Economics Bulletin

Volume 44, Issue 1

How asset transformation matters for the fate of technology-led banks?

Maxence Miéra
Univ Artois, CNRS, IESEG School of management, Univ Lille, UMR 9221, Lille Economie Management (LEM)

Nicolas Bédu
ART-Dev, Univ Montpellier, CNRS, Univ Paul Valéry Montpellier 3, Univ Perpignan Via Domitia, CIRAD

Viola Lamani
Univ Paul Valéry Montpellier 3, Univ Montpellier, Univ Perpignan, CNRS, CIRAD, ART Dev UMR 5281

Abstract

This paper examines the efficiency of technology-led banks (i.e. internet banks, mobile banks or FinTech startups offering banking services) in a simple theoretical model using conventional banks as a competitive benchmark. We show that the fate of technology-led banks crucially relies on their level of asset transformation. We identify two critical thresholds of asset transformation in a general contractual setting. The first determines whether technology-led banks are feasible to set up, while the second determines when technology-led banks are at least as attractive as conventional banks.

The authors would like to express their gratitude to an anonymous referee for providing constructive feedback that helped to enhance the quality of this manuscript. They would also like to thank the Editorial Board and the Associate Editor for their professionalism and support throughout the publication process. The authors declare that they have no relevant financial or non-financial interests to disclose. Any remaining errors in the manuscript are the sole responsibility of the authors.

Citation: Maxence Miéra and Nicolas Bédu and Viola Lamani, (2024) "How asset transformation matters for the fate of technology-led banks?", *Economics Bulletin*, Volume 44, Issue 1, pages 74-87

Contact: Maxence Miéra - maxence.miera@univ-artois.fr, Nicolas Bédu - nicolas.bedu@umontpellier.fr, Viola Lamani - viola.lamani@univ-montp3.fr.

Submitted: July 18, 2023. **Published:** March 30, 2024.

1. Introduction

Conventional banks around the world have been facing competition from new challengers that emerged successively in the mid-2000s during the internet revolution and at the beginning of the 2010s in the wake of the FinTech revolution. This new competition has resulted in a highly fragmented competitive landscape. The boundaries of the banking sector have also become more difficult to ascertain because of the different uses of the term "banks" as well as varying definitions of FinTech. Indeed, the emergence of internet banks in a first step, followed by that of mobile banks and FinTech startups offering banking services, has led to an extensive perception of what a bank is.

In the academic literature, the definition of conventional banks traditionally relies on four characteristics (Chiorazzo et al. 2018): (i) granting credit, (ii) receiving deposits, which are the core source of funding, (iii) gathering several sources of income based on interest rate margins (lending) and fees (deposit and financial services), and (iv) developing a physical network of bank branches. Contrary to the conventional banking model, challengers do not necessarily exhibit these four characteristics. Indeed, some challengers are mono-product firms (e.g., FinTech startups), only offering payment or lending services for example, while others are multi-products companies (e.g., internet banks and digital banks). Sources of income vary between challengers. FinTech startups may depend almost exclusively on fundraising, while internet and digital banks have access to different sources of income. In addition, internet and digital banks may operate under a banking license (note that this is not the case for all of them), while FinTech startups tend to operate under a payment services agreement. Despite these differences, all challengers are similar in their use of digital technology. We define these challengers as *technology-led banks* (*T-L banks*). The fate of firms such as internet banks, digital banks and FinTech startups offering banking services largely depends on their competitiveness vis-à-vis conventional banks.

There is a large consensus that one of the competitive advantages of *T-L banks* derives from their more intensive – almost exclusive – use of digital technology and from the absence of a physical network of bank branches (Arnold and van Ewijk 2011), resulting in lower production costs than conventional banks (Thakor 2020).[1] Another feature that we observed in the few publicly available *T-L banks*' annual reports is that customers' deposits are mainly held in "cash and cash equivalent" and "cash and balances at central bank(s)", suggesting that these *T-L banks* either lack or have a limited asset transformation function. Two possible reasons may be put forward to explain this feature. First, regulation may prevent *T-L banks*, especially those operating under a payment services license, from transforming deposits into loans or investing them in the financial market. Second, there is a potential mismatch between the short-term liquidity needs of *T-L banks*' customers and *T-L banks*' investments in financial markets. *T-L banks* have to probably hold more liquid assets than conventional banks. These banks have mainly young and low-income customers (e.g., students) who may be less likely to apply for credit, such as real estate loans. Moreover, many customers hold secondary accounts in *T-L banks* (Arslanian and Fischer 2019) for daily payments and do not borrow from them.

In this context, our paper aims to examine the efficiency of *T-L banks* using conven-

[1] Many scholars have pointed out the potential of FinTech and, more broadly, digital technologies to transform and disrupt financial services by reducing operating costs in banking activities (see, among others, Philippon 2016, Vives 2019 and Allen et al. 2021).

tional banks as a competitive benchmark. More particularly, we address how important asset transformation is for the fate of *T-L banks*. For this purpose, we develop an original and general theoretical model in which *T-L banks* bear lower operating costs than conventional banks and have a limited ability to transform assets.

The main theoretical results of our article are summarized as follows. First, we show that the cost advantage of *T-L banks* is not enough to ensure their viability. The fate of *T-L banks* crucially relies on their level of asset transformation. Second, we identify two critical thresholds of asset transformation. Under the first threshold, *T-L banks* cannot offer a desirable deposit contract to consumers and, at the same time satisfy the budget constraint of the bank (otherwise the bank would register losses). Between the first and second threshold, *T-L banks* can offer a desirable deposit contract which remains nevertheless less attractive than that of conventional banks. Above the second threshold, *T-L banks* can offer a deposit contract at least as attractive as that of conventional banks.

