.

In this setting, the demand-side effects are alleviated but not eliminated. To fully control for credit demand, we proceed in two steps. First, we replicate the specification in equation (3) but use $Submarine_{ct}$ and $Submarine_{gt}$ as predictors. Table 3 reports the main results and is suggestive of a separate effect coming from the supply side.[28] Second, and most importantly, we augment the specification in equation (3) with the inclusion of country-by-year fixed effects, which directly absorb time-varying demand factors. The results are reported in Table 4 and provide robust evidence on the existence of a separate supply channel behind the overall effect of high-speed internet on banking.

[27]Notice that when the bank does not belong to an international group, the country of the headquarter corresponds to the country of the bank itself.

[28]In case the two variables were perfectly collinear, the coefficients associated with $Submarine_{ct}$ and $Submarine_{gt}$ would tend to abnormal numbers. In case only demand mattered, the coefficients associated with $Submarine_{gt}$ would not be statistically different from zero.

Table 3: High-Speed Internet and Banking: Demand and Supply

Variables	(1) Loans ln	(2) Government ln	(3) Deposits ln	(4) Equity over DST
$Submarine_{ct}$	0.132*	-0.028	0.065	-0.019
	(0.073)	(0.122)	(0.068)	(0.014)
$Submarine_{gt}$	0.309***	0.411***	0.274***	0.020
	(0.076)	(0.126)	(0.069)	(0.015)
Bank FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs.	6,483	3,593	6,469	6,518
Adj. R sq.	0.900	0.824	0.909	0.576
MDDV	5.131	4.001	5.551	0.196
SDDV	1.891	2.167	1.897	0.225

Notes: This table reports estimates from the staggered difference-in-difference design presented in equation (2). The dependent variables are as follows: *Loans* (natural logarithm of net loans (in millions of US dollars)), *Government* (natural logarithm of government securities (in millions of US dollars)), *Deposits* (natural logarithm of customer deposits (in millions of US dollars)) and *Equity* (share of total equity over deposits and short-term funding). The main predictors are $Submarine_{ct}$, a binary variable for the arrival of the first fibre-optic submarine cable in the country, and $Submarine_{gt}$, a binary variable for the arrival of the first fibre-optic submarine cable in the country of the headquarter. These dummies take a value of zero before the cable's arrival and 1 from the time of the arrival onward. Obs. refers to the number of observations, Adj.R^2 is the adjusted R^2, MDV refers to the dependent variable's mean and SDDV refers to the its standard deviation. Fixed effects are at the bank and year level. Standard errors are in parentheses, clustered at the bank level. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

These numbers allows us to present a back-of-the-envelope calculation to quantitatively assess how much high-speed internet promoted credit supply. Comparing Tables B3 and 4, we find that 62% of the effect of fast internet on bank loans is unrelated to demand factors. Rather, it is driven by credit supply. Hence, of the total increase of 36% in loans to the private sector (see 2), 22% is due to supply and 14% stems from increasing demand. Considering the median bank, which issues 147 million US$ in private loans, the effect of having access to high-speed internet is an increase by 53 million (36%), of which 33 million (62%) is due to supply and 20 million is associated with a rise in credit demand. This finding has important implications for the policy debate over government investments in broadband infrastructures. Our results suggest that investing in new technologies stimulates banks efficiency and promotes the supply of credit to the private sector.

Table 4: High-Speed Internet and Banking: Supply

Variables	(1) Loans ln	(2) Government ln	(3) Deposits ln	(4) Equity over DST
$Submarine_{gt}$	0.241**	0.248**	0.257***	0.016
	(0.090)	(0.093)	(0.066)	(0.018)
Bank FE	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes
Obs.	6,418	3,504	6,404	6,454
Adj. R sq.	0.920	0.845	0.923	0.581
MDDV	5.143	4.044	5.561	0.197
SDDV	1.894	2.148	1.899	0.225

Notes: This table reports estimates from the staggered difference-in-difference design presented in equation (2). The dependent variables are as follows: *Loans* (natural logarithm of net loans (in millions of US dollars)), *Government* (natural logarithm of government securities (in millions of US dollars)), *Deposits* (natural logarithm of customer deposits (in millions of US dollars)) and *Equity* (share of total equity over deposits and short-term funding). The main predictor is $Submarine_{gt}$, a binary variable for the arrival of the first fibre-optic submarine cable in the headquarters' country. This dummy takes a value of zero before the cable's arrival and 1 from the time of the arrival onward. Obs. refers to the number of observations, Adj.R^2 is the adjusted R^2, MDV refers to dependent variable's mean and SDDV refers to the its standard deviation. Fixed effects are at the bank- and country-by-year level. Standard errors are in parentheses, clustered at the country level. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

The supply-driven effect of high-speed internet on credit in Africa is a core finding of this paper. In the next section, we provide supportive evidence on the existence of a specific mechanism associated with the development of domestic interbank markets.[29]

3.2 The role of interbank markets

The previous section shows how being connected to fast internet affects banking outcomes. In the last paragraphs, we document the existence of a separate supply channel and quantify its magnitudes. Here, we offer a foundation behind this channel and provide empirical evidence in favour of one specific mechanism: the increase in interbank market liquidity.

We propose three pieces of evidence to corroborate our hypothesis. First, we show that being connected to a fibre-optic submarine cable has a positive effect on the probability that countries adopt an RTGS and that banks within countries take part in these systems. Second, we show that high-speed internet positively affects the amount of loans to banks and deposits from banks, simultaneously reducing the dependence of African banks on hoarding liquid assets.

[29]The improved liquidity management through interbank markets is one of the mechanisms behind the effect of fast internet on banking. In Africa, we claim this mechanism to be first order. On the other hand, we acknowledge the importance of internet technologies in modifying other dimensions of credit supply. In particular, the literature provides evidence that broadband internet produces beneficial effects on bank lending by reducing communication costs and alleviating asymmetric information (D'Andrea et al. (2021)).

Finally, we show that these effects are larger for banks that were weak users of the interbank market before the cable's arrival (see Section 3.2.1).

