Do heterogeneous open banking regulatory approaches impact lending markets?

Ursula Silveira Monteiro de Lima
Fundação Getulio Vargas/EAESP

Rafael Felipe Schiozer
Fundação Getulio Vargas/EAESP

Abstract

Open banking can reshape competition in retail banking by reducing informational asymmetry about borrowers. This study introduces a novel classification tool to categorize regulatory approaches and examines their impact on lending. Using hand-collected cross-country, country-level, and bank-level data from 2014 to 2019, we employ the triple difference approach.

Our findings suggest that open banking enhances credit availability under less strict regulatory approaches, including hybrid-driven and market-driven models. Moreover, heterogeneous regulatory approaches influence loan quality differently. The strictest approach (mandatory) is less effective in reducing adverse selection costs than more flexible ones.

These insights suggest that open banking benefits from more adaptable regulations, as it relies on individual choice, unlike previous information-sharing systems. The study has practical and social implications: policymakers can refine regulatory frameworks, practitioners can enhance capital allocation, and researchers can build upon our classification tool and empirical findings to further explore open banking regulation.

Keywords: Open banking, Asymmetric information, Regulation, Lending markets.
JEL: G21, G28, K23, E58.

1. Introduction

Regulatory initiatives influence how existing and prospective players compete in the retail banking industry (Vives, 2019). Open Banking initiatives[1] aim to foster competition (He et al., 2023) and reduce consumers' stickiness by reducing informational asymmetries between players, incumbents, and new entrants (CMA, 2016). Worldwide, regulatory approaches for open banking implementation are heterogeneous in their specifications (Babina et al., 2024). Open banking regulations can be classified into three approaches: mandatory (or prescriptive), collaborative (or hybrid-driven), and industry-led (or market-driven) (Aytaş et al., 2021; De Araluze & Cassinello Plaza, 2022; OECD, 2023).

This research investigates whether different open banking regulatory approaches affect lending amounts heterogeneously, using a cross-country sample of financial institutions in several jurisdictions. We combine a hand-collected dataset on global open banking initiatives classified by regulatory approaches and timing of implementation across jurisdictions with bank-level and country-level data collected from Thomson Reuters Eikon and the International Monetary Fund (IMF), respectively, every year from 2014 to 2019.

Open banking regulatory approaches can be categorized into three types: (i) mandatory or prescriptive, where regulations are established through binding legal acts; (ii) collaborative or hybrid-driven, where Central Banks or Monetary Authorities issue guidelines and recommendations; and (iii) industry-led or market-driven, where market participants independently drive the initiative (Aytaş et al., 2021; World Bank, 2022; OECD, 2023).

Each country adopts a unique open banking framework, often differing in aspects such as the scope of data sharing and technical requirements (BCBS, 2019; Babina et al., 2024). This heterogeneity complicates the classification of regulatory approaches, mainly because jurisdictions may shift from one approach to another as policymakers adjust their implementation strategies (Colangelo, 2024).

Although Babina et al. (2024) introduced the Open Banking Strength Index to measure the comprehensiveness of regulatory frameworks, it does not address the classification of regulatory approaches. To fill this gap, we propose a novel classification

[1] According to Basel Committee on Banking Supervision (BCBS), open banking is defined as "the sharing and leveraging of customer-permissioned data by banks with third party developers and firms to build applications and services, including for example those that provide real-time payments, greater financial transparency options for account holders, marketing and cross-selling opportunities. Individual jurisdictions may define open banking differently" (BCBS, 2019, p. 4).

tool designed to categorize open banking regulatory approaches and provide a step-by-step procedure for its application.

Our empirical results suggest that open banking implementation increases credit availability in collaborative and industry-led regulatory approaches. Besides, different regulatory approaches have different impacts on the quality of loans, as we observe that the effect of Open Banking on net loan losses is heterogeneous depending on the approach used. Specifically, the strictest regulatory approach (i.e., mandatory) is less effective in diminishing the adverse selection costs than other less strict approaches (i.e., hybrid-driven and market-driven approaches).

Our paper contributes to the literature on Open Banking across several dimensions. First, it is related to regulation and banking competition literature. Regulation is critical to avoiding the lock-in problem and monopoly rents' extraction by interfering in market dynamics and consequently fostering competition (Degryse & Ongena, 2008; Vives, 2019); it promotes information sharing, which may improve competition in credit markets, determining the value of lending relationships (Petersen & Rajan, 1995). In this sense, the adoption of information technology has been changing the dynamics of the lending market (Petersen & Rajan, 2002).

Open banking regulatory initiatives change the market structure through regulation to foster competition, so we propose a straightforward tool to classify regulatory approaches related to open banking adoption. Besides, we examine credit amounts by presenting empirical evidence on whether different open banking regulatory approaches impact lending markets. These results complement previous results on regulation lessening information asymmetry in credit markets.

Second, our research contributes to relationship banking and information-sharing literature. Understanding the effects of different open banking regulatory approaches complements this literature by showing if and to what extent different regulatory approaches impact adverse selection costs differently. As Open Banking is a regulatory initiative that permits customers to share their data (De Araluze & Cassinello Plaza, 2022), it might also be one of the available instruments to reduce adverse selection costs (Karapetyan & Stacescu, 2014), switching costs, informational rents and relationship investments (Sutherland, 2015). So, we contribute by examining if open banking increases credit quality by investigating its impact on total net loans.

Third, our paper contributes to the emergent literature on open banking by proposing

a straightforward classification tool to categorize regulatory approaches for open banking. Further, our preliminary results provide empirical evidence of how heterogeneous regulatory approaches impact lending markets differently. Most of the research on open banking has been focused on exploring the impact of technological requirements, operational features, and data security on its implementation's success (Aytaş et al., 2021; Nanaeva et al., 2021; Fracassi & Magnuson, 2021; Patki & Sople, 2022), willingness to adopt this technology (Sivathanu, 2019; Chen et al., 2022; Rosati et al., 2022), credit score models improvement (Hjelkrem et al., 2022), creation of new retail products and services (Ramdani et al., 2020; Grassi et al., 2022), venture capital investments in fintechs (Babina et al., 2024) and how Open Banking adoption impacted the volume of traditional banks' loans and the consumer's willingness to borrow from incumbents in the BRICS emerging economies (Fang & Zhu, 2023). Regarding theoretical literature on open banking, the model of He et al. (2023) predicts that open banking implementation increases credit market competition as it increases the fintechs screening abilities; however, if open banking over-empowers the fintechs ability to discriminate between high-quality and low-quality borrowers, all of the borrowers will be worse off.

Our empirical results and regulatory classification tool proposition have practical and social implications for policymakers, practitioners, and researchers. Central Banks and Monetary Authorities may use these results to optimize their open banking regulatory design, further improving collective welfare. For practitioners, it might shed some light on whether different regulatory approaches improve the quality of credit, which would mean better capital allocation. For researchers, the proposition of a friendly regulatory classification tool and the empirical results might help to promote further research on the effects of open banking regulation.

The remainder of this article is structured as follows: Section 2 presents the regulatory approaches to open banking; Section 3 outlines the methodology used, which includes the regulatory classification tool, data, empirical strategy, and summary statistics; Section 4 presents and discusses the results; Section 5 addresses endogeneity concerns and Section 6 concludes.

2. Regulatory Approaches to Open Banking

In 2016, the UK Competition & Markets Authority (CMA) published its final report on its retail banking market investigation, concluding that in the retail banking industry,

consumers' stickiness and asymmetric information were important drivers to prevent new entrants into this market. It led to the first regulatory remedy package, which culminated in the implementation of open banking by the United Kingdom. The objective was to promote competition and innovation, which would lead to an increase in credit access and financial inclusion, which would improve the welfare of customers. (CMA, 2016; FCA, 2019; Chan et al., 2022; De Pascalis, 2022; Rivero & Vives, 2022).

Since the first open banking initiative promoted by the United Kingdom, each country has decided when and how to implement open banking within its jurisdiction. Open banking frameworks differ in rules, alternative dispute mechanisms, supervision authorities, operational requirements, security standards, and scope of shared data (BCBS, 2019). Besides, each jurisdiction sets its regulatory approach by specifying whether it is a mandatory or prescriptive approach, collaborative or hybrid-driven approach, and market-driven or industry-led approach (Aytaş et al., 2021; World Bank, 2022; OECD, 2023; Babina et al., 2024).

The prescriptive approach group comprises countries whose policymakers mandate requirements for incumbents in the data-sharing process and set rules for third parties to access the shared data, e.g., security standards. For example, the United Kingdom Competition and Markets Authority compelled the nine largest banks to make transaction data available to third parties via Application Programming Interface (API) at the customer's request. In 2018, the Central Bank of Bahrain[2] mandated the adoption of open banking for all retail banks by prescribing a specific deadline.

Further, in the hybrid-driven approach group, the regulator provides participants with general guidelines and recommendations on operational standards and security. In 2016, the Reserve Bank of India[3] (RBI) initiated the implementation of open banking under the hybrid approach by creating an account aggregator entity. In the same year, the Monetary Authority of Singapore (MAS) announced the guidelines on API standards for Open Banking in Singapore[4].

Under the market-driven approach, the industry sets the standards and requirements to implement open banking, so regulators issue no specific mandatory legal acts or guidance.

[2] The Central Bank of Bahrain: https://bahrainob.atlassian.net/wiki/spaces/BH/overview?homepageId=295043
[3] BIS. (2021). *Central bankers' speeches. Rajeshwar Rao: Open banking in India*
[4] BCBS (2019).

For example, the Swiss Bankers Association (SBA)[5] created a working group to facilitate cooperation between banks and third-party providers in implementing open banking in Switzerland. However, the SBA did not issue any guidelines or legal acts to do so.

Further, open banking regulatory approaches may change according to policymakers' implementation strategy. This means policymakers can change their regulatory approach during the open banking implementation to pursue their regulatory goals. For example, the United States adopted a market-driven approach until 2023, when its government issued mandatory rules concerning the sharing of financial data, which signals a change in its regulatory approach (Colangelo, 2024).

The changing nature of open banking regulatory approaches highlights that to examine the impact of different regulatory approaches, we had to construct a specific tool to determine which approach is adopted by a specific country in a prespecified time frame. This tool had to be straightforward and general enough to categorize each jurisdiction by its regulatory approach (i.e., mandatory, collaborative, or market-driven).

