

# Artificial intelligence and relationship lending

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# Outline

- 1 Introduction
- 2 Data and stylized facts
- 3 Empirical analysis
- 4 Conclusions

# Introduction

# Motivation

- **Artificial intelligence (AI)** enables the use of vast amounts of structured and unstructured data, reducing asymmetric information problems.
- The application of AI in the banking sector **can enhance efficiency and lower costs by using hard information** (Liberti and Petersen, 2018; Boot et al., 2021), with effects on the overall banking activity (Pierri and Timmer, 2021; Branzoli et al., 2022; Gambacorta et al., 2022).

## Motivation (cont'd)

- **Relationship lending** traditionally uses **soft information** about the borrower in order to mitigate information asymmetries.
- Empirical literature documents that **relationship borrowers pay higher interest rates in normal times** but **benefit from a certain protection during crises** (Bolton et al., 2016; Sette and Gobbi, 2015; Beck et al., 2018; Benarjee et al., 2021).
- Banks that use AI might rely more on hard information and less on soft information, **possibly mitigating the typical effects of relationship** lending on the credit supply.

# Research questions

- ① What are the **characteristics of AI lending vs relationship lending**?
- ② What are the **real effects** of AI lending vs relationship lending?

# Main results

- ① What are the **characteristics of AI lending vs relationship lending**?
  - AI banks mitigate the rent extraction effect of relationship lending in normal times, while offering similar credit conditions in crisis times. Thus, **AI lending is acyclical**.
  - However, we find evidence that AI lending may be **more reactive to idiosyncratic firm characteristics**.
- ② What are the **real effects** of AI lending vs relationship lending?
  - During the Covid crisis, exposure to AI lending **dampened the countercyclical effects** of relationship lending **on investments and employment**.

# Data and stylized facts

## How do we measure banks' AI investments?

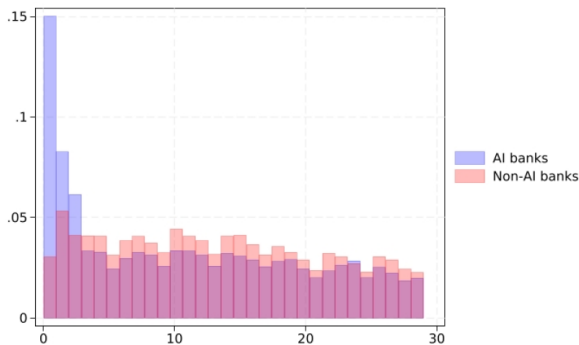
- We focus on Italian bank-firm relationships between 2018:Q4 and 2020:Q4: We compare one “normal” year and the Covid crisis.
- We use data from the **Regional Bank Lending Survey (RBLs)**, an annual survey of Italian banks conducted by the Bank of Italy.
- In the 2021 wave of the RBLs, banks were asked to indicate
  - whether they had invested in **machine learning techniques on big data** to **integrate their assessments of borrower creditworthiness**;
  - **the year in which they started** to make these investments.
- we define an intermediary as an **AI bank** in year  $t$  if it started to make these investments in  $T \leq t$ .
- The dataset includes a total of 124 banks, 9 of which are AI banks at the beginning of the sample (2018:Q4); 5 banks become AI in our sample.

## Other data sources

- Anacredit (euro area credit register) for data on lending volumes and interest rates at the bank-firm level from 2018Q4.
- Italian credit register since 2008 to measure the length of lending relationships between banks and firms (proxy for the strength of relationship lending).
- Bank of Italy supervisory Reports (banks' balance-sheet information), Orbis (firms' balance-sheet information).

# Relationship length and AI adoption

**Figure 2:** Distribution of relationship length for AI and non-AI banks (1)



Source: ECB. Elaborations on Anacredit and Italian credit registry data.

- AI banks and non-AI banks have a slightly different degree of relationship-based lending.
- At the end of 2018, AI banks have a shorter median lending relationship (10 quarters) than non-AI banks (13 quarters).