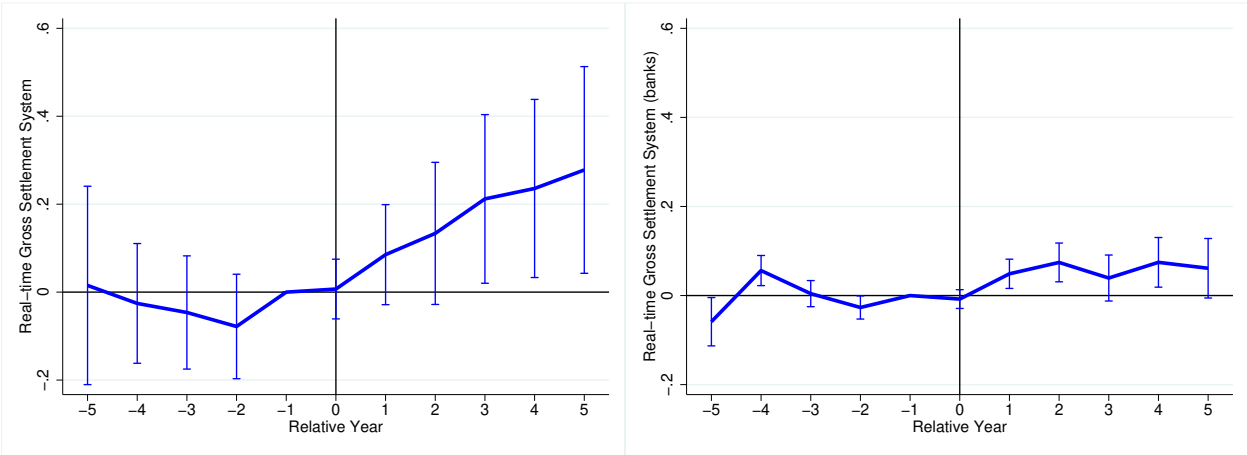
In this section, all of our dependent variables and the main predictor are at the country level. The latter is because the adoption of an RTGS is mostly a country-level phenomenon, with central banks leading the platform's introduction and promotion (World Bank (2013), Bank for International Settlements (2021)).[30] Commercial banks can decide whether to join the RTGS and become part of the network but only once the network has been created at the central level. Alternatively, they continue operating outside the platform by relying on alternative systems of interbank payments, such as the ACH system. Furthermore, interbank markets are generally domestic, with relatively weak cross-country transactions occurring in common currency areas.[31]

We start by considering the adoption of the RTGS. The left panel of Figure 5 plots the event study for RTGS adoption, where the x-axis refers to the relative year of the cable's arrival and the y-axis is the probability that the country adopts the RTGS. The right panel plots the same event study but at the bank level, distinguishing between banks that participate in the real-time system and those that do not. Two things are worth noting. First, coefficients in the left panel are positive and monotonically increasing after the cable arrival, underlining a positive relationship between being connected to high-speed internet and country adoption of RTGS. This is in line with Augereau and Greenstein (2001), Bech and Hobijn (2006) and our hypothesis that internet speed and connection reliability foster the take-up of financial technologies. Second, this positive relationship is confirmed for individual banks. The fact that the coefficients at the country level are larger in magnitude with respect to the coefficients at the bank level clarifies that not necessarily all the banks adopt RTGS when it is available. The latter is in line with what we know about the US interbank market and Fedwire adoption.

[30] Bech and Hobijn (2006) find that domestic real GDP growth, cost of capital and trade patterns are key variables motivating the choice of central banks to adopt the RTGS.

[31] As discussed by Raga and Tyson (2021), African interbank markets are severely segmented, with rates and amounts that are heterogeneous depending on market participants, levels of perceived risk and trust among participants (Allen et al. (2022)).

Figure 5: Event Study: High-Speed Internet and RTGS Adoption



Notes: This figure shows the event study for the period five years before to five years after the arrival of the first submarine cable in country c. The y-axis reports coefficients for the dependent variables: *RTGS* (Real-time Gross Settlement System) and *RTGS bank* (RTGS adoption for the single bank). The x-axis refers to the relative time from the cable's arrival. The blue (solid) line connects point estimates relative to the base year (–1). Standard errors are clustered at the country (bank) level, and 95% confidence intervals are also reported.

Table 5 presents compact estimates from the staggered difference-in-difference specification as defined in equation (2). Column 1 refers to the probability of adopting the RTGS at the country level, column 2 reports the number of banks participating in the RTGS, and column 3 shows the probability of individual banks joining the platform. Consistent with the event studies, the coefficients in Table 5 show a positive relationship between high-speed internet and the adoption of RTGS. Column 1 indicates that upon the cable's arrival, countries increase their probability of adopting the RTGS by 16 p.p., which is particularly high given that the endline mean dependent variable is 45%. Column 2 complements this result by showing that being connected to high-speed internet is associated with a 65% increase in the number of banks participating in the platform. Finally, Column 3 shows that fast internet induces a higher probability that a single bank joins the RTGS once its country adopt it. The magnitude in this case is smaller, 5.4 p.p., but very precise and sizeable as it implies a 30% increase relative to the probability that a bank adopts the RTGS when fast internet is not available.