3. Methodology

This section presents the regulatory classification tool created for this research. We also detail the data construction, the empirical strategy employed, and the summary statistics.

3.1. The Regulatory Classification Tool

Previously, Babina et al. (2024) proposed the Open Banking Strength Index to measure the comprehensiveness of open banking policies set by regulators. They selected four open banking dimensions to construct this index: whether regulators mandate banks to share data, reciprocity, financial products coverage beyond transaction accounts, and API standardization. The index is an average of these dimensions, ranging from 0 (where none of the four dimensions are met or have not been decided yet) to 1 (indicating all four dimensions were met). Further, in its conceptual construction, the authors did not differentiate between collaborative (or hybrid-driven) and prescriptive (or mandatory) approaches in their data categorization and variables' definitions section. They considered

[5] the Swiss Bankers Association (SBA): https://www.swissbanking.ch/en/news-and-positions/opinions/open-banking-in-switzerland-between-hype-and-reality

both to be government-led efforts[6]. Although pioneering, the open banking strength index did not classify the regulatory approaches as we needed so motivated by the dynamic nature of the adoption of open banking regulatory approaches and the lack of an appropriate tool to classify them clearly, we constructed a straightforward regulatory classification tool to classify the regulatory approaches for each country in our sample during the period of analysis to pursue their impact examination further.

We created a two-step procedure to build the regulatory classification tool used in this research. First, we gathered the Basel Committee on Banking Supervision, Bank for International Settlements, and Organization for Economic Cooperation and Development[7] reports, in which jurisdictions were classified into mandatory, hybrid, and market-driven regulatory approaches. Table A.1 in Appendix A presents each report's regulatory classification. It is noteworthy that some countries are not classified. However, they are mentioned as "Actively considering adopting Open Banking" (e.g., Canada) or "In process of developing rules" (e.g., Russia). In total, thirty-nine jurisdictions were mentioned in these reports.

Our second step was to build a regulatory classification tool to categorize the unclassified countries in Table A.1 and check whether the already classified countries kept their regulatory approach. Table A.2 in Appendix A details our regulatory tool. It comprises the evaluation of four features. The first feature investigates whether the Central Bank or Monetary Authority explicitly classified its regulatory approach to open banking. If so, the classification is set accordingly.

The second feature examines how technical requirements are determined: mandated by law act, released as recommendations or guidelines, or issued by industry participants. Further, the third feature examines whether legal acts enforce the market's participants' participation or if they are voluntary. If technical requirements are mandated and the law obligates participants to participate, this jurisdiction is classified as prescriptive. However, if the industry sets technical requirements and participants voluntarily participate, it is classified as market-led. On the other hand, if technical requirements are released as recommendations by policymakers and participants' participation is voluntary, then it is

[6] For example, in the field "regulatory technical specifications: Does the regulator set technical specifications for data sharing / payments?" (Babina et al., 2024, p. 83), the authors provide the following note concerning their decision rule, "What happens when regulators and industry collaborate on technical specifications? This field is 'Yes' if technical standards are either developed internally by the regulator, arrived at through collaboration of the regulator with industry participants, or mandated by the regulator to be developed by industry participants." (Babina et al., 2024, p.84).
[7] OECD (2023).

classified as a hybrid-driven regulatory approach.

The fourth feature objective is to label those jurisdictions that conducted public consultations, formed an internal work committee, or both to implement open banking but did not release an open banking timeline or further public documentation on technical requirements, for example. If so, these jurisdictions are classified as prescriptive.

Lastly, we used this regulatory classification tool to check whether the already classified countries remained in the same classification or if they should be reclassified. For example, due to the Central Banker's speech, we reclassified India as Hybrid-driven instead of prescriptive. We also used this tool to classify new jurisdictions we mapped in the process of hand-collecting data on global open banking initiatives.

3.2. Data

For this research, we combined three datasets. The first dataset comprises hand-collected data on open banking initiatives worldwide. Table 1 presents the main steps we followed to build it.

Table 1. Hand-collected data construction

Phase	Label	What	Goal
One	Mapping	Mapping countries pursuing open banking initiatives	Find the countries pursuing open banking implementation by compiling previous reports.
Two	Examining documentation and speeches	Examining each mapped jurisdiction's public documents, press releases, and official speeches of Central Banks or Monetary authorities.	Gather information on technical requirements, participants' participation, public consultation, internal working group committees, Central Banks or Monetary Authorities self-classification, and year of implementation. Verify whether selected countries have pursued open banking initiatives.
Three	Classifying regulatory approaches	Using the regulatory classification tool created.	Classify the selected countries using the regulatory classification tool using one of the following approaches: mandatory, hybrid, or market-driven.

Phase one encompasses mapping countries that pursued open banking. We did this by compiling BCBS (2019), BIS (2020), WB (2022), OECD (2023,a,b,c,d) reports, the

Global Open Finance Index[8], and grey literature reports[9]. Table A.3 in Appendix A presents the mapping process results. After phase one, we mapped seventy-two countries pursuing open banking implementation.

In phase two, we examined public documents and press releases by Central Banks or Monetary Authorities. Our objective was to gather information on technical requirements, participants' participation, public consultation, internal working group committees, Central Banks and Monetary Authorities' self-classification, and the year of implementation. Lastly, in phase three, we employed the regulatory classification tool we constructed to determine the regulatory approach of each country in our sample. They were classified as mandatory, hybrid-driven, or market-driven. After phases two and three, seventy-one countries[10] remained in our sample. Table A.4 in Appendix A shows the regulatory classification and year of implementation for each country in our sample.

After completing the hand-collection data process, we observed potential confounding effects from 2020 on due to COVID-19 countercyclical measures (e.g., Ceylan et al., 2020) adopted by governments worldwide that would drive our results. So, we decided to restrict our analysis period, meaning that our firm-level and country-level data were collected from 2014 to 2019 to avoid such confounding effects. Besides, it helped us to design our empirical strategy, which we will detail in the following section.

Our second dataset includes firm-level data from Thomson Reuters DataStream. We collected firm-level data yearly from 2014 to 2019 using the screener tool and the Thomson Reuters Business Classification (TRBC). Our filters were set to select publicly traded, active, and inactive companies for each country, considering only the primary security listing in local currency. We also filtered for the TRBC economic sector named "financials" and the TRBC industry name. We kept within the "financials" economic sector the following industries in our sample: Banks, Consumer Lending, Corporate Financial Services, Investment Banking and Brokerage Services, Investment Management and fund Operators, Diversified Investment Services, and Financial and Commodity Market Operators and

[8] The Global Open Finance Index 2023, published by the Open Banking Excellence (OBE), surveys open banking and open finance development worldwide.
[9] Mastercard (2021, 2024) and Konsentus (2023).
[10] Rwanda was excluded in phase two due to document examination. In Its fintech strategy 2022-2027 roadmap, policymaker asserts that there is "no formal regulatory initiatives have been implemented with respect to Open Banking in Rwanda, BNR, MINECOFIN, and MINICT are exploring the potential benefits that the introduction of such initiatives might have for the broader financial sector" (Rwanda Fintech Strategy 2022-2027, April 2022, p.19)

Service Providers. For each financial institution, we collected data on total gross loans, net loans, total equity, total assets, interest on deposits, total deposits, and net income. All variables were collected in local currency.

Our third dataset was collected from the International Financial Statistics (IFS), maintained by the International Monetary Fund (IMF). It comprises country-level data on gross domestic product, inflation, and exchange rates from 2014 to 2019 yearly. Table B.1 in Appendix B presents all country-level variables in panel A and all firm-level variables in panel B by their respective definitions and sources.

Further, we performed our cleaning process by excluding those countries with no firm-level data and with five or fewer financial institutions. We also winsorized firm-level variables at 1% and 99% levels. Our final sample comprises 5,941 annual observations and 61 countries. Figure C.1 in Appendix C presents the timeline representation of database after filtering and cleaning processes.

3.3. Empirical Strategy

We phased our analysis to examine how adopting different Open Banking regulatory approaches may heterogeneously affect lending markets when open banking is implemented. First, we employ the staggered difference approach using the Callaway and Sant'Anna (2021) estimator to verify if the parallel trends assumption is fulfilled. Then, we use the triple difference strategy to examine whether different regulatory approaches affect credit amounts differently.

We follow closely Callaway and Sant'Anna's (2021) baseline equation for the staggered difference phase. Our treatment group comprises all countries implementing open banking from 2016 to 2018. Our control group comprises those countries whose open banking implementation happened in 2020 or onwards. Countries treated in 2019 are excluded.

Equation (1) presents the mathematical specification used in this phase.

$$Y_{i,c,g,t} = \alpha_1^{g,t} + \alpha_2^{g,t}.\ G_{i,c,g} + \alpha_3^{g,t}.\ 1\{T = t\} + \beta^{g,t}.\left(G_{i,c,g} \times 1\{T = t\}\right) + \gamma.X + \epsilon_{i,c,g,t} \quad (1)$$

Where $Y_{i,c,g,t}$ is our proxy for lending amounts. Depending on the specification, it

can be either the natural logarithm of total gross loans or the natural logarithm of total net loans in the local currency of financial institution i, whose headquarters is in country c, in year t for treated group g. The treated group g reunites all countries whose treatment started in the same year.

$G_{i,c,g}$ is a binary variable equal to 1 if the financial institution i, whose headquarters is in country c, belongs to the treated group g, and 0 if otherwise. $1\{T = t\}$ is the indicator function equal to 1 for post-treatment periods and 0 otherwise. X represents the matrix of covariates comprising the variables: natural logarithm of total assets, return on equity, capital ratio, interest rate, the natural logarithm of gross domestic product in real terms, and inflation. The standard errors are clustered at the country-level and $\epsilon_{i,c,g,t}$ is the error term. Table B in Appendix B presents all variables used in this phase and their definitions. Figure C.2 in Appendix C presents the timeline representation of this empirical strategy.

Further, to examine the effect of heterogeneous regulatory approaches on credit amounts, we split our analysis into two parts. First, we use the triple difference[11] specification from 2014 to 2019 to analyze those countries whose implementation occurred in 2016 (hereafter, we call it "Pioneer"). Then, we use the triple difference again to examine those countries that implemented open banking in 2018; hereafter, we call it "Later."