While there is a growing empirical literature on challenger banks, including FinTech companies, there are only a few theoretical papers providing frameworks for analyzing the interaction between conventional banks and challengers (Tang 2019, Parlour et al. 2022, He et al. 2020). Furthermore, the main objectives of these theoretical studies are different from ours. For instance, Tang (2019) examines the interaction between conventional banks and peer-to-peer lending. Parlour et al. (2022) focus on payment services and payment data. He et al. (2020) study the competition between FinTech and conventional banks in lending services with banks' customer data sharing, i.e. in a context of open banking. We contribute to this scant theoretical literature by developing an original theoretical framework that explicitly aims at explaining how asset transformation matters for the fate of *technology-led banks*. We also make an indirect contribution to the modelling of deposit contracting and allocative efficiency under a liquidity constraint. Since asset transformation and the liquidity constraint are just two sides of the same coin, we characterize the optimal deposit contract and assess its desirability under all permissible liquidity constraints in a setting where banks bear an arbitrary cost of providing financial services.

The remainder of the paper is organized as follows. In section 2, we present the general setting of the model. In section 3, we characterize the optimal contracting in conventional banks. In section 4, we introduce the *T-L banking* model and then characterize the optimal deposit contract according to the level of asset transformation. We also derive two critical thresholds of asset transformation. Finally, section 5 concludes.

2. The general setting

The model is a variation on the model of asset transformation by Diamond and Dybvig (1983). The basic framework consists of three dates $t = \{0, 1, 2\}$, a mass of consumers subject to a liquidity shock at the interim date, and two types of assets (short-term and long-term ones). A single numeraire good is used for consumption and investment.

The numeraire good can either be allocated to a liquid risk-free short-term asset or to a more productive but illiquid long-term asset. The short-term asset is accessible to consumers without having to go through a bank. For one unit invested in t, this short-term asset provides a unit return in $t + 1$. In contrast, the long-term asset is only accessible through a bank.[2] For one unit invested in $t = 0$, the long-term asset provides

[2]This assumption, known as limited market participation, is widespread in the literature – see, e.g.,

a certain return $R > 1$ in $t = 2$. We assume that early liquidation of the long-term asset in $t = 1$ is not possible.

The economy is populated by a unitary mass of ex-ante identical consumers with an individual one-unit endowment. They may be subject to a liquidity shock in $t = 1$ with a probability λ that is common knowledge. Due to this shock, consumers can either consume all their endowment in $t = 1$ (i.e. early consumption, C_1) with a probability λ, or choose to consume their endowment in $t = 2$ (i.e. late consumption, C_2) with a probability $1 - \lambda$. The individual consumption pattern is private information which is revealed in $t = 1$. Consumers' preferences can be represented by an expected utility function: $U(C_1, C_2) = \lambda u(C_1) + (1 - \lambda) u(C_2)$ where $u(\cdot)$ is twice continuously differentiable, increasing, strictly concave and satisfies the Inada conditions ($\lim_{C\to 0} u'(C) = \infty$ and $\lim_{C\to\infty} u'(C) = 0$). We also assume that consumers are risk-averse agents with a relative risk aversion greater than unity, i.e. $-C[u''(C)/u'(C)] > 1$. This condition is sufficient (but not necessary) to ensure that liquidity insurance is desirable.

The characteristics of this economy make it possible to improve social welfare by setting up a banking organization. We study two alternative types of organization successively: the conventional bank and the *T-L bank*. To avoid any misunderstanding, this paper does not aim at modelling monopolistic competition or studying the interaction between the two types of banks. The conventional bank is simply used here as a benchmark to assess the efficiency of the *T-L bank*.

3. The conventional bank: a competitive benchmark

The bank is set up in $t = 0$. It collects one unit of deposit from consumers and incurs a fixed cost of c^B for setting up the banking structure. We assume that the fixed cost is low enough for the banking formation to be strictly desirable. The bank then invests its available resources in either short-term or long-term assets. We denote by τ_F^B the share of resources allocated to the long-term asset and correspondingly $1 - \tau_F^B$ the share placed in the short-term asset. In $t = 1$, all consumers discover their "type" (i.e. early or late). On the one hand, early consumers immediately withdraw their deposits in $t = 1$ and each receive D_1^B per unit of the initial deposit, which corresponds to a global payout of λD_1^B. Given that the long-term asset is illiquid in $t = 1$, the resources that will serve to meet these early withdrawals must be placed in the short-term asset: $(1 - \tau_F^B)(1 - c^B) = \lambda D_1^B$. On the other hand, late consumers wait to withdraw their deposits in $t = 2$ and each receive D_2^B per unit of the initial deposit, which corresponds to a global payout of $(1 - \lambda)D_2^B$. Given the early and late withdrawals, the bank's budget constraint is $\lambda D_1^B + (1 - \lambda)D_2^B \leq (1 - \tau_F^B)(1 - c^B) + \tau_F^B(1 - c^B)R$, which can be rewritten as $\lambda D_1^B + (1 - \lambda)(D_2^B/R) \leq 1 - c^B$.

At the competitive equilibrium, the bank determines the terms of the optimal contract

Mankiw and Zeldes 1991, Diamond 1997, Basak and Cuoco 1998, Allen and Gale 2004, Marini 2005, He and Krishnamurthy 2013, Kučinskas 2019, and Gale and Gottardi 2020.

by maximizing the utility of consumers under different constraints:

$$\underset{D_1^B, D_2^B}{\text{Max}} \quad \lambda\, u(D_1^B) + (1-\lambda)\, u(D_2^B) \tag{1}$$

$$\text{s.t.} \quad \lambda D_1^B + (1-\lambda)\frac{D_2^B}{R} \leq 1 - c^B, \tag{2}$$

$$\lambda u(D_1^B) + (1-\lambda) u(D_2^B) \geq u(1), \tag{3}$$

$$D_1^B \leq D_2^B. \tag{4}$$

Constraint (2) is the budget constraint mentioned above. It states that the actualized payouts to consumers must not exceed the initial consumers' endowment net of the cost of setting up the bank, i.e. it ensures that the bank does not make losses. Next, constraint (3) is the participation constraint of consumers. It states that the utility derived from the deposit contract must be at least equal to the utility derived from the investment in the short-term asset. Finally, constraint (4) is an incentive-compatibility constraint stating that withdrawal in $t = 1$ must not dominate withdrawal in $t = 2$. This constraint ensures that the bank does not experience a run in $t = 1$.[3]

There exists an optimal contract that satisfies all the aforementioned constraints if the cost of setting up the bank c^B is low enough[4], which we assume to be true in our case:

Proposition 1. *The optimal contract is characterized by the following conditions:*

$$\frac{u'(D_1^{B*})}{u'(D_2^{B*})} = R \tag{5}$$

and

$$\lambda D_1^{B*} + (1-\lambda)\frac{D_2^{B*}}{R} = 1 - c^B. \tag{6}$$

This result is close to that of Diamond and Dybvig (1983), except for the cost of setting up the bank. Condition (5) is a usual one about the marginal rate of substitution between consumption flows in $t = 1$ and $t = 2$. Condition (6) is simply the active budget constraint of the bank. Technical details are provided in Appendix A.