Table 5: High-Speed Internet and RTGS Adoption

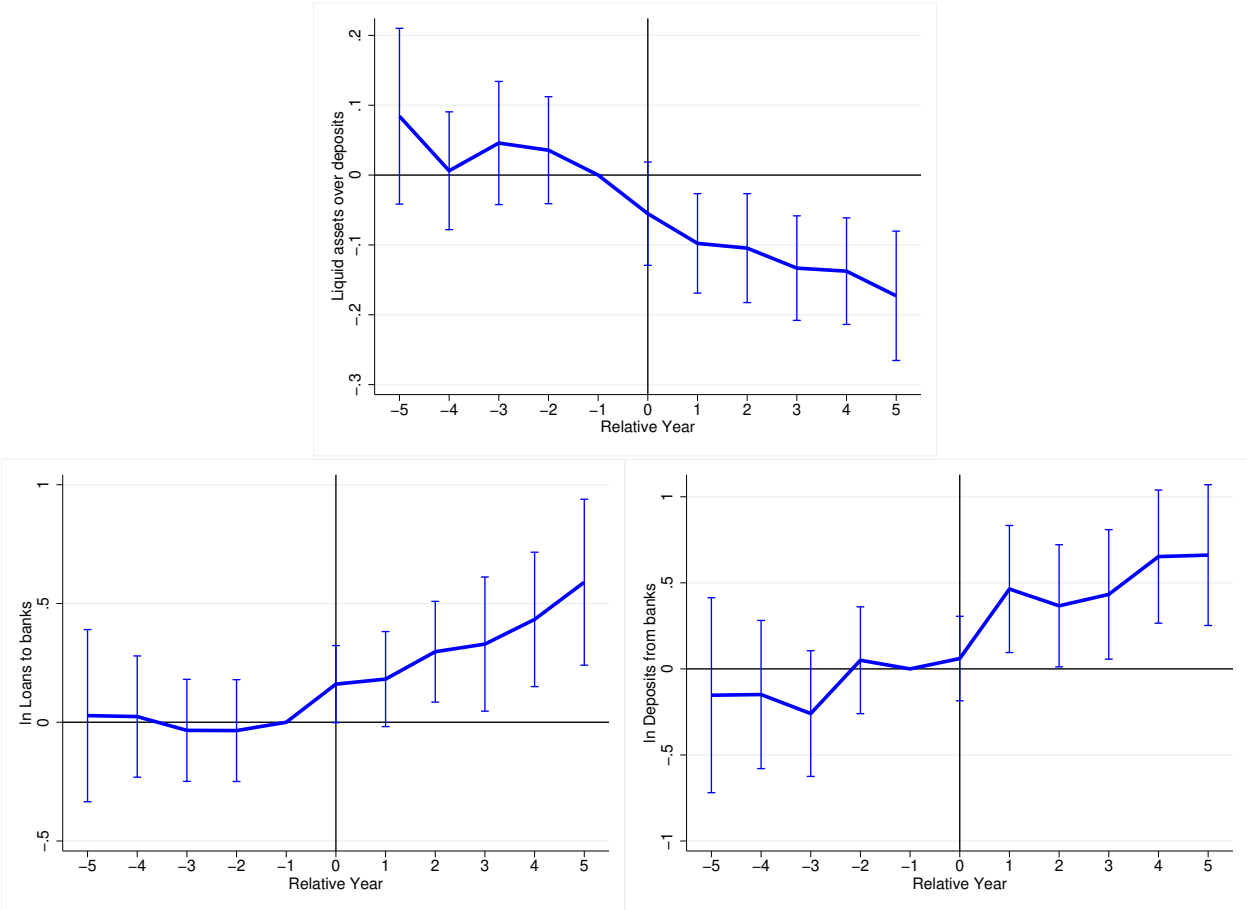
Variables	(1) RTGS Country dummy	(2) RTGS N. banks asinh	(3) RTGS Bank dummy
$Submarine_{ct}$	0.160*	0.506*	0.055***
	(0.084)	(0.271)	(0.020)
Country FE	Yes	Yes	No
Bank FE	No	No	Yes
Year FE	Yes	Yes	Yes
Obs.	814	814	10,568
Adj. R sq.	0.670	0.687	0.701
MDV	0.456	1.419	0.174
SDDV	0.498	1.665	0.499

Notes: This table reports estimates from the staggered difference-in-difference design presented in equation (2). The dependent variables are as follows: *RTGS Country* (a dummy variable equal to one if the country adopted the RTGS), *RTGS N. banks* (the inverse hyperbolic sine transformation of the number of banks participating in the RTGS) and *RTGS Bank* (a dummy variable equal to one if the bank participates in the RTGS). The main predictor is *Submarine*_ct, a binary variable for the arrival of the first fibre-optic submarine cable in the country. This dummy takes a value of zero before the cable's arrival and 1 from the time of the arrival on. Obs. refers to the number of observations, Adj.R^2 is the adjusted R^2, MDV refers to the dependent variable's mean (we take the mean when fast internet is not available for RTGS bank) and SDDV refers to the standard deviation of the dependent variable. Fixed effects are at the country (or bank) and year level. Standard errors are in parentheses, clustered at the country (or bank) level. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

We continue by showing the direct effects of high-speed internet on interbank transactions. The event study in Figure 6 provides evidence in this direction. The bottom-left panel refers to bank's loans to other banks and shows two phases: no pre-trends before the arrival of the submarine cable, with point estimates close to zero and non-statistically significant, and an upward trend with statistically significant coefficients after the arrival of the fibre-optic cable, with a jump at year zero and a gradual increase in loans to banks in the following years. The bottom-right panel refers to banks' deposits from other banks. Similar to before, the pattern is almost flat previous to the cable's arrival and increases from then on, with a jump at year zero and a gradual increase in the next five years. The magnitude of the effect is even larger for deposits from banks.[32] Finally, the top panel refers to banks' liquid assets as a share of deposits and short-term funding. The pattern for the share of liquid assets is almost flat before the cable's arrival, with none of the estimates statistically significant, and then it sharply declines at year zero, remaining negative and stable over time.

[32]This finding seems to suggest that the new technology, which reduces transaction costs for interbank operations and lends risk within the interbank market, changes the structure of the banking network. Small and marginal banks benefit from the reduced interbank lending risk and lend their excess liquidity to big and core banks. Big and core banks, which mostly comprise our sample, mostly act as liquidity hubs. This occurrence is even more plausible if lending risk outside of the interbank market does not decrease.

Figure 6: Event Study: High-Speed Internet and Interbank Markets



Notes: This figure shows the event study for the period five years before to five years after the arrival of the first submarine cable in country c. The y-axis reports coefficients for the dependent variables: *Liquid Assets over DST* (the share of liquid assets over deposits and short-term funding), *ln Loans to Banks* (the natural logarithm of loans to banks (in millions of US dollars)) and *ln Deposits from Banks* (the natural logarithm of loans to banks (in millions of US dollars)). The x-axis refers to the relative time from the cable's arrival. The blue (solid) line connects point estimates relative to the base year (–1). Standard errors are clustered at country level, and 95% confidence intervals are also reported.