For the "Pioneer" analysis, our treatment group comprises countries implementing open banking in 2016. These countries have different regulatory classifications, which enables us to examine whether different regulatory approaches affect lending markets. Our control group consists of countries that implemented open banking from 2020 onwards. In this set of analyses, we exclude all countries that implemented open banking in 2018 and 2019. Figure C.3 in Appendix C presents the timeline representation of this empirical strategy.

For the "Later" analysis, our treatment group comprises countries implementing open banking in 2018. These countries also have different regulatory classifications, which enables us to go further in our examination. Our control group consists of countries that implemented open banking from 2020 onwards. In "Later" analyses, we exclude all countries implementing open banking in 2016 and 2019. Figure C.4 in Appendix C presents the timeline representation of this empirical strategy.

Equation (2) presents our baseline regression for the triple difference phase; we run

[11] For an in-depth examination of the triple difference estimator, see Olden & Møen (2022).

it for “Pioneer” and “Later” analyses.

$$Y_{icrt} = \beta_0 + \beta_1\, treat_c + \beta_2\, post_t + \beta_3\, regulatory_r + \beta_4\, treat_c \times post_t + \\ + \beta_5(treat_c \times regulatory_r) + \beta_6\,(post_t \times regulatory_r) + \beta_7\,(treat_c \times post_t \times regulatory_r) + \\ + \beta_8\, X_{it} + \delta_t + \delta_c + \epsilon_{icrt} \quad (2)$$

where Y_{icrt} is the natural logarithm *of total gross loans* for the bank *i*. whose headquarters is in country *c* and adopted the regulatory approach *r* in year *t*. In the alternative specification, we use the natural logarithm of *total net loans* as our dependent variable.

Treat is a binary variable equal to 1 for treated countries and zero otherwise. *Post* is a binary variable equal to 1 for post-treatment periods and zero otherwise. *Regulatory* is a binary variable equal to 1 if the treated countries adopted the mandatory approach and zero if the treated countries adopted either hybrid-driven or market-driven approaches to implement open banking. X_{it} is the matrix of covariates, δ_t is the year fixed effect and δ_c is the country fixed effect. Finally, ϵ_{icrt} is the error term, and the parameter of interest is the triple interaction term β_7. Table B.3 in Appendix B presents the triple different regression variables and their definitions.

Finally, we address potential endogeneity concerns related to each jurisdiction's regulatory approach when implementing open banking. This could affect the causal interpretation of our parameters of interest. To cope with this, we adopt the instrumental variable strategy, which we present in section 5.

3.4. **Summary Statistics**

Table 2 presents the firm-level and country-level data summary statistics for the “Pioneer” and “Later” analyses segregated by treatment and control groups. Panels A and B present the “Pioneer” summary statistics, and panels C and D show the “Later” summary statistics. In the “Pioneer” set of analyses, the treatment group comprises those countries treated in 2016, and the control group includes those countries implementing open banking in 2020 or later. For this, countries treated in 2018 and 2019 were excluded from the sample. In the “Later” set of analyses, the treatment group comprises countries implementing open banking in 2018, and the control group encompasses countries treated in 2020 onwards. In this set of analyses, countries treated in 2016 and 2019 were excluded from our sample.

Table 2. Summary Statistics for "Pioneer" and "Later" analysis set by treatment and control groups.

Panel A – Treatment Group summary statistics: Pioneer

	Mean	SD	Min	Max	Median	N
Gross Loans (unit: million)	174,539.22	254,054.23	228.69	895,623.88	23,006.77	125
Net Loans (unit: million)	186,582.02	262,998.9	230.29	880,988.94	22,583.87	122
Total Assets (unit: million)	303,772.65	414,794.14	308.92	1,038,007.6	28,169.14	122
Roe	.08	.07	-0.12	.29	.08	122
Capital Ratio	.1	.05	0.05	.26	.09	122
Interest Rate	0	0	0.00	.01	0	81
Ln(GDP)	14.19	.92	12.93	18.79	14.54	125
GDP growth	4.15	1.51	1.12	11.65	3.85	125
Inflation	1.24	.97	-0.53	3.94	1.03	125

Panel B – Control Group summary statistics: Pioneer

	Mean	SD	Min	Max	Median	N
Gross Loans (unit: million)	22,732.75	58,136.4	72.31	525,996.19	4,163.9	1,694
Net Loans (unit: million)	23,589.33	61,045.83	3.03	542,130.56	4,382.12	1,679
Total Assets (unit: million)	40,921.14	118,740.5	7.37	1,038,007.6	6,527.17	1,679
Roe	.11	.13	-2.01	.77	.11	1,679
Capital Ratio	.13	.07	0.03	.91	.12	1,679
Interest Rate	.01	.03	0.00	.61	0	1,239
Ln(GDP)	15.81	3.78	10.21	23.12	14.54	1,548
GDP growth	6.82	7.2	-29.46	37.99	6.61	1,694
Inflation	4.67	4.7	-2.09	48.7	3.45	1,673

Panel C – Treatment Group summary statistics: Later

	Mean	SD	Min	Max	Median	N
Gross Loans (unit: million)	45,928.52	139,539.15	72.31	895,623.88	3,989.41	3,883
Net Loans (unit: million)	47,668.62	143,303.41	3.03	880,988.94	4,127.65	3,872
Total Assets (unit: million)	76,638.87	212,507.10	52.51	1,038,007.6	6,139.22	3,870
Roe	.09	.71	-7.43	43.67	.08	3,863
Capital Ratio	.1	.04	-0.07	.73	.1	3,867
Interest Rate	0	.01	0.00	.11	0	2,055
Ln(GDP)	16.59	2.08	9.00	20.13	16.77	3,569
GDP growth	4.14	2.26	-7.26	29.87	4.1	3,883
Inflation	1.48	.94	-2.10	6.04	1.62	3,883

Panel D – Control Group summary statistics: Later

	Mean	SD	Min	Max	Median	N
Gross Loans (unit: million)	22,732.75	58,136.4	72.31	525,996.19	4,163.9	1,694
Net Loans (unit: million)	23,589.33	61,045.83	3.03	542,130.56	4,382.12	1,679
Total Assets (unit: million)	40,921.14	118,740.5	7.37	1,038,007.6	6,527.17	1,679
Roe	.11	.13	-2.01	.77	.11	1,679
Capital Ratio	.13	.07	0.03	.91	.12	1,679
Interest Rate	.01	.03	0.00	.61	0	1,239
Ln(GDP)	15.81	3.78	10.21	23.12	14.54	1,548
GDP growth	6.82	7.2	-29.46	37.99	6.61	1,694
Inflation	4.67	4.7	-2.09	48.7	3.45	1,673

Note: This table presents the summary statistics for the "pioneer" and "later" analyses separated by treatment and control groups. Panels A and B show the treatment and control groups' summary statistics for the "pioneer" analysis set. In the "pioneer", the treatment group comprises those countries that initiated open banking implementation in 2016, and the control group is those countries that implemented open banking from 2020 onwards. Countries treated in 2018 or 2019 are excluded for the sake of this analysis. Panels C and D present the treatment and control groups' summary statistics for the "later" analysis set. In the "later" section, the treatment group comprises those countries that initiated open banking implementation in 2018, and the control group comprises those countries that implemented open banking from 2020 onwards. Countries treated in 2016 or 2019 are excluded for the sake of this analysis. The winstorization process has proceeded at 1% and 99% levels for firm-level variables. The term *Gross Loans* refers to the total gross loans, which is

the nominal value of loans to customers, which may be further delineated in various categories such as by consumer and industrial customers, short-term or long-term maturities, or underlying securities (secured or not secured). *Net Loans* refer to the total net loans, which are the total loans to customers reduced by possible default losses and unearned interest income. *Capital Ratio* is calculated by dividing total equity by total assets (financial stability measure). *Interest rate* is calculated by the diving interest paid on deposits by the total deposits. *ROE* is calculated by dividing net income by equity. *Ln(GDP)* is the natural logarithm of gross domestic product in real terms. *GDP growth* is the Growth of gross domestic product in nominal terms, and *Inflation* is the percentage change in the price level in a given period measured by the consumer price index.

4. Results and discussion

This section presents the preliminary results and their respective discussion of each phase of our empirical strategy.

4.1. Parallel Trends: The Staggered Difference Phase

Table 3 presents the results of the pretreatment hypothesis testing using the staggered difference regressions on Equation (1). The null hypothesis is that all pretreatment group-time average treatment effects are statistically equal to zero. The results suggest that the assumption of parallel trends is fulfilled.

Table 3. Pre-treatment hypothesis testing.

	Gross Loans	Net Loans
chi2(4)	5.5247	4.1629
p-value	0.2376	0.3844

Note: This table presents the results of the pre-treatment hypothesis testing for the staggered difference approach using the Callaway and Sant'Anna (2021) estimator. The null hypothesis is that all Pre-treatment ATTGTs are equal to 0.

4.2. Triple Difference Phase

Tables 4 and 5 present the results for triple difference equations that we ran so far. For these tables, columns (1), (3), and (5) have the natural logarithm of total gross loans as their dependent variable. In contrast, Columns (2), (4), and (6) have the natural logarithm of total net loans as their dependent variable. We use no fixed effects for specifications (1) and (2); Time fixed effects only for specifications (3) and (4); and, for specifications (5) and

(6), we use time and country fixed effects.