It can be deduced from Proposition 1 that:[5]

Corollary 1. *The optimal contract is characterized by*

$$1 < D_1^{B*} < D_2^{B*} < R. \tag{7}$$

The bank thus uses the deposit contract to provide liquidity insurance to consumers (i.e. smoothing of consumption patterns depending on consumer types).

---

[3] The long-term asset cannot be liquidated in $t = 1$. This implies that withdrawals cannot exceed the investment in the short-term asset in $t = 1$ and that the bank can meet its contractual commitments in $t = 2$. The bank then experiences no run of late depositors if $D_1^B \leq D_2^B$.

[4] We assume that there exists a certain threshold c^B_{max} such that the optimal contract satisfies both the budget constraint of the bank and the participation constraint of consumers if $c^B < c^B_{max}$ (see Lemma 1 in Appendix A).

[5] See proof of Lemma 1 in Appendix A.

4. The transformation issue in the *technology-led bank*

In this section, we analyze the allocation of resources of a *T-L bank*. Henceforth we adapt our notations by using the superscript TL. Analogous to the previous section, we denote by D_1^{TL} and D_2^{TL} the terms of the deposit contract offered by the *T-L bank*. While the basic framework is similar to that of the conventional bank, there are two features upon which we can distinguish the *T-L bank* from the conventional bank. First, the *T-L bank* has a more efficient technology that reduces the production cost of banking services such as $c^{TL} < c^B$. Second, the *T-L bank* can possibly face more constraints than the conventional bank in terms of investment opportunities stemming from regulations or its business model.

Without loss of generality, we assume that the transformation level of the *T-L bank* is capped at a level τ^{TL} that is less than or equal to the free optimum τ_F^{TL}: $0 \leq \tau^{TL} \leq \tau_F^{TL}$.[6] It is therefore optimal for the *T-L bank* to saturate this transformation constraint and invest a share τ^{TL} of its resources in the long-term asset that dominates the short-term asset (i.e. the bank has no reason to invest less than τ^{TL} in the long-term asset if $\tau^{TL} \leq \tau_F^{TL}$). The budget constraint of the *T-L bank* is then given by $(1-\tau^{TL})(1-c^{TL}) - \lambda D_1^{TL} + \tau^{TL}(1-c^{TL})R - (1-\lambda)D_2^{TL} \geq 0$. It is also necessary to introduce the following liquidity constraint in $t = 1$ to ensure that the payouts provided to consumers do not exceed the total amount of funds at the *T-L bank*'s disposal at that date: $\lambda D_1^{TL} \leq (1-\tau^{TL})(1-c^{TL})$.[7]

As a result, the optimization program of the *T-L bank* is the following:

$$\max_{D_1^{TL}, D_2^{TL}} \quad \lambda\, u(D_1^{TL}) + (1-\lambda)\, u(D_2^{TL}) \tag{8}$$

$$\text{s.t.} \quad (1-\tau^{TL})(1-c^{TL}) - \lambda D_1^{TL} + \tau^{TL}(1-c^{TL})R - (1-\lambda)D_2^{TL} \geq 0, \tag{9}$$

$$\lambda D_1^{TL} \leq (1-\tau^{TL})(1-c^{TL}), \tag{10}$$

$$\lambda u(D_1^{TL}) + (1-\lambda)u(D_2^{TL}) \geq u(1), \tag{11}$$

$$D_1^{TL} \leq D_2^{TL}. \tag{12}$$

Constraints (9) and (10) are respectively the budget constraint and the liquidity constraint mentioned above. Constraints (11) and (12) are respectively the participation constraint of consumers and the incentive-compatibility constraint, defined in a similar way to the conventional bank.

To solve the *T-L bank*'s maximization problem and determine the characteristics of the optimal deposit contract, we disregard at first the participation constraint of consumers (11). Then we examine both the attractiveness of the deposit contract and the status of the participation constraint of consumers with regard to the level of asset transformation.

We show in Appendix B that:

---

[6] The free optimum τ_F^{TL} corresponds to the share of resources allocated to the long-term asset when the *T-L bank* faces no constraints of asset transformation. Analogous to the conventional bank in the previous section, $\tau_F^{TL} = 1 - (\lambda D_1^{TL}/(1-c^{TL}))$ with $c^{TL} < c^B$.

[7] The liquidity constraint was implicitly integrated into the optimal portfolio choice for the conventional bank: $\left(1-\tau_F^B\right)\left(1-c^B\right) = \lambda D_1^B$. The analogous equality, however, does not necessarily hold for the *T-L bank* because of the constraint on its placements. Therefore, the liquidity constraint must be explicitly stated to ensure that the deposit contract is honored by the *T-L bank* in $t = 1$.

Proposition 2. *There exists a switching threshold of transformation*

$$\tau_S^{TL} = \frac{1-\lambda}{1+\lambda(R-1)}, \qquad 0 < \tau_S^{TL} < \tau_F^{TL}, \tag{13}$$

such as:

— *if* $0 \leq \tau^{TL} \leq \tau_S^{TL}$*, then the optimal contract is characterized by*

$$D_1^{TL*} = D_2^{TL*} = D^{TL*} \tag{14}$$

and

$$D^{TL*} = (1-c^{TL})\left[1+\tau^{TL}(R-1)\right]; \tag{15}$$

— *if* $\tau_S^{TL} < \tau^{TL} \leq \tau_F^{TL}$*, then the optimal contract is characterized by*

$$u'(D_1^{TL*}) = u'(D_2^{TL*}) + \mu_2, \qquad \mu_2 > 0 \tag{16}$$

and

$$\lambda D_1^{TL*} + (1-\lambda)\frac{D_2^{TL*}}{R} = 1 - c^{TL}, \tag{17}$$

where μ_2 *is the Lagrange multiplier associated with the liquidity constraint* (10).