# AI adoption and bank characteristics

**Table:** Adoption of AI for credit scoring and bank characteristics

| Variables               | (1) AI                       | (2) AI pre Covid             |
|-------------------------|------------------------------|------------------------------|
| Capital ratio           | 0.1053<br>(2.948)            | 0.2237<br>(3.000)            |
| Liquidity ratio         | 1.9925<br>(2.177)            | 1.9506<br>(2.335)            |
| ROA                     | 0.5066<br>(0.475)            | 0.0899<br>(0.541)            |
| Interbank funding ratio | -1.3867<br>(1.430)           | -1.5532<br>(1.478)           |
| Size                    | <b>0.7748***</b><br>(0.187)  | <b>0.8042***</b><br>(0.194)  |
| Duration                | -0.3299<br>(0.391)           | -0.6207<br>(0.583)           |
| Constant                | <b>-8.4024***</b><br>(1.756) | <b>-7.9181***</b><br>(1.878) |
| Observations            | 356                          | 239                          |

- Larger banks are more likely to adopt AI due to the high fixed costs associated with IT infrastructure.
- AI adoption is not correlated with relationship duration.

# AI adoption and firm characteristics

**Table:** Dynamic sorting test

| Dependent variables: | (1) ROA           | (2) Leverage       | (3) EBIDTA/int. exp. | (4) Log(TA)               | (5) Credit rating |
|----------------------|-------------------|--------------------|----------------------|---------------------------|-------------------|
| AI                   | 0.6468<br>(0.509) | -1.9560<br>(1.338) | -2.1263<br>(1.785)   | <b>0.0324*</b><br>(0.018) | 0.0354<br>(0.026) |
| Observations         | 5,440,806         | 5,437,036          | 5,092,583            | 5,376,939                 | 5,436,618         |
| R-squared            | 0.000             | 0.000              | 0.000                | 0.025                     | 0.017             |
| Bank FE              | yes               | yes                | yes                  | yes                       | yes               |
| Time FE              | yes               | yes                | yes                  | yes                       | yes               |

- Dynamic sorting tests do not provide strong evidence of a match between firms and AI-adopting banks.

# Empirical analysis

## Empirical methodology: credit volumes and interest rates

We estimate the effects of the interplay between AI and relationship lending on credit volumes and interest rates:

$$Y_{i,j,t} = \beta_1 \log(\text{Rel.Duration})_{i,j,t-1} + \beta_2 \log(\text{Rel.Duration})_{i,j,t-1} \times D(2020) + \beta_3 \log(\text{Rel.Duration})_{i,j,t-1} \times AI_{i,t-1} + \beta_4 \log(\text{Rel.Duration})_{i,j,t-1} \times AI_{i,t-1} \times D(2020) + \beta_5' X_{i,j,t} + \mu_{j,t} + \eta_{i,t} + \epsilon_{ij,t}$$

- $Y_{i,j,t}$ : log difference of credit granted; level of interest rates.
- $D(2020)$  is dummy equal to one in 2020 and zero otherwise.
- Bank  $\times$  time and firm  $\times$  time fixed effects control for time-varying heterogeneity - both observable and unobservable - at the bank and firm level.
- $X_{i,j,t}$ : vector of controls at the bank-firm level (dimension of loan, collateral over loan, residual duration, etc).

# Results - effects of relationship length on credit volumes

| Dependent variables: | Credit volumes (term loans) |                        |                    |
|----------------------|-----------------------------|------------------------|--------------------|
|                      | (1)<br>AI banks             | (2)<br>non-AI<br>banks | (1) - (2)          |
| Normal times (a)     | 0.75***<br>(0.236)          | -0.45**<br>(0.183)     | 1.20***<br>(0.291) |
| Crisis (b)           | 0.65***<br>(0.275)          | 0.91***<br>(0.242)     | -0.26<br>(0.360)   |
| (b) - (a)            | -0.10<br>(0.313)            | 1.36***<br>(0.277)     |                    |
| Observations         | 957,750                     |                        |                    |
| R-squared            | 0.417                       |                        |                    |
| Bank-firm controls   | yes                         |                        |                    |
| Bank*quarter FE      | yes                         |                        |                    |

- **In normal times**, AI banks increased credit to relationship firms, while non-AI banks reduced it.