Table 6 reports the estimates from the staggered difference-in-difference specification as defined in equation (2). Evidence from the table is in line with that presented in the event studies. Access to the fibre-optic connection determines an increase in loans to banks and deposits from banks and a correspondent decrease in the share of liquid assets over deposits and short-term funding. All the coefficients are statistically significant and large in magnitude. The introduction of high-speed internet increases the amount of loans that banks in the sample provide to other banks by 30% and the amount of deposits from banks by 63%. Considering a hypothetical bank that has median values of both loans to banks (46 million US$) and deposits from banks (22 million US$), the access to the new technology causes an increase in loans to banks by 13.8 million US$ and an increase in deposits from banks by 13.9 million US$. The coefficient associated with the share of liquid assets is negative and significant. Having access

to the fibre-optic technology causes a decrease in the share of liquid assets over deposits and short-term funding of about 14 p.p. (that is a large number if we consider that the average share in our sample is 46%). Our interpretation of these findings is that the connection to high-speed internet reduces transaction costs for interbank operations, allowing interbank markets to be effective in smoothing for liquidity shocks and leading banks to substitute unprofitable hoarding of liquid assets with real-time interbank transactions.[33]

Table 6: High-Speed Internet and Interbank Markets

Variables	(1) Liquid Assets over DST	(2) Loans to Banks ln	(3) Deposits from Banks ln
$Submarine_{ct}$	-0.139***	0.264**	0.491**
	(0.030)	(0.117)	(0.186)
Bank FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs.	6,641	6,308	4,889
Adj. R sq.	0.429	0.767	0.676
MDV	0.463	3.783	3.007
SDDV	0.441	2.053	2.351

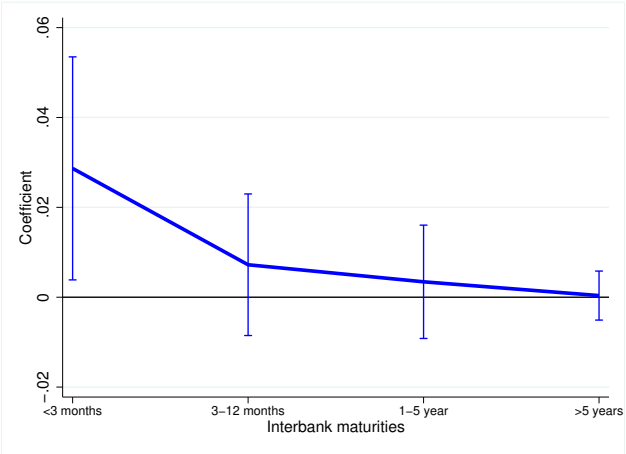
Notes: This table reports estimates from the staggered difference-in-difference design presented in equation (2). The dependent variables are as follows: *Liquid Assets over DST* (share of liquid assets over deposits and short-term funding), *Loans to Banks* (natural logarithm of loans to banks (in millions of US dollars)) and *Deposits from Banks* (natural logarithm of loans to banks (in millions of US dollars)). The main predictor is $Submarine_{ct}$, a binary variable for the arrival of the first fibre-optic submarine cable in the country. This dummy takes a value of zero before the cable's arrival and 1 from the time of the arrival onward. Obs. refers to the number of observations, Adj.R^2 is the adjusted R^2, MDV refers to the dependent variable's mean and SDDV refers to its standard deviation. Fixed effects are at the bank and year level. Standard errors are in parentheses, clustered at the country level. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

To corroborate our interpretation, we implement an additional exercise where we look at interbank maturities. Following our hypothesis, once interbank transactions become an effective tool for smoothing liquidity shocks, banks substitute hoarding of liquid assets with shorter-term interbank securities. In that regard, we expect a relative increase in short-term interbank transactions with respect to longer-term transactions once the fibre-optic technology is available. To show that, we repeat our staggered difference-in-difference regression as in equation (2) but use as dependent variables a set of dummies identifying different interbank maturities. The results are reported in Figure 7 and show that the coefficient associated with short-term interbank maturities (less than three months) is positive and statistically significant, while those

[33]This chain of events eventually unblocks new investment opportunities and contributes to the expansion in credit to the private sector that we have documented in the previous section.

associated with longer-term maturities are lower in magnitude and indistinguishable from zero. While this exercise offers valuable insights, we acknowledge that the limited availability of data poses serious concerns on its accuracy. Hence, we interpret the corresponding results with caution as suggestive evidence of the effects of fast internet on interbank maturities.

Figure 7: High-Speed Internet and Interbank Maturity



Notes: This figure reports the coefficients of the regression of interbank maturities on $Submarine_{ct}$. The blue (solid) line connects point estimates. Standard errors are clustered at country level, and 95% confidence intervals are also reported.