The characteristics of the optimal contract can be explained in an intuitive way. On the one hand, if $0 \leq \tau^{TL} \leq \tau_S^{TL}$, then the investment level in the long-term asset is relatively limited. Consequently, the *T-L bank* has significant liquidity in $t = 1$ and it can equalize the proposed payouts in $t = 1$ and $t = 2$ without any negative trade-off, which is desirable given the risk aversion of consumers. On the other hand, if $\tau_S^{TL} < \tau^{TL} \leq \tau_F^{TL}$, then the investment level in the long-term asset is relatively large and the remaining liquidity in $t = 1$ is relatively low. To be desirable, equalizing payouts in $t = 1$ and $t = 2$ would require to increase the payout in $t = 1$. This is however impossible to achieve by the *T-L bank* without relaxing the liquidity constraint. To equalize payouts on both dates, the *T-L bank* could eventually reduce its investment in the long-term asset. However, we show in Appendix B that this is not a desirable solution either, because it reduces the utility derived from the deposit contract. We can therefore deduce that if $\tau_S^{TL} < \tau^{TL} \leq \tau_F^{TL}$, the optimal contract is characterized by $D_1^{TL*} < D_2^{TL*}$.

The switching threshold τ_S^{TL} can occur in any arbitrary region of the interval $[0, \tau_F^{TL}]$, depending on the value of the parameters. Nevertheless, knowledge of the characteristics of the optimal contract allows us to show that the corresponding maximum-value function is continuous and monotonous, regardless of the region where the switching threshold occurs (see Lemma 6 in Appendix C). The intermediate value theorem then directly establishes the following proposition regarding the attractiveness of the contract according to the level of asset transformation (Appendix C):

Proposition 3. *There are two critical levels of asset transformation* $\underline{\tau}^{TL}$ *and* $\overline{\tau}^{TL}$ *that define three degrees of attractiveness of the deposit contract offered by the T-L bank:*

1. *If* $0 \leq \tau^{TL} < \underline{\tau}^{TL}$*, then the deposit contract cannot simultaneously satisfy the participation constraints of consumers and the budget constraint of the bank (i.e. unfeasible contract);*

2. *If* $\underline{\tau}^{TL} \leq \tau^{TL} < \overline{\tau}^{TL}$*, then the deposit contract is feasible but less attractive than the one offered by the conventional bank (i.e. dominated contract);*

3. *If* $\overline{\tau}^{TL} \leq \tau^{TL} \leq \tau_F^{TL}$*, then the deposit contract is feasible and at least as attractive as the one offered by the conventional bank (i.e. dominant contract – strict dominance when* $\tau^{TL} > \overline{\tau}^{TL}$*).*

Figure 1 summarizes graphically proposition 3. The function $V(c, \tau)$ represents the maximum-value function which is the maximum utility derived by consumers from the optimal allocation for a given implementation cost c and a given asset transformation level τ. It follows that $V(0, 0) = u(1)$ represents the participation constraint of consumers, $V(c^B, \tau_F^B)$ is the utility derived from the optimal contract of the conventional bank with free asset transformation, and $V(c^{TL}, \tau^{TL})$ is the utility derived from the optimal contract of the *T-L bank* depending on its level of asset transformation τ^{TL}.[8] When this transformation level is below $\underline{\tau}^{TL}$, the *T-L bank* cannot implement a contract that satisfies the participation constraint of consumers, assuming the *T-L bank* respects its budget constraint. When its transformation level is between $\underline{\tau}^{TL}$ and $\overline{\tau}^{TL}$, the *T-L bank* can implement a contract that satisfies the participation constraint of consumers but remains less attractive than the one offered by the conventional bank. When its transformation level is higher than $\overline{\tau}^{TL}$, the *T-L bank* can implement a contract that satisfies the depositor participation constraint and is more attractive than that of the conventional bank.

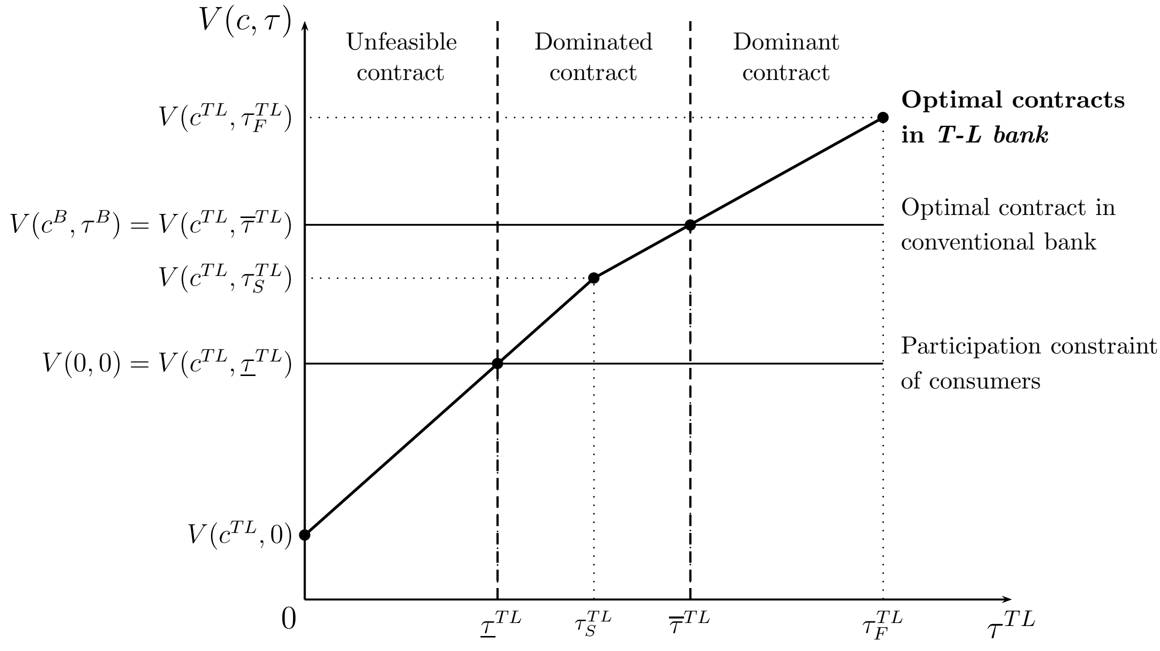

Figure 1: The *T-L bank*'s attractiveness according to the transformation level of assets

The attractiveness of the contract offered by the *T-L bank* ultimately depends on its capacity to transform its assets given the cost savings made possible by its production technology.