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- **During the Covid crisis**, both AI banks and non-AI banks extended credit to relationship firms.

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- **In normal times**, AI banks increased credit to relationship firms, while non-AI banks reduced it.
- **During the Covid crisis**, both AI banks and non-AI banks extended credit to relationship firms.
- While non-AI banks act countercyclically, **AI lending is acyclical**.

# Results - effects of relationship length on interest rates

| Dependent variables: | Interest rates on term loans |                        |                     |
|----------------------|------------------------------|------------------------|---------------------|
|                      | (3)<br>AI banks              | (4)<br>non-AI<br>banks | (3) - (4)           |
| Normal times (a)     | 0.09***<br>(0.017)           | 0.16***<br>(0.014)     | -0.07***<br>(0.021) |
| Crisis (b)           | 0.05**<br>(0.020)            | 0.07***<br>(0.015)     | -0.02<br>(0.024)    |
| (b) - (a)            | -0.04<br>(0.027)             | -0.09***<br>(0.018)    |                     |
| Observations         |                              | 957,750                |                     |
| R-squared            |                              | 0.675                  |                     |
| Bank-firm controls   |                              | yes                    |                     |
| Bank*quarter FE      |                              | yes                    |                     |

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| Bank-firm controls   |                              | yes                 |                     |
| Bank*quarter FE      |                              | yes                 |                     |

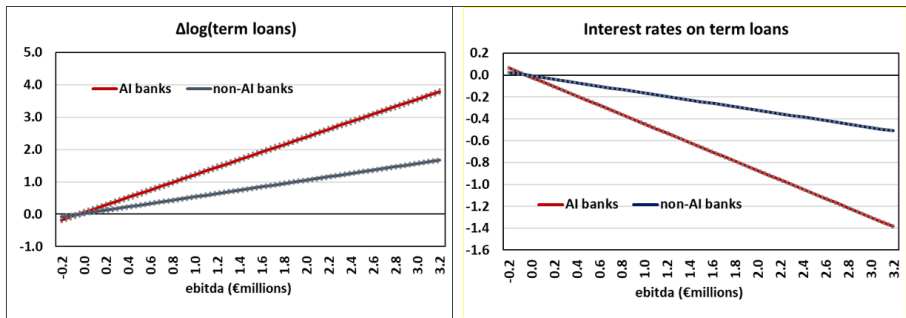
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- **In normal times**, AI banks increased the cost of credit to relationship firms, but significantly less than non-AI banks.
- **During the Covid crisis**, both AI banks and non-AI banks increased interest rates on loans to relationship firms.
- **Interest rates on loans granted by AI banks are acyclical**, while those on credit granted by non-AI banks are countercyclical.

# Results - reactivity of lending to changes in firms' EBIDTA



- An increase of EBITDA by 1 standard deviation (0.8 million euros), other things being equal, is associated with
  - an increase in the quarterly growth rate of term loans by 1.0% for AI banks and 0.4% for non-AI banks;
  - a reduction in the interest rate on term loans by 35 basis points for AI banks and 13 basis points for non-AI banks.
- **AI lending is more reactive to firms' profitability**

## Empirical methodology: real effects

We estimate the differential effect of AI on firms' credit, investment and employment in 2020 vis à vis 2019:

$$\Delta Z_{j,t} = \beta_1 \overline{Rel.Duration}_{j,2018} \times D(2020) + \beta_2 \overline{Rel.Duration}_{j,2018} \times \overline{AI}_{j,2018} \times D(2020) + \beta_3 \overline{AI}_{j,2018} \times D(2020) + \beta_4' X_{j,t} + \mu_j + \eta_t + \epsilon_{j,t}$$

- $\Delta Z_{j,t}$ : growth in loans, investments, employment over firms' total assets.
- $\overline{Rel.Duration}_{j,2018} = \sum_j \log(\text{Rel.Duration})_{i,j,2018} \times \text{share}_{i,j,2018}$ .  
 $\overline{AI}_{j,2018}$  share of the main lender if this is an AI bank and zero otherwise. Both measures refer to 2018 to limit endogeneity.
- $\mu_j$  are firm fixed effects, which restrict identification to the differential impact of AI in 2020 vis à vis 2019;
- $X_{j,t}$ : vector of controls at the firm level (ROA, size, Leverage, EBITDA-to-interest ratio, Z-score, etc).