3.2.1 Interbank markets and weak users

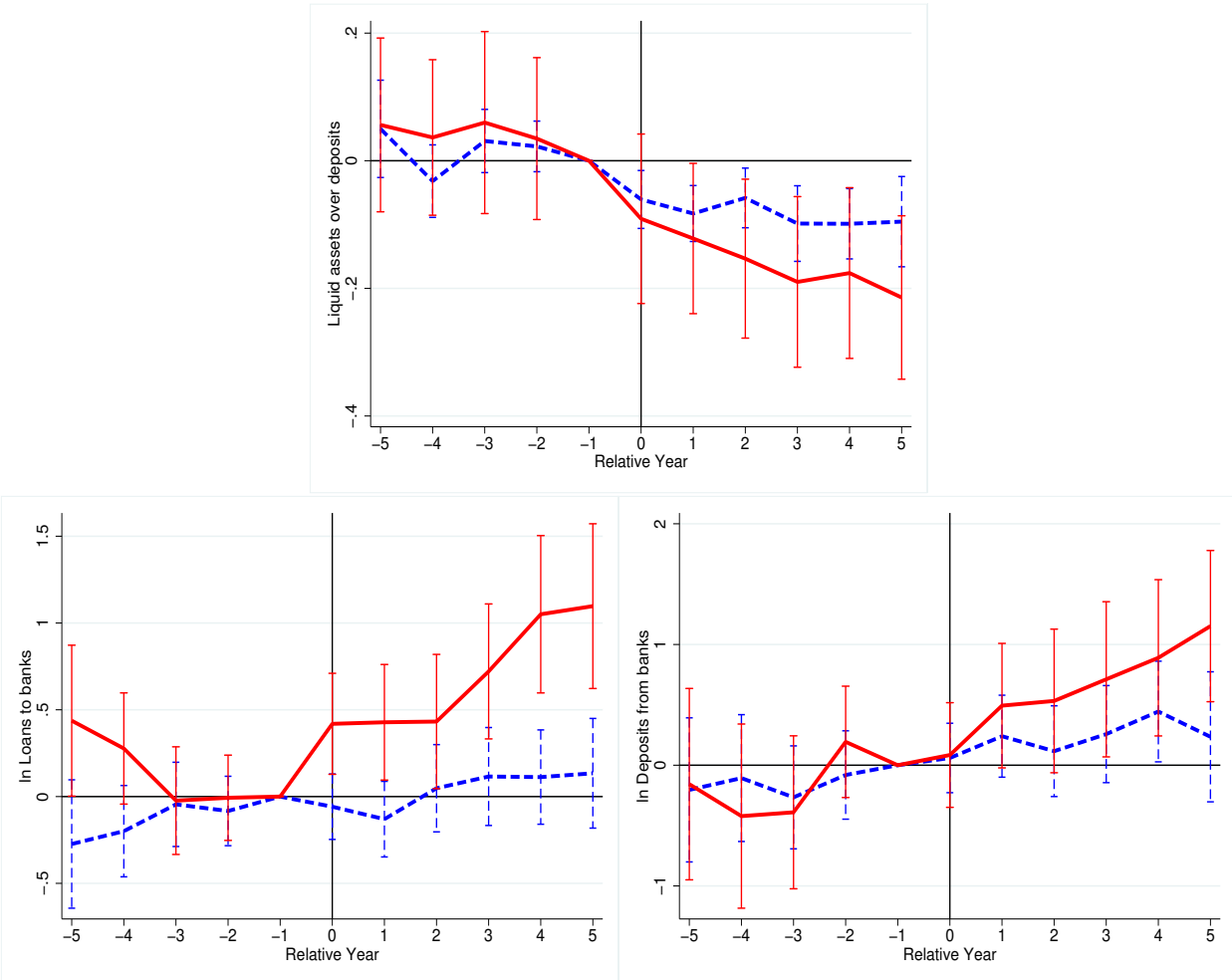
In this section, we show that the effect of high-speed internet on banking is heterogeneous among banks. Our proposed mechanism suggests that the connection to fast internet affects bank credit supply through reduced transaction costs in the interbank market. Following this reasoning, we expect banks that were minor players in the interbank market before the cable's arrival to be mostly affected by access to fast internet. To test this hypothesis, we augment the event study and the staggered difference-in-difference specification in equations (1) and (2) with the inclusion of the heterogeneity as defined in equation (4). We define a dummy variable for weak interbank users that, for each country, takes a value of 1 if the bank was below the median of loans to banks and deposits from banks before the cable's arrival and zero otherwise.

In Appendix Table A4, we provide a balance table for this variable. *Weak users* tend to be smaller than other banks and have more assets over deposits. In Appendix Figure A2, we also plot a scatter of *weak user* versus *non-weak user* banks and show that the two groups do not differ in their ratio of net loans over deposits and short-term funding. Then, we interact

this predetermined variable with the dummy that identifies the presence of high-speed internet, D_{ct}, and focus on the specification in equation (4).[34]

The results from this specification are reported in Figure 8 and Table 7. In line with our hypothesis, most of the findings from Figure 6 and Table 6 come from the changing behaviour of (pre-) weak users. The increase in deposits from banks and the reduction in the share of liquid assets over deposits and short-term funding, common to all banks, are sensibly higher for weak users. On the other hand, the increase in loans to banks is mostly attributed to weak users.

Figure 8: Event Study: High-Speed Internet, Interbank Markets and Weak Users



Notes: This figure shows the event study for the period five years before to five years after the arrival of the first submarine cable in country c. The y-axis reports coefficients for the dependent variables: *Liquid Assets over DST* (the share of liquid assets over deposits and short-term funding), *ln Loans to Banks* (the natural logarithm of loans to banks (in millions of US dollars)) and *ln Deposits from Banks* (the natural logarithm of loans to banks (in millions of US dollars)). The x-axis refers to the relative time from the cable's arrival. The blue (dashed) line connects point estimates relative to the base year (–1) for *Non-Weak Users*. The red (solid) line connects point estimates relative to the base year (–1) for *Weak Users*. Standard errors are clustered at the bank level, and 95% confidence intervals are also reported.

[34]Notice that the variable *weak user* is available for a restricted sample of banks (those that have data for the years before the cable's arrival). In Appendix Table B8, we show that our main results on the effect of high-speed internet on banking were stable for this restricted sample of banks.

In Table 7, beyond providing compact estimates of the heterogeneous effect of fast internet on interbank outcomes, we also add a column for net loans. The table shows a differential increase in loans to banks by 50%, 0.397 log points, and in deposits from banks by 75%, 0.559 log points, for weak users. The reduction of liquid assets over deposits and short-term funding is 7.7 p.p., on average, with weak users reducing this ratio by 11 p.p. The last column shows that loans to the private sector increase for all banks, with weak users further increasing loans by 14%, 0.134 log points. The results from this table confirm our hypothesis: being connected to high-speed internet lowers transaction costs in interbank exchanges, allowing constrained banks to change their liquidity management by reducing inside liquidity (hoarding short-term assets) and increasing outside liquidity (using interbank assets and liabilities), thus strengthening lending to the private sector.

To conclude, we modify equation (4) by including country-by-year fixed effects. The results are presented in Table 7 and show that the point estimates remain basically unchanged (if something they increase), while the standard errors decrease. We interpret this finding as a powerful test supporting our main results.

3.3 Firms

This section studies the effects of high-speed internet on firms, through the banking channel. We use data from the WB ES and focus on survey waves for African coastal countries, from 2002 to 2018.