[8]The shape of the maximum value function follows directly from the proof of Lemma 6 in Appendix C. The switching threshold is arbitrarily set in the central region for illustration purposes. However, it can occur in any of the three regions, depending on the parameter values.

A point of discussion regarding the possible empirical implications of our model concerns the lack of co-existence of the T-L bank and the traditional bank in our current setting. Indeed, studying the interaction between the two types of banks goes beyond the initial scope of our paper as mentioned at the end of section 2. Despite this apparent limit of our model, real world observations of T-L banks suggest that while they remain on the market, many of them have registered negative profits. For example, the net loss of Nubank, one of the biggest challenger banks in Latin America with 65 million of claimed users in 2022, was as high as USD 175 million in the very same year. In Europe, the net loss of Monzo was around 130 GBP million in 2021. The latest figures reported by Revolut revealed losses around of 168 GBP million in 2020. Other examples include Klarna and N26, two main European T-L banks. In the US, Dave or even Varo are not profitable to date. As mentioned in the introduction, many T-L banks do not disclose information about their net incomes, but for those that do, we observed that customers' deposits are mainly held in "cash and cash equivalent" and "cash and balances at central bank(s)", suggesting that these T-L banks do not have or have a limited asset transformation function. Thus, we believe that the main result of our model stating that the fate of T-L banks is closely related to the asset-transformation level does not strike very far from real-world observations.

5. Concluding remarks

In this article, we build an original theoretical framework and analyze the importance of asset transformation for the fate of *T-L banks* in a contractual setting where *T-L banks* bear lower operating costs than conventional banks. Our results suggest that the cost advantage of *T-L banks* is not enough to ensure their viability, which crucially relies on their level of asset transformation. We also identify two critical thresholds of asset transformation that define the degrees of attractiveness of *T-L banks*' deposit contract compared to that of conventional banks. Our model provides a solid theoretical background to deepen the understanding of these new challengers featuring lower production costs.

An issue that arises from our model concerns the viability of *T-L banks*. Empirical evidence shows that most *T-L banks* make losses, suggesting that their level of asset transformation is not sufficient to simultaneously attract customers and be profitable. It should be noted, however, that both the cost and the asset transformation levels are part of the *T-L banks*' business model. Future developments will show whether the *T-L banks* will be able to transform their model while maintaining their cost advantage.

Appendices

A. Proof of Proposition 1

The Lagrangian function corresponding to the optimization problem of the conventional bank is

$$\begin{aligned}\mathcal{L}^B =& \lambda u(D_1^B) + (1-\lambda)u(D_2^B) - \mu_1 \left[\lambda D_1^B + (1-\lambda)\frac{D_2^B}{R} - 1 + c^B\right] \\ &- \mu_2 \left[u(1) - \lambda u(D_1^B) - (1-\lambda)u(D_2^B)\right] - \mu_3 \left[D_1^B - D_2^B\right], \end{aligned} \tag{A.1}$$

where μ_i are the Lagrange multipliers.

The strict concavity of the Lagrangian function implies that the following conditions are sufficient for optimality (Karush-Kuhn-Tucker conditions):

$$\frac{\partial \mathcal{L}^B}{\partial D_1^{B*}} = (1+\mu_2)u'(D_1^{B*}) - \mu_1 - \frac{\mu_3}{\lambda} = 0, \tag{A.2}$$

$$\frac{\partial \mathcal{L}^B}{\partial D_2^{B*}} = (1+\mu_2)u'(D_2^{B*}) - \frac{\mu_1}{R} + \frac{\mu_3}{1-\lambda} = 0, \tag{A.3}$$

$$\mu_1 \geq 0, \quad \text{and} \quad \mu_1 = 0 \quad \text{if} \quad \lambda D_1^{B*} + (1-\lambda)\frac{D_2^{B*}}{R} < 1 - c^B, \tag{A.4}$$

$$\mu_2 \geq 0, \quad \text{and} \quad \mu_2 = 0 \quad \text{if} \quad \lambda u(D_1^{B*}) + (1-\lambda)u(D_2^{B*}) > u(1), \tag{A.5}$$

$$\mu_3 \geq 0, \quad \text{and} \quad \mu_3 = 0 \quad \text{if} \quad D_1^{B*} < D_2^{B*}. \tag{A.6}$$

It comes directly from (A.3) that $\mu_1 > 0$. It then results from (A.4) that the budget constraint of the bank (2) is active:

$$\lambda D_1^B + (1-\lambda)\frac{D_2^B}{R} = 1 - c^B. \tag{A.7}$$

If $\mu_3 > 0$, then it comes directly from (A.6) that $D_1^{B*} = D_2^{B*} = D^{B*}$. However, we deduce from conditions (A.2) and (A.3) that $\mu_1 < 0$ if $\mu_3 > 0$, which contradicts the non-negativity condition on μ_1 (A.4). It results from this contradiction that $\mu_3 = 0$. Nevertheless, the nullity of the multiplier μ_3 does not imply that the corresponding incentive-compatibility constraint (4) is inactive. We examine the status of this constraint in the next paragraph.

Since $\mu_3 = 0$, we can combine conditions (A.2) and (A.3) by eliminating $1 + \mu_2$:

$$\frac{u'(D_1^{B*})}{u'(D_2^{B*})} = R. \tag{A.8}$$

Note that $u'(D_1^{B*})/u'(D_2^{B*}) = R > 1$. Thus, the strict concavity of $u(.)$ implies that $D_1^{B*} < D_2^{B*}$, which proves that the incentive-compatibility constraint (4) is inactive.