## Results - real effects

The real effects of relationship lending and financial innovation at the firm level.

| VARIABLES  | (1)<br>Credit        | (2)<br>Investments   | (3)<br>Employment    |
|--|----------------------|----------------------|----------------------|
| $\overline{Dur} \times \overline{AI} \times D(2020)$ | -0.0277**<br>(0.014) | -0.0883*<br>(0.048)  | -0.0047*<br>(0.003)  |
| $\overline{Dur} \times D(2020)$                      | 0.0476***<br>(0.007) | 0.2481***<br>(0.018) | 0.0163***<br>(0.001) |
| $\overline{AI} \times D(2020)$                       | 0.0154<br>(0.010)    | 0.0255<br>(0.031)    | -0.0007<br>(0.002)   |
| Observations   | 292,666              | 296,296              | 220,642              |
| R-squared  | 0.927                | 0.696                | 0.982                |
| Firm FE  | yes                  | yes                  | yes                  |
| Time FE  | yes                  | yes                  | yes                  |

- During the COVID-19 crisis, firms with longer average relationship duration obtained more credit and increased investments and employment.
- However, this effect was diminished for firms associated with AI banks.

# Conclusions

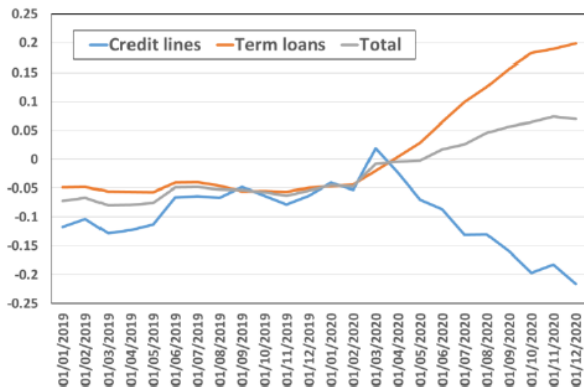
## Main takeaways

- **AI banks dampen the capture effect** which is typically associated with relationship lending in normal times, while offering similar credit conditions in crisis times.
- While lending by non-AI banks is characteristically countercyclical, **lending by AI banks is acyclical.**
- At the same time, we find evidence that lending by AI banks may be **more reactive to firms' idiosyncratic characteristics.**
- The acyclicity of AI lending has effects on firms' real activity: all else being equal, **employment** and **investments increased less during the COVID-19 crisis** for borrowers exposed to AI banks.

# Appendix

# Term loans and credit lines during the Covid crisis

Figure 1: Lending growth to non-financial corporations in Italy (1)



Source: ECB. Elaborations on AnaCredit data.

- In 2019, the growth rate of term loans and credit lines remained consistently negative, primarily due to weak demand.
- In 2020, total loan growth increased, primarily driven by a rise in term loans.

## Results - credit supply: quantities

Effects of lending relationship on quantity of credit.

| VARIABLES          | (1)<br>Term loans | (2)<br>Term loans | (3)<br>Credit lines | (4)<br>Credit lines |
|--------------------|-------------------|-------------------|---------------------|---------------------|
| Log(ReI. duration) | -1.9694***        | -1.4654***        | -0.5751             | -0.7526             |
| × AI× D(2020)      | (0.467)           | (0.388)           | (1.108)             | (1.148)             |
| Log(ReI. duration) | 1.4586***         | 1.2002***         | 0.2388              | 0.3554              |
| × AI               | (0.335)           | (0.291)           | (0.668)             | (0.643)             |
| Log(ReI. duration) | 2.0387***         | 1.3647***         | 1.2382**            | 1.4112**            |
| × D(2020)          | (0.347)           | (0.277)           | (0.612)             | (0.620)             |
| Log(ReI. duration) | -0.7596***        | -0.4504**         | -1.2294***          | -1.3449***          |
|                    | (0.194)           | (0.183)           | (0.311)             | (0.313)             |
| AI×D(2020)         | 5.4495            |                   | -13.7833            |                     |
|                    | (7.084)           |                   | (14.757)            |                     |
| AI                 | 1.8478**          |                   | -5.3326**           |                     |
|                    | (0.788)           |                   | (2.019)             |                     |
| Observations       | 957,756           | 957,750           | 505,053             | 505,034             |
| R-squared          | 0.413             | 0.417             | 0.469               | 0.471               |
| Bank controls      | yes               | -                 | yes                 | -                   |
| Bank-firm controls | yes               | yes               | yes                 | yes                 |
| Bank FE            | yes               | -                 | yes                 | -                   |
| Bank*quarter FE    | no                | yes               | no                  | yes                 |
| Firm*quarter FE    | yes               | yes               | yes                 | yes                 |