We use similar empirical methodologies as the ones implemented in the previous sections, studying the effects of fast internet on the following dependent variables: *Access to Finance*, a dummy variable that indicates whether managers in the firm consider access to finance a minor problem; *Loans from Banks*, a dummy variable that indicates whether the firm took at least one loan with a commercial bank to finance its activity during the last fiscal year; *Loan Maturity*, the duration, in months, of loan maturities*; Sales*, the amount of total annual sales; and *Workforce*, the number of permanent and temporary full-time employees.

Table 8, columns 1 to 5 present the results from the staggered difference-in-difference specification as defined in equation (2). As usual, this two-way fixed effects regression provides a compact measure of the average causal effect of high-speed internet on firms access to finance,

Table 7: High-Speed Internet, Interbank Markets and Weak Users

Variables	(1) Liquid Assets over DST	(2) Loans to Banks ln	(3) Deposits from Banks ln	(4) Loans ln	(5) Liquid Assets over DST	(6) Loans to Banks ln	(7) Deposits from Banks ln	(8) Loans ln
$Submarine_{ct}$	-0.077***	0.066	0.200	0.239***				
	(0.024)	(0.120)	(0.168)	(0.081)				
$Submarine_{ct}$	-0.105**	0.397**	0.559**	0.134	-0.111***	0.449***	0.580**	0.233**
$\times$ $Weak\ user_{ic}$	(0.043)	(0.162)	(0.220)	(0.107)	(0.039)	(0.158)	(0.237)	(0.098)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	No	No	No	No
Country-Year FE	No	No	No	No	Yes	Yes	Yes	Yes
Obs.	4,121	3,915	2,905	4,047	4,052	3,824	2,801	3,976
Adj. R sq.	0.474	0.735	0.638	0.886	0.504	0.743	0.662	0.912
MDDV	0.466	3.500	2.612	4.856	0.460	3.494	2.617	4.876
SDDV	0.385	1.943	2.234	1.767	0.377	1.943	2.224	1.768

Notes: This table reports estimates from the staggered difference-in-difference design presented in equation (4). The dependent variables are as follows: *Liquid Assets over DST* (share of liquid assets over deposits and short-term funding), *Loans to Banks* (natural logarithm of loans to banks (in millions of US dollars)) and *Deposits from Banks* (natural logarithm of loans to banks (in millions of US dollars)). The main predictors are $Submarine_{ct}$, a binary variable for the arrival of the first fibre-optic submarine cable in the country, and $Submarine_{ct} \times Weak\ user_{ic}$, the interaction between $Submarine_{ct}$ and a dummy that takes a value of one if the bank was below the median of interbank loans and deposits (with respect to its own country and the period before the arrival of high-speed internet). Obs. refers to the number of observations, Adj.R^2 is the adjusted R^2, MDV refers to the dependent variable's mean and SDDV refers to its standard deviation. Fixed effects are at the bank and year (or country-year) level. Standard errors are in parentheses, clustered at the bank level. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

their ability to borrow from banks, loan maturities, their total annual sales, and workforce. The baseline assumptions are absent of pre-trends and constant treatment effect among groups and through time. The results from the table suggest a positive relationship between high-speed internet and firm activity. Being connected to the fibre-optic cable is associated with easier access to finance, a higher probability of receiving a bank loan, and an increase in loan maturities. To a lesser extent, we also see an increase in total annual sales, while the coefficient on workforce is closer to zero and non-significant.

Table 8, columns 6 to 10 present the results from the staggered difference-in-difference specification as defined in equation (4). Mirroring the analysis in Section 3.2.1, we test the hypothesis that the real effects associated with access to fast internet are larger for those countries where the interbank market was underdeveloped before the cable's arrival. To test this hypothesis, we define an indicator of weak interbank market that takes a value of 1 if the amount of interbank volumes in the country was below the median before the arrival of high-speed internet and zero otherwise. Then, we interact this predetermined variable with the dummy that identifies connection to the submarine cable, D_{ct}. The results from Table 8 corroborate our hypothesis. The effect of high-speed internet on corporate finance, loan maturity, sales and workforce is (positive and) especially marked for firms in countries where the interbank market was relatively underdeveloped. We observe that the arrival of fast internet in these countries is associated with a 26 p.p. increase in access to finance, a 20 p.p. higher likelihood of receiving a bank loan, a doubling in loan maturities, a sizeable expansion in yearly sales and an increase in workforce.[35]

Although this part of the analysis mainly offers suggestive evidence on the real effects of fast internet, it complements in a coherent way the findings on banking. The arrival of high-speed internet in Africa reduced transaction costs in the interbank markets, encouraging national central banks to invest in new financial infrastructures (as the RTGS) and banks to reduce their holding of liquid assets. Banks reallocated funds towards the private sector, and this partly explains the beneficial effect of fast internet on the activity of local businesses that we report in Table 8.

[35]The coefficient associated with total sales is particularly high in magnitude. We interpret this coefficient with caution and look for new and comparable data to corroborate our findings.

Table 8: High-Speed Internet and Firms

Variables	(1) Access to Finance dummy	(2) Loans from Banks dummy	(3) Loans Maturity ln	(4) Sales ln	(5) Workforce ln	(6) Access to Finance dummy	(7) Loans from Banks dummy	(8) Loans Maturity ln	(9) Sales ln	(10) Workforce ln
$Submarine_{ct}$	0.166***	0.150***	1.005**	0.587	0.063	0.135**	0.131***	0.456**	0.344	-0.007
	(0.062)	(0.038)	(0.393)	(0.419)	(0.126)	(0.067)	(0.044)	(0.192)	(0.363)	(0.129)
$Submarine_{ct}$						0.098*	0.056*	0.743*	1.196***	0.211*
$\times$ $Weak\ user_c$						(0.059)	(0.034)	(0.425)	(0.453)	(0.116)
Controls	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Country FE	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	25,389	27,863	2,694	22,856	26,706	25,126	27,597	2,694	22,618	26,454
Adj. R sq.	0.103	0.124	0.201	0.440	0.097	0.098	0.127	0.257	0.443	0.101
MDV	0.580	0.199	3.253	-2.306	2.790	0.574	0.198	3.253	-2.345	2.787
SDDV	0.494	0.399	1.071	2.222	1.047	0.495	0.399	1.071	2.218	1.047