It is furthermore possible to prove that the participation constraint of consumers is inactive when the cost of setting up the bank is sufficiently low:

Lemma 1. *There exists a positive threshold c^B_{max} such that $\lambda u(D_1^{B*}) + (1-\lambda)u(D_2^{B*}) > u(1)$ if $c^B < c^B_{max}$.*

Proof. The budget constraint of the bank is active for all c^B (A.7), which implies that:

(i) The participation constraint of consumers is inactive when $c^B = 0$:
Condition (A.8) can be written as $1u'(D_1^{B*}) = Ru'(D_2^{B*})$, where $R > 1$. The risk aversion of consumers implies that $1u'(1) > Ru'(R)$.[9] Consequently, condition (A.8) is only satisfied if $D_1^{B*} > 1$ and $D_2^{B*} < R$. As previously shown, the strict concavity of $u(.)$ implies that $D_1^{B*} < D_2^{B*}$ if $u'(D_1^{B*})/u'(D_2^{B*}) = R > 1$. It then results that $1 < D_1^{B*} < D_2^{B*} < R$. Moreover, the terms of this deposit contract are compatible

[9] We assume in the model that the coefficient of relative risk aversion of consumers is greater than unity: $-Cu''(C)/u'(C) > 1$. This inequality can be rewritten as $u'(C) + Cu''(C) < 0$, or $\partial Cu'(C)/\partial C < 0$.

with the bank's budget constraint when $c^B = 0$. It results that the contract is feasible and the participation constraint of consumers is inactive when $c^B = 0$: $\lambda u(D_1^{B^*}) + (1-\lambda)u(D_2^{B*}) > u(1)$.

(ii) The participation constraint of consumers cannot be fulfilled when $c^B = 1$:
If $c^B = 1$, then the [active] budget constraint of the bank is given by $\lambda D_1^{B*} + (1-\lambda)(D_2^{B*}/R) = 0$. Since consumers have entrusted the bank with all their endowment in $t = 0$, they cannot make any further deposits, and the terms of the deposit contract cannot be negative: $D_1^{B*} \geq 0$ and $D_2^{B*} \geq 0$. As a result, the bank's budget constraint can only be satisfied when $D_1^{B*} = D_2^{B*} = 0$. This last condition then implies that the deposit contract cannot fulfill the participation constraints of consumers: $\lambda u(0) + (1-\lambda)u(0) = u(0) < u(1)$.

Let $V^B(c^B)$ be the maximum-value function associated with the optimization problem of the conventional bank (we omit all irrelevant parameters):

$$V^B(c^B) = \max\{U(D_1^B, D_2^B) : g_i(D_1^B, D_2^B, c^B) \leq 0,\ i = 1, \ldots, m\}, \tag{A.9}$$

where $U(D_1^B, D_2^B) = \lambda u(D_1^B) + (1-\lambda)u(D_2^B)$ is the objective function of the conventional bank, and $g_i(D_1^B, D_2^B, c^B) \leq 0$, the various constraints to which the deposit contract is subject. It follows from the envelope theorem that $V^B(c^B)$ is a strictly decreasing function of the cost of setting up the bank c^B: $\partial V^B/\partial c^B = \partial \mathcal{L}^B/\partial c^B = -\mu_1 < 0$. Since $V^B(0) > u(1)$ and $V^B(1) < u(1)$ (items i and ii), the intermediate value theorem implies that there exists a unique value $0 < c^B_{max} < 1$ such that $V^B(c^B_{max}) = u(1)$. The strict decrease of $V^B(c^B)$ in c^B also implies that $V^B(c^B) > u(1)$ if $c^B < c^B_{max}$. □

We assume in the model that the cost of setting up the bank is low enough that this solution is desirable ($c^B < c^B_{max}$). It follows that the participation constraint of consumers (3) is inactive and that $\mu_2 = 0$.

B. Proof of Proposition 2

Excluding the participation constraint of consumers (11), the Lagrangian function associated with the optimization problem of the *T-L bank* is

$$\begin{aligned}\mathcal{L}^{TL} &= \lambda u(D_1^{TL}) + (1-\lambda)\, u(D_2^{TL}) \\ &- \mu_1 \left[-(1-\tau^{TL})(1-c^{TL}) + \lambda D_1^{TL} - \tau^{TL}(1-c^{TL})R + (1-\lambda)D_2^{TL}\right] \\ &- \mu_2 \left[\lambda D_1^{TL} - (1-\tau^{TL})(1-c^{TL})\right] - \mu_3 \left[D_1^B - D_2^B\right],\end{aligned} \tag{B.1}$$

where μ_i are the Lagrange multipliers.

The strict concavity of the Lagrangian function implies that the following conditions are sufficient for optimality (Karush-Kuhn-Tucker conditions):

$$\frac{\partial \mathcal{L}^{TL}}{\partial D_1^{TL*}} = u'(D_1^{TL*}) - \mu_1 - \mu_2 - \frac{\mu_3}{\lambda} = 0, \tag{B.2}$$

$$\frac{\partial \mathcal{L}^{TL}}{\partial D_2^{TL*}} = u'(D_2^{TL*}) - \mu_1 + \frac{\mu_3}{1-\lambda} = 0, \tag{B.3}$$

$$\mu_1 \geq 0, \quad \text{and} \quad \mu_1 = 0 \quad \text{if} \quad (1-\tau^{TL})(1-c^{TL}) - \lambda D_1^{TL} + \tau^{TL}(1-c^{TL})R - (1-\lambda)D_2^{TL} > 0, \tag{B.4}$$

$$\mu_2 \geq 0, \quad \text{and} \quad \mu_2 = 0 \quad \text{if} \quad \lambda D_1^{TL} < (1-\tau^{TL})(1-c^{TL}), \tag{B.5}$$

$$\mu_3 \geq 0, \quad \text{and} \quad \mu_3 = 0 \quad \text{if} \quad D_1^{TL*} < D_2^{TL*}. \tag{B.6}$$

It comes directly from (B.3) that $\mu_1 > 0$. It then results from (B.4) that the budget constraint of the bank (9) is active.

As in the case of the conventional bank, it can easily be proved by contradiction that $\mu_3 = 0$. We examine the status of the corresponding incentive-compatibility constraint (12) in Lemma 2.