Table 4. Triple difference regressions' results for Pioneer set

	(1)	(2)	(3)	(4)	(5)	(6)
Treat	0.1196**	0.1424**	0.1214**	0.1416**	-0.0314	-0.0563
	(0.0580)	(0.0640)	(0.0562)	(0.0647)	(0.1484)	(0.0890)
Post	-0.0231	-0.0154	-0.0655	-0.0163	-0.0933	-0.0776**
	(0.0212)	(0.0188)	(0.0594)	(0.0218)	(0.0641)	(0.0395)
Treat x Post	0.0134	0.0153	0.0157	0.0154	0.0142	0.0165
	(0.0216)	(0.0185)	(0.0231)	(0.0187)	(0.0244)	(0.0182)
Regulatory	0.0132	-0.0811	0.0179	-0.0814	-0.1568	-0.2607***
	(0.0814)	(0.0728)	(0.0836)	(0.0738)	(0.1222)	(0.0562)
Treat x Regulatory	-0.3071***	-0.2307***	-0.3081***	-0.2304***	0.0000	0.0000
	(0.0851)	(0.0855)	(0.0846)	(0.0861)	(0.0000)	(0.0000)
Post x Regulatory	0.0018	0.0303	0.0016	0.0305	-0.0080	0.0259
	(0.0443)	(0.0300)	(0.0453)	(0.0302)	(0.0422)	(0.0273)
Treat x Post x Regulatory	0.0472	-0.0365	0.0489	-0.0363	0.0637	-0.0185
	(0.0509)	(0.0288)	(0.0522)	(0.0289)	(0.0475)	(0.0243)
Ln (Assets)	0.9827***	0.9649***	0.9853***	0.9652***	0.9960***	0.9736***
	(0.0241)	(0.0165)	(0.0235)	(0.0164)	(0.0295)	(0.0168)
ROE	-0.1356***	0.0298	-0.1401***	0.0291	-0.1053*	0.0492
	(0.0472)	(0.0321)	(0.0502)	(0.0331)	(0.0589)	(0.0311)
Capital Ratio	-0.4018	-0.8551***	-0.3740	-0.8479***	-0.4788	-0.8568***
	(0.6067)	(0.2223)	(0.6321)	(0.2235)	(0.6429)	(0.2162)
Interest Rate	-0.3108	0.0678	-0.2640	0.0556	0.0049	0.0862
	(0.2918)	(0.3098)	(0.3388)	(0.3000)	(0.1771)	(0.3445)
Ln(GDP)	0.0452**	0.0491***	0.0443**	0.0488***	0.2195	0.3938***
	(0.0176)	(0.0152)	(0.0172)	(0.0151)	(0.2521)	(0.1265)
Inflation	-0.0141	0.0014	-0.0152	0.0014	-0.0115	0.0030
	(0.0101)	(0.0017)	(0.0109)	(0.0018)	(0.0132)	(0.0019)
Intercept	-0.9706***	-0.8760***	-0.9687***	-0.8759***	-3.5342	-5.7687***
	(0.1986)	(0.1985)	(0.1972)	(0.1981)	(3.5475)	(1.7703)
Time FE	No.	No.	Yes.	Yes.	Yes.	Yes.
Country FE	No.	No.	No.	No.	Yes.	Yes.

Note 1: This table presents the results of triple difference regressions for "Pioneer" set. In the "Pioneer", the treatment group comprises those countries that initiated open banking implementation in 2016, and the control group is those countries that implemented open banking from 2020 onwards. Countries treated in 2018 or 2019 are excluded for the sake of this analysis. Standard errors are in parenthesis. The logarithm of total gross loans is the dependent variable for Columns (1), (3) and (5). The logarithm of total net loans is the dependent variable for Column (2), (4) and (6). Standard errors are in parenthesis. *Ln(Gross Loans)* is the natural logarithm of total gross loans in local currency. *Ln(Net Loans)* is the natural logarithm of total net loans in local currency. *Ln(Assets)* is the natural logarithm of total assets in local currency. *Capital Ratio* is calculated by dividing total equity by total assets. *Interest rate* is calculated by the diving interest paid on deposits by the total deposits. *ROE* is calculated by dividing net income by equity. *Ln(GDP)* is the natural logarithm of a country's gross domestic product in real terms. *Inflation* is the percentage change in the price level in a given period measured by the consumer price index. Note 2: *** p<.01, ** p<.05, * p<.1.

For all specifications in Table 4, the results suggest that for countries treated in 2016, adopting different regulatory approaches does not result in different impacts of open banking implementation. The triple interaction term is not statistically significant or economically relevant. Further, for Pioneers, the interaction term between treatment and post-treatment variables is not statistically significant or economically relevant. Perhaps our results are biased by the huge difference between the total observations in the treatment group and the total observations in the control group.

Table 5. Triple difference regressions' results for Later set

	(1)	(2)	(3)	(4)	(5)	(6)
Treat	-0.2393***	-0.1946**	-0.2475***	-0.2052***	-0.2794	-0.5778*
	(0.0834)	(0.0818)	(0.0825)	(0.0791)	(0.5734)	(0.3191)
Post	0.0253	-0.0093	0.0266	0.0059	0.0237	-0.0223
	(0.0288)	(0.0216)	(0.0352)	(0.0260)	(0.0500)	(0.0366)
Treat x Post	0.0195	0.0435*	0.0219	0.0440*	0.0225	0.0510**
	(0.0309)	(0.0234)	(0.0320)	(0.0242)	(0.0350)	(0.0240)
Regulatory	-0.0205	-0.1034	-0.0209	-0.1088	0.5454	0.9560**
	(0.0967)	(0.0796)	(0.0985)	(0.0811)	(0.8869)	(0.4843)
Treat x Regulatory	0.1961**	0.2291**	0.2014**	0.2406***	0.0000	0.0000
	(0.0975)	(0.0918)	(0.0991)	(0.0924)	(0.0000)	(0.0000)
Post x Regulatory	-0.1028	0.0216	-0.1016	0.0220	-0.1021	0.0209
	(0.0880)	(0.0277)	(0.0875)	(0.0281)	(0.0877)	(0.0264)
Treat x Post x Regulatory	0.0664	-0.0730**	0.0628	-0.0746**	0.0594	-0.0775**
	(0.0979)	(0.0334)	(0.0972)	(0.0341)	(0.0990)	(0.0336)
Ln (Assets)	0.9535***	0.9648***	0.9522***	0.9624***	0.9447***	0.9659***
	(0.0101)	(0.0089)	(0.0101)	(0.0088)	(0.0172)	(0.0112)
ROE	0.0933	-0.1596***	0.0907	-0.1618***	0.0890	-0.1608***
	(0.0614)	(0.0500)	(0.0605)	(0.0499)	(0.0579)	(0.0510)

Capital Ratio	-0.6490*	-0.2677	-0.6687*	-0.2915	-0.7723**	-0.3135
	(0.3719)	(0.4028)	(0.3743)	(0.4008)	(0.3927)	(0.4160)
Interest Rate	-0.3458	-0.0682	-0.3080	-0.0551	-0.1767	-0.0221
	(0.2450)	(0.1994)	(0.2400)	(0.2004)	(0.1977)	(0.2317)
Ln(GDP)	0.0545***	0.0396***	0.0552***	0.0404***	0.1035	0.2176*
	(0.0143)	(0.0117)	(0.0144)	(0.0117)	(0.2145)	(0.1174)
Inflation	-0.0114	0.0038**	-0.0122	0.0039**	-0.0107	0.0045**
	(0.0095)	(0.0016)	(0.0100)	(0.0018)	(0.0109)	(0.0018)
Intercept	-0.9445***	-0.7703***	-0.9570***	-0.7786***	-1.7229	-3.3572**
	(0.2221)	(0.1814)	(0.2236)	(0.1833)	(3.0197)	(1.6469)
Time FE	No.	No.	Yes.	Yes.	Yes.	Yes.
Country FE	No.	No.	No.	No.	Yes.	Yes.

Note 1: This table presents the results of triple difference regressions for the "Later" set. In the "Later", the treatment group comprises those countries that initiated open banking implementation in 2018, and the control group comprises those countries that implemented open banking from 2020 onwards. Countries treated in 2016 or 2019 are excluded for the sake of this analysis. Standard errors are in parenthesis. The logarithm of total gross loans is the dependent variable for Columns (1), (3), and (5). The logarithm of total net loans is the dependent variable for Columns (2), (4), and (6). Standard errors are in parenthesis. Ln(Gross Loans) is the natural logarithm of total gross loans in local currency. Ln(Net Loans) is the natural logarithm of total net loans in local currency. Ln(Assets) is the natural logarithm of total assets in local currency. Capital Ratio is calculated by dividing total equity by total assets. Interest rate is calculated by the diving interest paid on deposits by the total deposits. ROE is calculated by dividing net income by equity. Ln(GDP) is the natural logarithm of a country's gross domestic product in real terms. Inflation is the percentage change in the price level in a given period measured by the consumer price index. Note 2: *** p<.01, ** p<.05, * p<.1.

Table 5 presents the results for countries treated in 2018. Open banking adoption, measured by the interaction term between treatment and post variables, positively impacts credit amounts when loan net proxy is used. No matter what regulatory approach is used, implementing open banking resulted in an average increase of 4.6% in total net loans for those countries that implemented open banking compared to those that implemented it in 2020 or later.

This preliminary result provides empirical evidence for the theoretical prediction that loan loss reduction occurs due to information sharing (Karapetyan & Stacescu, 2014) through open banking. It provides empirical evidence for the theoretical prediction that open banking implementation should improve new entrants' screening abilities. Information sharing improves their ability to identify low-quality and high-quality borrowers (He et al., 2023), increasing credit availability.

When the triple interaction term is analyzed, the results suggest that different regulatory approaches impact total net loans; however, it is not statistically different from zero when total gross loans are examined. Our results suggest that a mandatory approach

reduces total net loans by 7.5% on average compared to less strict regulatory approaches such as collaborative or market-driven ones.

These results may indicate that the informational content of the shared information in a prescriptive approach could not improve credit quality concession as much as the less strict approaches did. The mandatory approach's open banking framework seems less effective in reducing adverse selection costs than in collaborative and market approaches, which would, for example, impact policymakers' financial inclusion goals.

Besides, less strict regulatory approaches such as hybrid-driven and market-driven should be more successful in addressing the challenges related to the willingness to adopt open banking as it relates, for example, to whether individuals trust an open banking ecosystem to share their data if they have financial education, or can use mobile devices (Sivathanu, 2019; Chen et al., 2022; Rosati et al., 2022). The behavioral aspect of open banking is out of the scope of this research. However, these empirical results shed some light on how impactful it might be, which would be examined in future research.

These results suggest that open banking increases credit amounts, measured by total net loans, no matter what regulatory approach is implemented. However, when different regulatory approaches are examined, the results suggest that, on average, the mandatory approach is less effective in increasing the quality of credit concession than collaborative and market-driven approaches.

One might be concerned about potential endogeneity in these results, as regulatory decisions might be influenced by market structural features, preventing a causal interpretation of them. In the next section, we address such concerns in detail.