Notes: This table reports estimates from the staggered difference-in-difference design presented in equations (2) and (4), weighted by WB ES re-scaled weights. The dependent variables are the following: *Access to finance* (dummy variable, where 1 indicates easy access to finance), *Loans from banks* (dummy variable, where 1 indicates at least one loan from a commercial bank), *Loan maturity* (natural logarithm of the term, in months, of loans from banks), *Sales* (natural logarithm of total annual sales) and *Workforce* (natural logarithm of the number of permanent and temporary full-time employees). The main predictors are $Submarine_{ct}$, a binary variable for the arrival of the first fibre-optic submarine cable in the country, and $Submarine_{ct} \times Weak\ user_c$, the interaction between $Submarine_{ct}$ and a dummy that takes a value of one if the country was below the median of interbank loans and deposits (in the period before the arrival of high-speed internet). Obs. refers to the number of observations, Adj.R^2 is the adjusted R^2, MDV refers to the dependent variable's mean and SDDV refers to its standard deviation. Controls include an indicator of the firm's sector and size (only sector in the specification with *Workforce*). Fixed effects are at the country and year level. Standard errors are in parentheses, clustered at the country-sector level. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

4 Robustness

In this section, we provide additional checks to test the robustness of our results.

Appendix Table A1 presents the list of countries included in our sample. For each country, we report their first fibre-optic submarine cable and the year from which it is ready to serve. Anecdotal evidence indicates that submarine cables approached Africa in their route from Europe and America to Asia. Furthermore, the first cables aimed to accommodate general telecommunication needs, namely long-distance telegraphic communication, telephone calls, fax and internet transmission. Connecting African banks was not the primary purpose behind the cable's installation, though concerns remain about the exogeneity of its arrival.

In Appendix Tables B1 and B2, we provide empirical support to the fact that the timing of connection is exogenous to the economic and financial characteristics of the countries being connected. Table B1 shows cross-country regressions where the year of the cable's arrival is regressed on three indicators that proxy for the economic outlook of the country and its banking sector before its arrival.[36] The pre-levels of economic and banking activity do not predict the timing of connection. Table B2 reports panel regressions where submarine connectedness is regressed over the current values of the economic and banking indicators and their 10-year average. Again, the evidence suggests that none of the variables are correlated with fibre-optic submarine cable connection.

In the main analysis we exploit the connection of the headquarter to disentangle the effect of supply from that of demand. There, we present a table (Table 3) with connection at the country level and at the headquarter level to show the existence of a separate supply channel. We then introduce country-by-year fixed effects to isolate the effect of supply. In Appendix Figure B1 and Table B3, we substantiate these findings by providing the event study and the difference-in-difference regression in which the connection of the headquarter is used as the main predictor. Both the difference-in-difference estimates and the dynamics of the effects resemble those in Figure 4 and Table 2.

Multi-country banks may be different from single-country banks in several dimensions. We verify that this is not the case in our sample in Appendix Table A3. At the same time, it is worth investigating whether being connected to high-speed internet generates heterogeneous

[36] These indicators are collected from the WB GFD database.

effects on multi- versus single-country banks. We explore this dimension in Appendix Table B4, in which we split the sample between single- versus multi-country banks. The table shows that both groups of banks respond to the arrival of (country-level) high-speed internet. Interestingly, single-country banks are the ones responding the most in terms of the effect's magnitude and significance. This result is in line with the discussion on within versus between frictions that we report in the next paragraph.

By using the headquarters' access to fast internet to isolate supply from demand, we place more emphasis on the role of frictions across banks. However, we acknowledge these frictions exist also within banking groups and that high-speed internet may alleviate these clutches as well (D'Andrea et al. (2021)). We show the importance of high-speed internet connection on within/between frictions more clearly in Appendix Table B5, where we split the sample into banks that receive fast internet when already connected through the headquarter versus banks that receive fast internet for the first time (without a headquarter connection). The results show that the effect of fast internet is positive in both samples but is lower in magnitude for banks already connected through the headquarter. These findings are in line with the hypothesis that high-speed internet mostly benefits banks that are connected for the first time, and they show how the headquarter connection helps to alleviate some of the frictions that banks face but not completely.

In the second part of this paper, we provide evidence on one of the mechanisms behind the effect of high-speed internet on banking. We highlight the importance of having liquid interbank markets and illustrate the positive relationship between fast internet and the adoption of real-time payment systems (as well as the consequent revival of interbank markets). In Appendix Table B6 we further document this channel. We define a bank as never treated if it never accesses RTGS during our sample period[37] and replicate the exercise in Table 2 by using the interaction between access to high-speed internet and the never-treated dummy as our main predictor. The results are reported in Appendix Table B5 and show the negative (even if not significant) relationship between the interaction term and banking outcomes. In the table, we also provide an F-test on the significance of the total effect of fast internet for banks that never adopt the RTGS (the sum of the two coefficients in Table B5). As we can see from the table, the latter effect cannot be distinguished from zero in a statistical sense, a result in line with the

[37] This corresponds to almost 10% of the banks in our sample.

hypothesis that access to fast internet produces lower effects on banks that never participate in the RTGS.

In this paper we also show that having an indirect connection to high-speed internet, through the headquarter, boosts the activity of the subsidiaries. Since the RTGSs that we consider are mostly domestic, one interesting aspect is to show how much of the effect coming from the headquarter connection is related to the latter also participating in the RTGS. We provide evidence on this in Appendix Table B7, where we concentrate on the restricted sample of banks that receive the first connection to fast internet through the headquarter. For those banks, fast internet at the headquarter matters, but the effect is larger when the headquarter has also access to the RTGS. This result is in line with the literature on banking group internal capital markets (Cetorelli and Goldberg (2012)) and withXu (2022), who offers evidence on the ability of multi-national bank networks to transmit shocks across countries.