- Lending by non-AI banks decreases (increases) with relationship duration in normal (crisis) times.
- For the same amount of soft information, AI banks grant more credit than non-AI banks in normal times and keep the credit supply constant in crisis times (credit scoring through the cycle).

## Results - credit supply: interest rates

Effects of lending relationship on interest rates.

| VARIABLES                          | (1)<br>Term loans   | (2)<br>Term loans   | (3)<br>Credit lines | (4)<br>Credit lines |
|------------------------------------|---------------------|---------------------|---------------------|---------------------|
| Log(Rel. duration)×<br>AI× D(2020) | 0.05*<br>(0.024)    | 0.05*<br>(0.025)    | 0.13**<br>(0.060)   | 0.11*<br>(0.062)    |
| Log(Rel. duration)×<br>AI          | -0.07*<br>(0.036)   | -0.07*<br>(0.036)   | 0.11<br>(0.068)     | 0.11<br>(0.068)     |
| Log(Rel. duration)×<br>D(2020)     | -0.09***<br>(0.017) | -0.09***<br>(0.018) | -0.01<br>(0.049)    | -0.02<br>(0.051)    |
| Log(Rel. duration)                 | 0.16***<br>(0.022)  | 0.16***<br>(0.023)  | 0.51***<br>(0.053)  | 0.51***<br>(0.052)  |
| AI × D(2020)                       | 0.12<br>(0.096)     |                     | -0.03<br>(0.190)    |                     |
| AI                                 | 0.02<br>(0.018)     |                     | -0.10**<br>(0.047)  |                     |
| Observations                       | 957,756             | 957,750             | 545,346             | 545,335             |
| R-squared                          | 0.672               | 0.675               | 0.673               | 0.673               |
| Bank controls                      | yes                 | -                   | yes                 | -                   |
| Bank-firm controls                 | yes                 | yes                 | yes                 | yes                 |
| Bank FE                            | yes                 | -                   | yes                 | -                   |
| Bank*quarter FE                    | no                  | yes                 | no                  | yes                 |
| Firm*quarter FE                    | yes                 | yes                 | yes                 | yes                 |

- In normal times, the cost of term loans granted by AI banks (for the same level of soft information) is lower, but this advantage disappears during the crisis.

## Public guarantee loans and AI

Table A2: Public guarantee loans and AI

|                          | (1)                                | (2)                                |
|--------------------------|------------------------------------|------------------------------------|
| Dependent variables:     | Share of public<br>guarantee loans | Share of public<br>guarantee loans |
| AI                       | 4.84<br>(2.986)                    | 3.47<br>(3.494)                    |
| Tier 1                   |                                    | -0.53<br>(10.819)                  |
| ROA                      |                                    | -42.89<br>(266.826)                |
| Liquidity ratio          |                                    | 12.97<br>(9.863)                   |
| Interbank deposits ratio |                                    | -2.22<br>(6.818)                   |
| Bank size                |                                    | -0.77<br>(0.887)                   |
| Size of loan (median)    |                                    | -2.03<br>(1.241)                   |
| Share (median)           |                                    | -0.13***<br>(0.044)                |
| Observations             | 117                                | 117                                |
| R-squared                | 0.029                              | 0.212                              |
| Bank fixed effects       | yes                                | yes                                |

Notes: The dependent variable is the incidence of public guarantees over total loans granted during the pandemic Standard errors in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 All explanatory variables are lagged of one period.