5. Addressing Endogeneity

The regulatory approach chosen to implement open banking might be closely related to the time-varying unobserved features of each jurisdiction, such as its market structural features, which might indicate the presence of the omitted variable bias. To address endogeneity concerns, we implement the instrumental variable strategy. Open banking regulation affects market structure by lessening informational asymmetry among lenders and fostering competition in credit markets (He et al., 2023). Consequently, the choice of regulatory approach should be closely related to the banking sector's competitiveness in a specific country (or jurisdiction).

Following this rationale, we based our instrumental variable choice on the literature on measuring competition. We use the structure–conduct–performance (SCP) paradigm, which argues that more concentrated banking markets lead to less competitive behavior, which might, in turn, positively impact the bank's performance as our theoretical foundation. It examines market structure and competition relationships using concentration ratios (Bikker & Haaf, 2002b) as proxies for market concentration.

The Herfindahl-Hirschman Index is a concentration ratio popularly used in empirical banking literature as a proxy for the market structure (Bikker & Haaf, 2002a). The SCP paradigm's empirical research provides evidence of the relationship between market structure (measured by its concentration level) and a bank's performance and between market structure and deposit rates (Degryse et al., 2009).

The HHI is a valid instrument for regulatory variables, as market concentration affects regulatory choices but does not directly impact the outcome variables of interest, i.e., total gross and net loans, thus satisfying the relevance condition and the exclusion restriction requirements. Besides, as the Herfindahl-Hirschman Index is a structural measure of banking sector concentration, it does not suffer from reverse causality due to its aggregate nature at the country level. Definition B.1 in Appendix B presents the HHI concept and description.

Previously, we used the triple difference specification to analyze the impact of different regulatory approaches on credit amounts for countries that implemented open banking. The triple difference method enabled us to examine differences between subgroups within the treatment group (Cunningham, 2021), as it is an extension of the Diff-in-Diff estimator (Angrist & Pischke, 2009); the triple difference estimator is analogous to the difference between two difference-in-difference estimators (Olden & Møen, 2022).

To address the endogeneity concerns and enhance our interpretation, we split our triple difference specification into two difference-in-difference specifications, DiD_1 and DiD_2, and then we used the 2SLS model. We focused our examination on the "Later" set of analyses, that is, on countries that began implementing open banking in 2018 because the "Later" results were statistically significant and economically relevant.

For our first Difference-in-Differences specification (DiD_1), we define as our treatment group those countries that adopted the prescriptive regulatory approach to implement open banking. Further, we exclude those countries that implemented open banking using less strict regulatory approaches (i.e., collaborative and market-driven).

For our second difference-in-differences specification (DiD_2), we define it as treating those countries that adopted either the hybrid-driven or market-driven regulatory approaches to implement open banking. Further, we exclude those countries that implemented open banking using a mandatory approach.

Further, to calculate DiD_1 and DiD_2, we exclude all countries that implemented open banking in 2016 and 2019. Our control group for both calculations comprises those countries that implemented open banking from 2020 onwards. Equations (3), (4), and (5) present our baseline regressions for both difference-in-differences specifications DiD_1 and DiD_2 and the triple difference estimator:

$$DiD_1: Y_{ict} = \beta_0 + \beta_1 mandatory_c + \beta_2 post_t + \beta_3 mandatory_c \times post_t + \beta_4 X_{it} + \delta_t + \delta_c + \epsilon_{ict} \quad (3)$$

$$DiD_2: Y_{ict} = \alpha_0 + \alpha_1 HMD_c + \alpha_2 post_t + \alpha_3 HMD_c \times post_t + \alpha_4 X_{it} + \delta_t + \delta_c + \epsilon_{ict} \quad (4)$$

$$TripleDiffEstimator: \Delta = \beta_3 - \alpha_3 \quad (5)$$

Where Y_{ict} is the dependent variable can be either the natural logarithm of total gross loans or the natural logarithm of total net loans for bank i, whose headquarters is in country c, which implemented open banking in 2018 in year t.

Mandatory is a binary variable equal to 1 for treated countries that adopted the regulatory mandatory approach to implement open banking and zero otherwise. Besides, *HMD* is a dummy variable equal to 1 for treated countries that adopted either the hybrid or the market-driven regulatory approach to implement open banking in their jurisdictions.

Post is a binary variable equal to 1 for post-treatment periods and zero otherwise. X_{it} is the matrix of covariates, δ_t is the year fixed effect, and δ_c is the country fixed effect and, ϵ_{ict} is the error term. Lastly, Δ is the triple difference estimator.

Once the DiD_1 and DiD_2 specifications have been defined, we estimate the 2SLS model. Equations (6) and (7) present our baseline first-stage equations of the 2SLS model for DiD_1 and DiD_2, where the variable can represent either the variable *mandatory* or *HMD* depending on which DiD specification we are dealing with:

$$treat_c = \gamma_0 + \gamma_1 HHI_c + \gamma_2 X_{it} + \delta_t + \delta_c + \xi_{ict} \quad (6)$$

$$(treat_c \times post_t) = \theta_0 + \theta_1 (HHI_c \times post_t) + \theta_2 X_{it} + \delta_t + \delta_c + \vartheta_{ict} \quad (7)$$

HHI_c and $(HHI_c\, x\, post_t)$ instrument, respectively, the variable $treat$ and its interaction term. We estimate the equation (8) in the second stage of the 2SLS model for DiD_1 and DiD_2:

$$Y_{ict} = \psi_0 + \psi_1 \widehat{treat}_c + \psi_2 post_t + \psi_3 (\widehat{treat_c \times post_t}) + \psi_4 X_{it} + \delta_t + \delta_c + \mu_{ict} \qquad (8)$$

Where $\widehat{treat}_c$ and $(\widehat{treat_c \times post_t})$ are the estimated values by first-stage equations, whereas other variables' definitions were defined previously. For each DiD specification, our parameter of interest is the coefficient of interaction term estimated. By computing both, we are able to calculate the triple difference estimator and compare with our previous results. We focus our analyses on the two most complete specifications of the triple difference estimator for the "Later" set of analyses, that is, columns (5) and (6) of Table 5. To address endogeneity, we decomposed our triple difference estimator into two Difference-in-Differences estimators and proceeded with the 2SLS model estimation.

Table 6 presents the results for the second-stage equations of the 2SLS model. Columns (1) and (2) in Table 6 relate to column (5) in Table 5. On the other hand, columns (3) and (4) in Table 6 relate to column (6) in Table 5.

Table 6. The second-stage results for the 2SLS model for Later set

	(1)	(2)	(3)	(4)
Mandatory	0.0000		0.0000	
	(0.0000)		(0.0000)	
HMD		0.0000		0.0000
		(0.0000)		(0.0000)
Mandatory x post	-0.0625		-0.0549*	
	(0.0506)		(0.0282)	
HMD x post		0.0617*		0.0534**
		(0.0372)		(0.0224)
Ln (Assets)	0.8151***	0.8268***	0.9758***	0.9860***
	(0.1120)	(0.1124)	(0.0300)	(0.0305)
ROE	0.0797	0.0781	-0.1544***	-0.1558***
	(0.0522)	(0.0515)	(0.0497)	(0.0491)
Capital Ratio	-0.7020**	-0.7083**	-0.2206	-0.2257
	(0.3125)	(0.3045)	(0.4262)	(0.4215)

Interest Rate	-0.5324***	-0.4990***	-0.0250	0.0042
	(0.1867)	(0.1913)	(0.2779)	(0.2755)
Ln (GDP)	0.0016	0.0011	0.0002	-0.0002
	(0.0032)	(0.0032)	(0.0021)	(0.0022)
Inflation	-0.0073	-0.0087	0.0052***	0.0040***
	(0.0091)	(0.0085)	(0.0017)	(0.0013)
Post	0.0487***	0.0089	0.0233**	-0.0112
	(0.0111)	(0.0251)	(0.0093)	(0.0148)
Intercept	0.4337	0.3878	-0.3019*	-0.3421**
	(0.5154)	(0.5121)	(0.1628)	(0.1623)
Time FE	Yes.	Yes.	Yes.	Yes.
Country FE	Yes.	Yes.	Yes.	Yes.

Note 1: This table presents the second stage of the 2SLS regressions results for "Later" set of analyses. These results address potential endogeneity concerns about omitted variables affecting the choice of regulatory approach. In the "Later", the treatment group comprises those countries that initiated open banking implementation in 2018, and the control group comprises those countries that implemented open banking from 2020 onwards. Countries treated in 2016 or 2019 are excluded for the sake of this analysis. Standard errors are in parenthesis. The logarithm of total gross loans is the dependent variable for Columns (1) and (2). The logarithm of total net loans is the dependent variable for Columns (3) and (4). *Ln(Gross Loans)* is the natural logarithm of total gross loans in local currency. *Ln(Net Loans)* is the natural logarithm of total net loans in local currency. *Ln(Assets)* is the natural logarithm of total assets in local currency. *Capital Ratio* is calculated by dividing total equity by total assets. *Interest rate* is calculated by the diving interest paid on deposits by the total deposits. *ROE* is calculated by dividing net income by equity. *Ln(GDP)* is the natural logarithm of a country's gross domestic product in real terms. *Inflation* is the percentage change in the price level in a given period measured by the consumer price index. HMD is a dummy variable that equals 1 if the regulatory approach is hybrid-driven or market-driven and zero otherwise. Mandatory is a binary variable equal to 1 if the regulatory approach is mandatory and zero otherwise. Note 2: The HHI and its interaction term are our instrumental variables in the first stage of 2SLS regressions. Note 3: *** p<.01, ** p<.05, * p<.1.

Column (1) presents the estimated coefficients from the second stage of the 2SLS model, which uses total gross loans as its dependent variable for countries that implemented the prescriptive approach in 2018. In contrast, Column (3) displays the estimated coefficients from the second stage of the 2SLS model, where total net loans act as the dependent variable for countries that also implemented the prescriptive approach in 2018.

Column (2) shows the estimated coefficients from the second stage of the 2SLS model. It utilizes total gross loans as its dependent variable for countries using the collaborative or industry-

led approach in 2018. In contrast, Column (3) displays the estimated coefficients from the second stage of the 2SLS model, where total net loans function as the dependent variable for countries that also implemented the prescriptive approach in 2018.