In the section dedicated to the interbank market, we discuss an important role played by the bank heterogeneity on weak and non-weak (pre-) users. Through it, we highlight the heterogeneous effect of high-speed internet on banking associated with differences in transaction costs in the interbank market. Appendix Table A4 presents the balance table of the variable *Weak user*. The first two rows show the differences in loans to banks and deposits from banks that define the variable. They also show that weak users differ from non-weak users in terms of size, being generally smaller. However, the two groups are substantially similar regarding assets over deposits ratio, loans over assets, government securities over assets and liquid assets over total assets. In Figure A2, we present a scatter plot where weak and non-weak users are compared based on their loan/deposit composition. Importantly, the two categories lie on the same line and the cloud of points is mostly overlapping. To complete our analysis, we also replicate the exercise in Table 2 on the restricted sample of banks for which the variable *Weak user* is non-missing. The results are reported in Table B8 and show that the basic estimates are unaffected.

The analysis in Table 8 suggests that most of the effects on firms come from the formation of new banking networks (rather than the expansion of existing ones). In line with these findings, we ask whether the effects of high-speed internet on banking are also more pronounced in 'weak user' countries. Documenting the heterogeneity of the effects depending on the size

of the existing network may help us better understand the economic mechanism behind our results.[38] In Appendix Table B9, we replicate the regression in equation (2) by splitting the sample between countries with weak interbank markets versus strong ones before the arrival of high-speed internet. Our results show that the effects of fast internet are qualitatively the same for both groups (and in line with those in Table 2). However, they are larger in magnitudes for banks in countries with weak interbank markets before access to fast internet.

Allen et al. (2018) show that existing differences in interbank market usage can be explained by the market participants' trust in the stability of the country's banking sector and counterparties. To check for this alternative hypothesis, in Appendix Tables B10a and B10b, we include different control variables from the World Bank WGI database to our specification in equation (2). *Regulatory quality* captures perceptions of the government's ability to formulate and implement sound policies and regulations that permit and promote private sector development; *Rule of law* captures perceptions of the extent to which agents have confidence in and abide by the rules of society and in particular the quality of contract enforcement, property rights and the courts; *Control of corruption* captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption as well as 'capture' of the state by elites and private interests. The results illustrate that our estimates are highly resilient to the inclusion of these controls.

A last conceptual issue is that the increase in loans to the private sector, documented throughout our analysis, may be associated with an increase in the riskiness of banking assets. In Appendix Figure B2, we investigate this aspect, focusing on loan loss reserves. The results suggest that the level of risk associated with loans remains basically unchanged after the arrival of fast internet. From here, the robustness checks are mostly methodological.

Appendix Figures C1a and C1b perform the same event studies as in the main analysis but focus on a three-year event window. Graphical analysis indicates that our results are not sensitive to the choice of the event window.

Recent developments in the literature on difference-in-differences and event study design show the importance of controlling for heterogeneous treatment effects. We add this check by following the methodology of Sun and Abraham (2021). We replicate our analysis using the

[38] Our coefficients are likely picking up the effects of the bank joining the RTGS and the effect of peer banks joining the platform.

eventstudyinteraction package in Stata to control for the treatment's time heterogeneity. The results are reported in Appendix Figures C2a and C2b and show that all of our findings are confirmed.

In our sample, there are cases in which banks change the consolidation procedure used to draw up their balance sheets. To control for the confounding effect of a change in the consolidation procedure, in Appendix Tables C1a and C1b, we add bank-by-consolidation code fixed effects. The results are almost unchanged.

Some of the main outcome variables in our dataset have missing values. To overcome this issue in Appendix Tables C2a and C2b, we replicate our analysis on an extended sample, where missing values are imputed using multivariate normal regressions.[39] The estimates from these specifications validate those in the main analysis and show that our results are robust to the inclusion of imputed data.

Finally, we provide a robustness test at the firm level. Appendix Table C3 focuses on expenses for electricity and raw materials. As the table reflects, high-speed internet is associated with higher investments in firms inputs, especially in countries that had weaker interbank markets before the cable's arrival. The increase in expenses in firm inputs is in line with the evidence on access to finance and sales that we document in the main analysis.

5 Conclusion

In this paper, we offer empirical evidence on the impact of high-speed internet on banking in Africa. To address this question, we combine data on African banks with those on the arrival of fibre-optic submarine cables as well as country and bank reports with information on domestic financial infrastructures. We follow 629 banks in 37 African coastal countries, during the period 1997–2018, and show the effects of connection to fibre-optic cables in a quasi-experimental design. The latter relies on the staggered arrival of submarine cables and the fact that African countries were primarily connected in order to increase the connectivity between America, Europe and Asia.

[39] We use *mi impute mvn*, from STATA, to fill in missing values using multivariate normal regression. Our procedure accommodates arbitrary missing value patterns and uses an iterative Markov chain Monte Carlo (MCMC) method to impute missing values.

To explore our research question, we offer a variety of econometric methods and focus on credit supply. We use event studies to show the dynamics of banking outcomes around the year of the cable's arrival, while the difference-in-difference specifications provide compact estimates. We exploit multi-country banks to identify the supply channel and use a source of bank heterogeneity, based on whether the bank was a weak interbank user before the cable installation, to better characterise our results. Our findings highlight that high-speed internet promotes the role of banks and credit in Africa. In particular, we show that countries connected to fast internet are more inclined to adopt a technology central for bank intermediation, the RTGS, which contributes to a systematic increase in interbank transactions that in turn promote lending to the private sector.

In a supplementary exercise, we follow 32,761 African firms and show the real effects of high-speed internet. The results in this second part indicate that being connected to fast internet increases firm access to finance and loan maturity. This effect, together with an increase in sales and full-time employment, is particularly relevant in countries that had an underdeveloped interbank market before the cable's arrival.

Overall, we believe that our results are consistent with high-speed internet promoting financial technology adoption, liquidity and credit. In particular, this paper sheds light on two critical elements for future research. First, the adoption of innovative financial technologies can shape business outside the bank and the bank's own functioning as the liquidity management. Second, promoting the size and speed of interbank markets can improve financial integration, risk sharing and ultimately credit and development. Our paper also directly speaks to policy-makers as it suggests that investments in new technologies can favour capital market integration and help the convergence of underdeveloped countries.

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