Given that $\mu_3 = 0$, we can combine conditions (B.2) and (B.3) by eliminating μ_1:

$$u'(D_1^{TL*}) = u'(D_2^{TL*}) + \mu_2. \tag{B.7}$$

It appears in (B.7) that the characteristics of the optimal deposit contract crucially depend on the value of the multiplier μ_2:

Lemma 2. *There are two possible types of deposit contracts depending on the value of the multiplier μ_2:*

(i) If $\mu_2 = 0$, then the optimal contract is characterized by

$$D_1^{TL*} = D_2^{TL*} = D^{TL*} \tag{B.8}$$

and

$$D^{TL*} = (1-c^{TL})\left[1 + \tau^{TL}(R-1)\right]; \tag{B.9}$$

(ii) If $\mu_2 > 0$, then the optimal contract is characterized by

$$u'(D_1^{TL*}) = u'(D_2^{TL*}) + \mu_2 \qquad (\mu_2 > 0) \tag{B.10}$$

and

$$\lambda D_1^{TL*} + (1-\lambda)\frac{D_2^{TL*}}{R} = 1 - c^{TL}. \tag{B.11}$$

Proof. We deal with the two cases separately:

(i) It comes directly from (B.7) that $D_1^{TL*} = D_2^{TL*} = D^{TL*}$ when $\mu_2 = 0$. The bank's budget constraint (9) can then be rewritten as $D^{TL*} = (1-c^{TL})\left[1 + \tau^{TL}(R-1)\right]$.

(ii) It comes directly from (B.7) that $u'(D_1^{TL*}) = u'(D_2^{TL*}) + \mu_2$ when $\mu_2 > 0$. If $\mu_2 > 0$, then the liquidity constraint (10) is active: $\lambda D_1^{TL*} = (1-\tau^{TL})(1-c^{TL})$. As a result, the bank's budget constraint (9) can be rewritten as $\lambda D_1^{TL*} + (1-\lambda)D_2^{TL*}/R = 1 - c^{TL}$.

□

The value of the multiplier μ_2 associated with the liquidity constraint (10) in turn relies on the level of asset transformation τ^{TL}, which then leads to determining the threshold value of τ^{TL} below which μ_2 is zero:

Lemma 3. *The multiplier μ_2 is zero when*

$$\tau^{TL} \leq \tau_S^{TL} = \frac{1-\lambda}{1+\lambda(R-1)}. \tag{B.12}$$

Proof. It follows from the definition of τ_S^{TL} that: (i) the liquidity constraint (10) is inactive and $\mu_2 = 0$ when $\tau^{TL} < \tau_S^{TL}$; (ii) the liquidity constraint (10) is active and $\mu_2 > 0$ when $\tau^{TL} > \tau_S^{TL}$.[10] Then, the switching threshold τ_S^{TL} is the only point where both the liquidity constraint (10) is active and the multiplier μ_2 is zero simultaneously. It results from $\mu_2 = 0$ that $D_1^{TL*} = D_2^{TL*} = D^{TL*}$ (B.7). The active liquidity constraint (10) also implies that $\lambda D^{TL*} = (1-\tau_S^{TL})(1-c^{TL})$. We get τ_S^{TL} directly by putting these last two expressions into the bank's budget constraint. Note that the set of parameters values is such that $0 < \tau_S^{TL} < \tau_F^{TL}$. □

Proposition 2 follows directly from the combination of Lemmas 2 and 3.

C. Proof of Proposition 3

Let $V^\theta(c^\theta, \tau^\theta)$ be the maximum-value function of both types of banks:

$$V(c^\theta, \tau^\theta) = \max\{U(D_1^\theta, D_2^\theta) : g_i(D_1^\theta, D_2^\theta, c^\theta, \tau^\theta) \leq 0,\ i = 1, \ldots, m\} \tag{C.1}$$

with $\theta = \{B, TL\}$, the type of bank, $U(D_1^\theta, D_2^\theta) = \lambda u(D_1^\theta) + (1-\lambda)u(D_2^\theta)$, the objective function of the bank, and $g_i(D_1^\theta, D_2^\theta, c^\theta, \tau^\theta) \leq 0$, the various constraints to which the deposit contract is subject.

Lemma 4. *If $\tau^{TL} = 0$, then $V^{TL}(c^{TL}, \tau^{TL}) < u(1)$.*

Proof. If $0 \leq \tau^{TL} \leq \tau_S^{TL}$, then the optimal deposit contract of the *T-L bank* is characterized by $D_1^{TL*} = D_2^{TL*} = D^{TL*}$ and $D^{TL*} = (1-c^{TL})\left[1+\tau^{TL}(R-1)\right]$ (Proposition 2). In the particular case where $\tau^{TL} = 0$, the second condition becomes $D^{TL*} = (1-c^{TL}) < 1$. It follows that $u(D^{TL*}) < u(1)$ if $\tau^{TL} = 0$, which proves that $V^{TL}(c^{TL}, 0) < u(1)$. □

Lemma 5. *If $\tau^{TL} = \tau_F^{TL}$, then $V^{TL}(c^{TL}, \tau^{TL}) > V^B(c^B, \tau_F^B)$.*

Proof. If $\tau_S^{TL} < \tau^{TL} \leq \tau_F^{TL}$, then the optimal deposit contract of the *T-L bank* is characterized by (16) and (17). The free optimal level of asset transformation τ_F^{TL} is also characterized by

$$\frac{\partial \mathcal{L}^{TL}}{\partial \tau_F^{TL}} = (1-c^{TL})\left[\mu_1(R-1) - \mu_2\right] = 0. \tag{C.2}$$

It follows from (C.2) that $\mu_2 = \mu_1(R-1)$ when $\tau^{TL} = \tau_F^{TL}$. Given that $\mu_3 = 0$, it also comes directly from (B.3) that $\mu_1 = u'(D_2^{TL*})$. We then deduce that $\mu_2 = u'(D_2^{TL*})(R-1)$. Replacing the latter expression in (16), it results that $u'(D_1^{TL*})/u'(D_2^{TL*}) = R$. Thus, when $\tau^{TL} = \tau_F^{TL}$, the optimal deposit contract of the *T-L bank* is characterized by $u'(D_1^{TL*})/u'(D_2^{TL*}) = R$ and $\lambda D_1^{TL*} + (1-\lambda)(D_2^{TL*}/R) = 1 - c^{TL}$. The optimal contract of the *T-L bank* is then identical to the conventional bank one, except for the cost of setting up the bank ($c^{TL} < c^B$). Given that $V(c)$ is a strictly decreasing function in c ($\partial V/\partial c = \partial \mathcal{L}/\partial c = -\mu_1 < 0$), the deposit contract of the *T-L bank* trivially dominates the deposit contract of the conventional bank: $V^{TL}(c^{TL}, \tau_F^{TL}) > V^B(c^B, \tau_F^B)$. □

[10] Note that the liquidity constraint (10) is inactive ($\mu_2 = 0$) when τ^{TL} is arbitrarily close to 0 and active (with $\mu_2 > 0$) when τ^{TL} is arbitrarily close to 1.