The interaction term between mandatory and post variables in column (3) and the interaction term between HMD and post variables in column (4) do not corroborate our previous results that no matter what regulatory approach is adopted, the total net loans increase. In fact, after instrumenting our endogenous variables, the results suggest that for prescriptive approaches, the total net loans decrease by approximately 5.49%, while in hybrid and market-driven approaches, total net loans increase by approximately 5.34%; both results are statistically significant and economically relevant. Reconstructing our triple difference estimator, we would say that it would be after addressing endogeneity approximately -10.83% (i.e., -0.0549 - 0.0534), what is economically more impactful than the triple difference estimator results presented in Table 5, column 6 represented by the triple interaction term whose value was approximately -7.75% .

When examining the results in column (2), the interaction term between HMD and post, the results suggest total gross loans increase for less strict regulatory approaches when endogeneity is addressed. This result contradicts the result in Table 5, column (5), as the interaction term between treat and post shows no statistical significance or economic relevance.

The results after addressing endogeneity corroborate that the collaborative and industry-led approaches increase total net loans, suggesting a better screening ability by market participants. Besides, they show that these regulatory approaches perform better in total gross loans. However, the results do not reiterate that credit availability increases no matter what regulatory approach each jurisdiction adopts.

6. Conclusion

Using a comprehensive sample, this paper examined the impacts of open banking's different regulatory approaches on credit volumes. This research proposes a straightforward regulatory classification tool. It presents preliminary empirical evidence on whether and to what extent different open banking regulatory approaches result in different economic impacts on lending markets.

We propose a regulatory classification tool and show how to implement it. Our empirical results suggest that open banking increases credit availability in less strict approaches measured by total gross loans. Further, the results suggest that the mandatory approach is less effective in reducing loan losses than collaborative and market-driven approaches measured by total net loans.

To address potential endogeneity concerns related to the time-varying unobserved features of each jurisdiction, we adopted the 2SLS model and used the Herfindahl-Hirschman Index as our instrumental variable. To do so, we used the triple difference estimator and adopted two double difference estimators. These results also suggest that more flexible approaches should be advisable, as open banking depends on each individual's exercise of free will. This might work differently from previous information-sharing ecosystems such as those between lenders (i.e., private credit bureaus and public credit registers). Previous researchers in open banking literature have been signaling the importance of financial education and other variables related to behavior for open banking flourishment. It opens a new path for future research.

This research has social and practical implications. It encourages further exploration of regulatory aspects of open banking by proposing a regulatory classification tool and detailed execution steps to promote further research. For practitioners and policymakers, it sheds some light on improving future regulatory designs and promoting better capital allocation.

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Appendix A

Appendix A presents each phase of countries regulatory classification.

Tables

Table A.1 – Regulatory approaches classification - Phase one: Comparing reports

Country	BCBS (2019)	BIS (2020)	WB (2022)
Argentina	Market	-	-
Australia	In process of developing rules.	Prescriptive	-
Austria	-	Prescriptive	Regulatory driven
Belgium	Prescriptive	Prescriptive	Regulatory driven
Brazil	In process of developing rules.	Prescriptive	-
Bulgaria	-	-	Regulatory driven
Canada	Actively considering adopting Open Banking.	-	-
China	Market	-	-
Croatia	-	-	Regulatory driven
Cyprus	-	-	Regulatory driven
Denmark	-	-	Regulatory driven
Estonia	-	-	Regulatory driven
Finland	-	-	Regulatory driven
France	Prescriptive	Prescriptive	Regulatory driven
Germany	Prescriptive	Prescriptive	Regulatory driven
Greece	-	-	Regulatory driven
Hong Kong	Facilitative	Facilitative	Collaborative
Hungary	-	-	Regulatory driven
India	Prescriptive	-	Regulatory driven
Ireland	-	-	Regulatory driven
Italy	Prescriptive	Prescriptive	Regulatory driven
Japan	Facilitative	Facilitative	Collaborative
South Korea	Facilitative	-	-
Malta	-	-	Regulatory driven
Mexico	Prescriptive	Prescriptive	-
Netherlands	Prescriptive	Prescriptive	Regulatory driven
New Zealand	-	-	Industry led
Poland	-	Prescriptive	Regulatory driven
Romania	-	-	Regulatory driven
Russia	In process of developing rules.	-	-
Singapore	Facilitative	Facilitative	Collaborative
Slovenia	-	-	Regulatory driven
South Africa	Prescriptive	-	-
Spain	Prescriptive	Prescriptive	Regulatory driven
Sweden	Prescriptive	Prescriptive	Regulatory driven
Switzerland	-	Prescriptive	-
Turkey	Actively considering adopting Open Banking.	Prescriptive	-
United Kingdom	Prescriptive	Prescriptive	Regulatory driven

United States of America	Market	-	Industry led

Note: This table presents the regulatory approach classification performed by the Basel Committee on Banking Supervision, the Bank for International Settlements, and the Organization for Economic Cooperation and Development. In total, 39 different jurisdictions were found in such reports.

Table A.2 – Regulatory classification tool: overview

What is examined?	Public documents available in Central Banks and Monetary Authority sites and Central Banker's speeches	Examples:
Feature 1	**Does the Central bank or Monetary authority explicitly classify their regulatory approach?**	
	Yes. → Final classification = Central Banks or Monetary Authority self-classification	India
	No. → Final classification = (Feature 2 + Feature 3) or (Feature 4)	South Africa
Feature 2	**Technical Requirements**	
	If mandated by legal act → prescriptive	United Kingdom
	If recommendations or guidelines → collaborative	Singapore
	Nonbinding issued by industry participants → market-driven	Switzerland
Feature 3	**Participants' participation**	
	If mandatory → prescriptive	Brazil
	If voluntary → it can be either hybrid or market-driven	USA
Feature 4	**Is there only public consultation, an Internal working committee, or both?**	
	Yes. → labeled as prescriptive	Sri Lanka
	No. → to classify, use feature 1 decision rule.	USA

Note: This table details the regulatory tool created to classify jurisdictions that pursue open banking implementation. We used this tool to classify those unclassified countries in Table A,1 and new jurisdictions pursuing open banking implementation. We also checked if the countries that had already been classified remained in the same classification. For example, due to the central banker's speech, India was reclassified as Hybrid-driven instead of prescriptive.

Table A.3 – Constructing hand-collected database – Phase one: Mapping Countries to pursue further research on public documents and classification.

Country	BCBS (2019)	BIS (2020)	WB (2022)	OBE (2023)	OECD (2023a,b,c,d)	Grey Literature
Angola	-	-	-	-	-	cited[(2)]
Argentina	cited	-	-	cited	-	cited[(1)]
Australia	cited	cited	-	cited	cited	cited[(3)]
Austria	-	cited	cited	-	cited	
Azerbaijan	-	-	-	-	-	cited[(3)]
Bahrain	-	-	-	cited	-	cited[(2)]
Belgium	cited	cited	cited	-	cited	-
Brazil	cited	cited	-	cited	-	cited[(1)]
Bulgaria	-	-	cited	-	cited	-
Canada	cited	-	-	cited	-	cited[(3)]
Chile	-	-	-	cited	-	cited[(1)]
China	cited	-	-	-	-	-
Colombia	-	-	-	cited	-	cited[(1)]
Croatia	-	-	cited	-	cited	-
Cyprus	-	-	cited	-	cited	-
Denmark	-	-	cited	-	cited	-
Egypt	-	-	-	-	-	cited[(3)]
Estonia	-	-	cited	-	cited	cited[(3)]
Finland	-	-	cited	-	cited	cited[(3)]
France	cited	cited	cited	cited	cited	cited[(3)]
Germany	cited	cited	cited	cited	cited	cited[(3)]
Ghana	-	-	-	-	cited	cited[(3)]
Greece	-	-	cited	-	-	-
Hong Kong	cited	cited	cited	-	-	cited[(2)]
Hungary	-	-	cited	-	-	
India	cited	-	cited	cited	cited	cited[(2)]
Indonesia	-	-	-	-	cited	cited[(2)]
Ireland	-	-	cited	-	-	cited[(2)]
Israel	-	-	-	cited	cited	cited[(2)]
Italy	cited	cited	cited	-	-	cited[(2)]
Japan	cited	cited	cited	-	cited	cited[(2)]
Jordan	-	-	-	-	-	cited[(3)]
Kazakhstan	-	-	-	-	-	cited[(2)]
Kenya	-	-	-	-	cited	cited[(2)]
South Korea	cited	-	-	-	-	cited[(3)]
Kuwait	-	-	-	-	-	cited[(3)]
Malaysia	-	-	-	-	-	cited[(2)]
Malta	-	-	cited	-	-	-
Mauritius	-	-	-	-	cited	-
Mexico	cited	cited	-	cited	-	cited[(1)]
Netherlands	cited	cited	cited	cited	-	-

New Zealand	-	-	cited	-	-	cited[3]
Nigeria	-	-	-	cited	cited	cited[3]
Oman	-	-	-	-	-	cited[3]
Peru	-	-	-	-	-	cited[1]
Philippines	-	-	-	-	-	cited[2]
Poland	-	cited	cited	-	cited	-
Qatar	-	-	-	-	-	cited[3]
Romania	-	-	cited	-	-	-
Russia	cited	-	-	-	-	cited[2]
Rwanda	-	-	-	-	cited	-
Saudi Arabia	-	-	-	cited	-	cited[2]
Singapore	cited	cited	cited	cited	-	cited[2]
Slovenia	-	-	cited	-	-	-
South Africa	cited	-	-	-	cited	cited[2]
Spain	cited	cited	cited	cited	-	cited[2]
Sri Lanka	-	-	-	-	-	cited[2]
Sweden	cited	cited	cited	-	-	cited[2]
Switzerland	-	cited	-	-	-	cited[2]
Taiwan	-	-	-	-	-	cited[2]
Turkey	cited	cited	-	-	-	cited[2]
Ukraine	-	-	-	-	-	cited[2]
United Arab Emirates	-	-	-	cited	-	cited[2]
United Kingdom	cited	cited	cited	cited	cited	cited[2]
United States	cited	-	cited	cited	cited	cited[2]

Note 1: This table presents the mapped countries pursuing open banking implementation. The mapping resulted in a sample of seventy countries to be further investigated. **Note 2 - Column "Grey Literature":** (1) Mastercard (2024) - Open Banking in Latin America; (2) Mastercard (2021) - Open Finance: A framework for the Arab region is more than a question of scope; (3) Konsentus (2023) - The World of Open Banking Map.

Table A.4 – Constructing hand-collected database – Phase three: Countries by regulatory classification and year of implementation

Country	Year	Classification
Angola	2020	Mandatory
Argentina	2023	Mandatory
Australia	2019	Mandatory
Austria	2018	Mandatory
Azerbaijan	2022	Mandatory
Bahrain	2018	Mandatory
Belgium	2018	Mandatory
Brazil	2020	Mandatory
Bulgaria	2018	Mandatory
Canada	2023	Hybrid Driven
Chile	2022	Mandatory
China	2018	Market Driven
Colombia	2023	Hybrid Driven
Croatia	2018	Mandatory
Cyprus	2018	Mandatory
Denmark	2018	Mandatory
Egypt	2021	Mandatory
Estonia	2018	Mandatory
Finland	2018	Mandatory
France	2018	Mandatory
Germany	2018	Mandatory
Ghana	2024	Mandatory
Greece	2018	Mandatory
Hong Kong	2018	Hybrid Driven
Hungary	2018	Mandatory
India	2016	Hybrid Driven
Indonesia	2021	Market Driven
Ireland	2018	Mandatory
Israel	2020	Mandatory
Italy	2018	Mandatory
Japan	2018	Hybrid Driven
Jordan	2022	Mandatory
Kazakhstan	2024	Mandatory
Kenya	2020	Mandatory
South Korea	2019	Hybrid Driven
Kuwait	2023	Mandatory
Malaysia	2018	Hybrid Driven
Malta	2018	Mandatory
Mauritius	2019	Mandatory
Mexico	2018	Mandatory
Netherlands	2018	Mandatory
New Zealand	2024	Market Driven
Nigeria	2021	Hybrid Driven
Oman	2023	Mandatory
Peru	2023	Mandatory

Philippines	2023	Mandatory
Poland	2018	Mandatory
Qatar	2024	Mandatory
Romania	2018	Mandatory
Russia	2020	Mandatory
Saudi Arabia	2022	Mandatory
Singapore	2016	Hybrid Driven
Slovenia	2018	Mandatory
South Africa	NA	Mandatory
Spain	2018	Mandatory
Sri Lanka	NA	Mandatory
Sweden	2018	Mandatory
Switzerland	2020	Market Driven
Taiwan	2019	Hybrid Driven
Turkey	2020	Mandatory
Ukraine	2025	Mandatory
United Arab Emirates	2026	Market Driven
United Kingdom	2016	Mandatory
United States of America	2018	Market Driven

Note: This table presents the mapped countries in phase three of hand-collection data building process. Each country is presented by open banking implementation year and regulatory approach classification. Each country was classified by using the regulatory classification tool created. Countries labeled as 'NA' conducted only public consultation, formed an internal working committee, or both. However, they did not release any document on the open banking framework or timeline until December 2023.

Table A.5 – Final sample after filtering and cleaning procedures.

Country	Year	Classification
Argentina	2023	Mandatory
Australia	2019	Mandatory
Austria	2018	Mandatory
Bahrain	2018	Mandatory
Belgium	2018	Mandatory
Brazil	2020	Mandatory
Bulgaria	2018	Mandatory
Canada	2023	Hybrid Driven
Chile	2022	Mandatory
China	2018	Market Driven
Colombia	2023	Hybrid Driven
Croatia	2018	Mandatory
Cyprus	2018	Mandatory
Denmark	2018	Mandatory
Egypt	2021	Mandatory
Estonia	2018	Mandatory
Finland	2018	Mandatory
France	2018	Mandatory
Germany	2018	Mandatory
Ghana	2024	Mandatory
Greece	2018	Mandatory
Hong Kong	2018	Hybrid Driven
Hungary	2018	Mandatory
India	2016	Hybrid Driven
Indonesia	2021	Market Driven
Ireland; Republic of	2018	Mandatory
Israel	2020	Mandatory
Italy	2018	Mandatory
Japan	2018	Hybrid Driven
Jordan	2022	Mandatory
Kazakhstan	2024	Mandatory
Kenya	2020	Mandatory
Korea; Republic (S. Korea)	2019	Hybrid Driven
Kuwait	2023	Mandatory
Luxembourg	2018	Mandatory
Malaysia	2018	Hybrid Driven
Malta	2018	Mandatory
Mexico	2018	Mandatory
Netherlands	2018	Mandatory
New Zealand	2024	Market Driven
Nigeria	2021	Hybrid Driven
Oman	2023	Mandatory
Peru	2023	Mandatory
Philippines	2023	Mandatory
Poland	2018	Mandatory
Qatar	2024	Mandatory

Romania	2018	Mandatory
Russia	2020	Mandatory
Saudi Arabia	2022	Mandatory
Singapore	2016	Hybrid Driven
Slovenia	2018	Mandatory
South Africa	NA	Mandatory
Spain	2018	Mandatory
Sri Lanka	NA	Mandatory
Sweden	2018	Mandatory
Switzerland	2020	Market Driven
Taiwan	2019	Hybrid Driven
Turkey	2020	Mandatory
Ukraine	2025	Mandatory
United Arab Emirates	2026	Market Driven
United Kingdom	2016	Mandatory
United States of America	2018	Market Driven

Note: This table presents the final sample of countries after filtering and cleaning procedures detailed in the Methodology section. Each country is presented by its open banking implementation year and regulatory approach. Countries labeled 'NA' conducted only public consultation, formed an internal working committee, or both. However, they did not release any document on the open banking framework or timeline until December 2023. After the filtering and cleaning procedures, our final sample totals 61 countries.

Appendix B

Appendix B presents the variables used in this research by their definitions.

Tables and Definitions

Table B.1 – Variables definitions – building research's dataset

Panel A - Country-level Variables

Variable	Definition	Source
Country	The government, central bank, or Monetary Authority released one of the following documents concerning open banking: public consultation, operational or security standards, legal act, banks' association cooperation agreement, open banking framework, open banking timeline, press releases, or official speeches.	Hand-collected database
Year	It represents the year the first phase of open banking implementation was scheduled.	Hand-collected database
Regulatory Classification	It represents the regulatory approach classification of each country in our sample according to the analyzed documents. Mandatory (or prescriptive); Hybrid (or collaborative); Market-Driven (or industry-lead).	Hand-collected database
GDP Growth	Growth of gross domestic product	International Financial Statistics | IMF
Inflation	it is the percentage change in the price level in a given period measured by the consumer price index.	International Financial Statistics | IMF
Exchange rate	Official exchange rates. Domestic currency per dollar - end of period.	International Financial Statistics | IMF

Panel B - Firm-level Variables

Variable	Definition	Source
Total Gross Loans	It represents the nominal value of loans to customers. Loans to customers may be further delineated in various categories, such as by customers (consumer or industrial), by maturity (short-term or long-term), or by underlying securities (secured or not secured), either on the balance sheet or in a footnote to the financial statement. It excludes (deferred) loan fees and loans held for sale.	Thomson Reuters DataStream
Net Loans	It represents total loans to customers, reduced by possible default losses and unearned interest income.	Thomson Reuters DataStream
Total Equity	It consists of the equity value of preferred shareholders, general and limited partners, and common shareholders, but does not	Thomson Reuters DataStream

	include minority shareholders' interests.	
Total Assets	It represents a company's total assets, which are the sum of Cash and due from banks; Other Earning Assets, Total; Net Loans; property/Plant/Equipment, Total-net; goodwill, Net; intangibles, Net; Long-Term Investments; Other Long-Term Assets, Total; and Other Assets, Total.	Thomson Reuters DataStream
Interest on Deposits	It represents interest paid on deposits from customers. Types of deposits may include demand/checking deposits, non-interest-bearing/interest-bearing deposits, savings deposits, money market accounts, NOW accounts (which were not used anymore after the Dodd-Frank Act of 2010), time deposit accounts, and certificates of deposit. It excludes Interest paid on short-term and long-term borrowings (classified as Interest on Other Borrowings).	Thomson Reuters DataStream
Total Deposits	It represents the sum of Non-Interest-Bearing Deposits, Interest-Bearing Deposits, and Other Deposits.	Thomson Reuters DataStream
Net Income	It represents Net Income Before Taxes, offset by the Provision for Income Taxes. Net Income Before Taxes is calculated as the sum of Net Interest Income After Loan Loss Provision, Net Interest Income, Loan Loss Provision, Non-Interest Income, and Non-Interest Expense.	Thomson Reuters DataStream

Note: This table presents the variables' definitions of building datasets for this research.

Table B.2 – Staggered difference regression: Variables used and their definitions.

Variable	Definition	Type
Ln(Gross_Loans)	It is the natural logarithm of total nominal value of gross loans to customers in local currency.	Dependent variable
Ln(Net_Loans)	It is the natural logarithm of total nominal value of net loans to customers in local currency.	Dependent variable
$G_{i,c,g}$	It is a binary variable equal to 1 if the financial institution i, whose headquarters is in country c, belongs to the treated group g, and 0 if otherwise	Binary
$1\{T=t\}$	It is the indicator function equal to 1 for post-treatment periods and 0 otherwise.	Binary
Ln(Assets)	It is the natural logarithm of total assets.	Covariate Matrix
Return on equity (ROE)	It is the net income divided by equity.	Covariate Matrix
Capital Ratio	It is the total equity divided by total assets.	Covariate Matrix
Interest Rate	It is the interest paid on deposits divided by total deposits.	Covariate Matrix
Ln(GDP)	It is the natural logarithm of gross domestic product in real terms.	Covariate Matrix
Inflation	It is the percentage change in the price level in a given period measured by the consumer price index.	Covariate Matrix

Note: This table presents the variables used in staggered difference regression and their respective definition.

Table B.3 – Triple difference regressions: Variables used and their definitions

Variable	Definition	Type
Ln(Gross_Loans)	It is the natural logarithm of the total nominal value of gross loans to customers in local currency.	Dependent variable
Ln(Net_Loans)	It is the natural logarithm of the total nominal value of net loans to customers in local currency.	Dependent variable
Post	it is a dummy variable that equals 1 for post-treatment periods and 0 otherwise.	Binary
Treat	It is a dummy variable that equals 1 for countries that implemented open banking in the period of analyses and 0 if they belong to the control group.	Binary
Regulatory	It is a dummy variable equal to 1 if the country adopted a "mandatory" regulatory approach and 0 if it adopted a "hybrid" or "market-led" regulatory approach.	Binary
Ln(Assets)	It is the natural logarithm of total assets.	Covariate Matrix
Return on equity (ROE)	It is the net income divided by equity.	Covariate Matrix
Capital Ratio	It is the total equity divided by total assets.	Covariate Matrix
Interest rate	It is the interest paid on deposits divided by total deposits.	Covariate Matrix
Ln(GDP)	It is the natural logarithm of gross domestic product in real terms.	Covariate Matrix
Inflation	It is the percentage change in the price level in a given period measured by the consumer price index.	Covariate Matrix

Note: This table presents the variables used in triple difference regressions and their respective definition. These variables are used for the "Pioneer" and "Later" analyses.

Definition B.1 - The Herfindahl-Hirschman Index (HHI)

The Herfindahl-Hirschman Index (HHI) is a measure of market concentration (Rhoades, 1993). It is equal to the sum of squares of the participants' market shares in the banking industry, according to the following formula:

$$HHI = \sum_{i=1}^{n} s_{ic}^2$$

$$s_{ic} = \frac{q_{ic}}{Q_c} \, x \, 100\%$$

where,

$s_{ic} \equiv$ market share of the i^{th} bank, whose headquarters is located in country c.

$q_{ic} \equiv$ total assets of the i^{th} bank, whose headquarters is located in country c.

$Q_c \equiv$ total assets value of the total banking sector of country c.

According to the Herfindahl-Hirschman Index's values, the banking sector of a specific jurisdiction can be classified as:

HHI < 1000 → non-concentrated;

1000 ≤ HHI < 1800 → moderately concentrated;

1800 ≤ HHI < 2600 → highly concentrated;

2600 ≤ HHI < 10000 → very highly concentrated; and

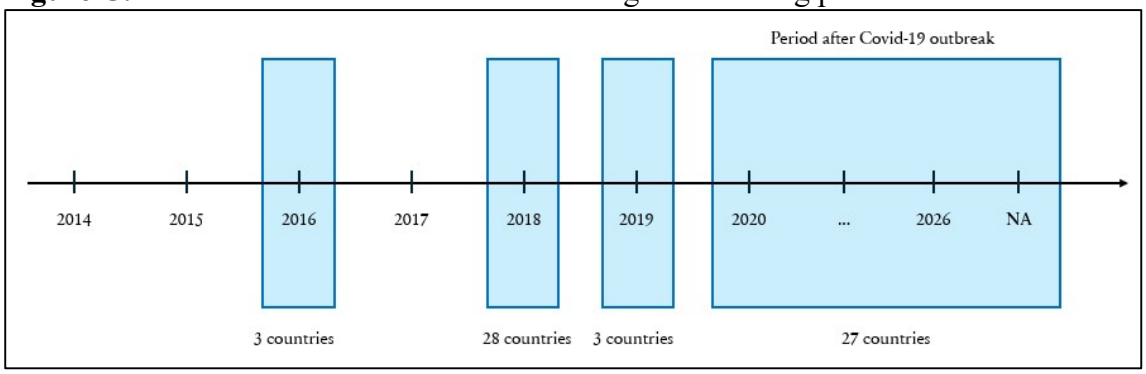
HHI = 10000 → fully concentrated (i.e., monopoly markets).

Appendix C

Appendix C presents the illustration of the database and empirical strategies employed.

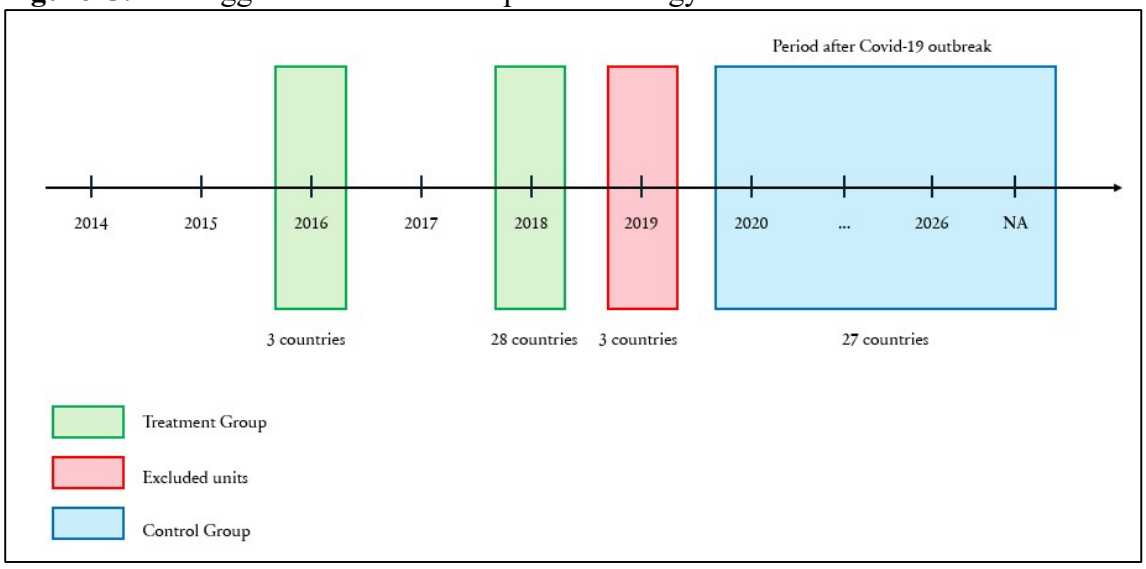
Figures

Figure C.1 – Database Overview – After filtering and cleaning processes



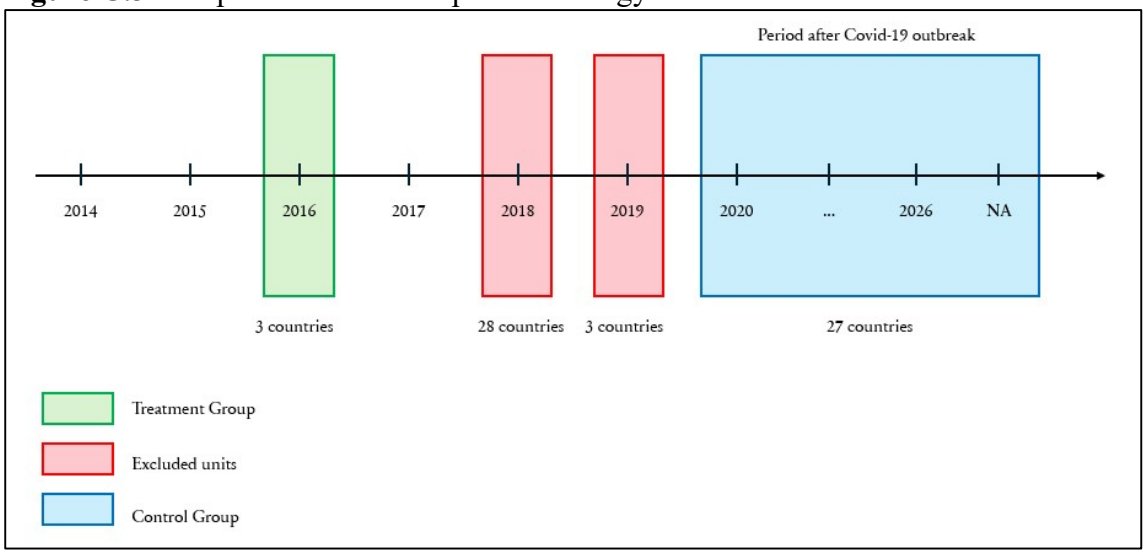
Note: This figure presents the database after the filtering and cleaning, showing how many countries implemented open banking at each time window.

Figure C.2 – Staggered Difference Empirical Strategy



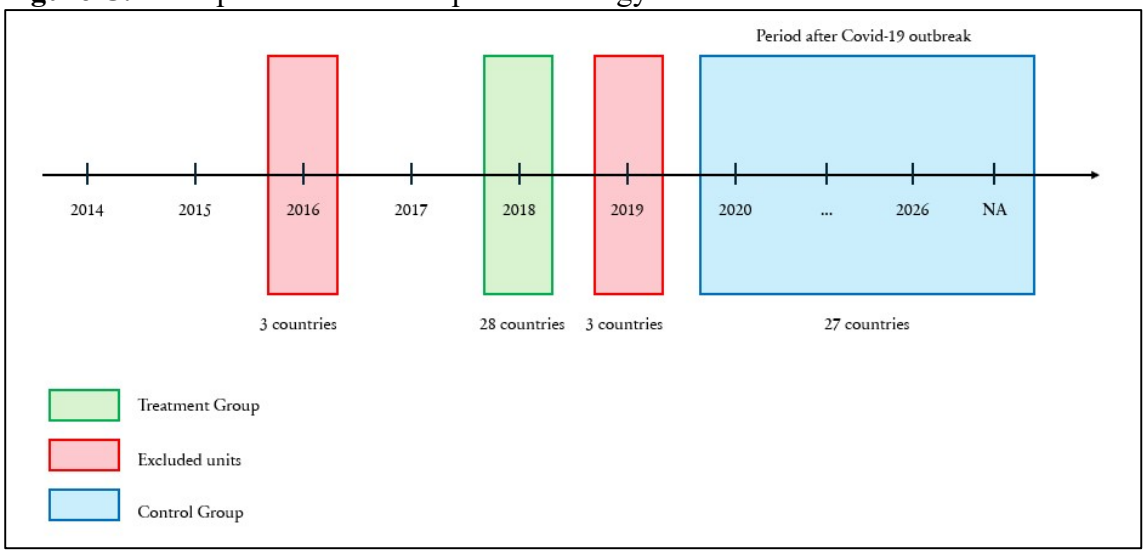
Note: This figure presents the staggered difference empirical strategy, signaling the treatment group, control group, and countries not considered for this strategy's implementation.

Figure C.3 – Triple Difference Empirical Strategy - Pioneer



Note: This figure presents the triple difference empirical strategy for the Pioneer set, signaling the treatment group, control group, and countries not considered for this strategy's implementation.

Figure C.4 – Triple Difference Empirical Strategy - Later



Note: This figure presents the triple difference empirical strategy for the Later set, signaling the treatment group, control group, and countries not considered for this strategy's implementation.