Lemma 6. *$V^{TL}(c^{TL}, \tau^{TL})$ is a continuous and strictly increasing function of τ^{TL} on $\left[0, \tau_F^{TL}\right]$.*

Proof. It is possible to split the value function $V^{TL}(c^{TL}, \tau^{TL})$ defined on $\left[0, \tau_F^{TL}\right]$ into a function $V_0^{TL}(c^{TL}, \tau^{TL})$ defined on $\left[0, \tau_S^{TL}\right]$ and a function $V_1(c^{TL}, \tau^{TL})$ defined on $\left]\tau_S^{TL}, \tau_F^{TL}\right]$. We can then observe that:

(i) $V_0^{TL}(c^{TL}, \tau^{TL})$ is continuous and strictly increasing in τ^{TL} on $\left[0, \tau_S^{TL}\right]$:
If $0 < \tau^{TL} < \tau_S^{TL}$, then $\mu_2 = 0$ (see proof of Proposition 2). The maximum-value function $V_0^{TL}(c^{TL}, \tau^{TL})$ then is continuous and strictly increasing in τ^{TL}: $\partial V_0^{TL}/\partial \tau^{TL} = \partial \mathcal{L}^{TL}/\partial \tau^{TL} = \mu_1(1 - c^{TL})(R - 1) > 0$. It follows from Lemma 4 that $V_0^{TL}(c^{TL}, \tau^{TL})$ is defined at $\tau^{TL} = 0$ and that $\lim_{\tau^{TL} \to 0} V_0^{TL}(c^{TL}, \tau^{TL}) = V^{TL}(c^{TL}, 0)$. It also follows from Proposition 2 that $V_0^{TL}(c^{TL}, \tau^{TL})$ is defined at $\tau^{TL} = \tau_S^{TL}$ and that $\lim_{\varepsilon \to 0} V_0^{TL}(c^{TL}, \tau_S^{TL} - \varepsilon) = V_0^{TL}(c^{TL}, \tau_S^{TL})$.It then results that $V_0^{TL}(c^{TL}, \tau^{TL})$ is continuous and strictly increasing in τ^{TL} on $\left[0, \tau_S^{TL}\right]$.

(ii) $V_1^{TL}(c^{TL}, \tau^{TL})$ is continuous and strictly increasing in τ^{TL} on $\left]\tau_S^{TL}, \tau_F^{TL}\right]$:
If $\tau_S^{TL} < \tau^{TL} < \tau_F^{TL}$, then $\mu_2 > 0$ (see proof of Proposition 2). The maximum-value function $V_1^{TL}(c^{TL}, \tau^{TL})$ then is continuous and strictly monotonous on $\left]\tau_S^{TL}, \tau_F^{TL}\right[$: $\partial V_1^{TL}/\partial \tau^{TL} = \partial \mathcal{L}^{TL}/\partial \tau^{TL} = (1 - c^{TL})[\mu_1(R - 1) - \mu_2]$. The fact that $\tau^{TL} < \tau_F^{TL}$ implies that $\partial V_1^{TL}/\partial \tau^{TL} > 0$. It follows that $V_1^{TL}(c^{TL}, \tau^{TL})$ is [continuous and] strictly increasing on $\left]\tau_S^{TL}, \tau_F^{TL}\right[$. It also follows from Lemma 5 that $V_1^{TL}(c^{TL}, \tau^{TL})$ is defined at $\tau^{TL} = \tau_F^{TL}$ and that $\lim_{\varepsilon \to 0} V_1^{TL}(c^{TL}, \tau_F^{TL} - \varepsilon) = V_1^{TL}(c^{TL} \tau_F^{TL})$. It then results that $V_1^{TL}(c^{TL}, \tau^{TL})$ is continuous and strictly increasing in τ^{TL} on $\left]\tau_S^{TL}, \tau_F^{TL}\right]$.

(iii) $V^{TL}(c^{TL}, \tau^{TL})$ is continuous and strictly increasing in τ^{TL} on $\left[0, \tau_F^{TL}\right]$:
If $\tau^{TL} = \tau_S^{TL} + \varepsilon$ then $D_1^{TL*} < D_2^{TL*}$ and the liquidity constraint (10) is active (see proof of Proposition 2): $\lambda D_1^{TL*} = [1 - (\tau_S^{TL} + \varepsilon)](1 - c^{TL})$. It follows that

$$\lim_{\varepsilon \to 0} D_1^{TL*} = \lim_{\varepsilon \to 0} \frac{[1 - (\tau_S^{TL} + \varepsilon)](1 - c^{TL})}{\lambda} = \frac{(1 - c^{TL})R}{1 + \lambda(R - 1)} = D^{TL*}. \tag{C.3}$$

Given that $\lambda D_1^{TL*} = [1 - (\tau_S^{TL} + \varepsilon)](1 - c^{TL})$, the bank's budget constraint (9) can be rewritten as:

$$D_2^{TL*} = \frac{R}{1 - \lambda}(\tau_S^{TL} + \varepsilon)(1 - c^{TL}). \tag{C.4}$$

It follows that

$$\lim_{\varepsilon \to 0} D_2^{TL*} = \lim_{\varepsilon \to 0} \frac{R}{1 - \lambda}(\tau_S^{TL} + \varepsilon)(1 - c^{TL}) = \frac{(1 - c^{TL})R}{1 + \lambda(R - 1)} = D^{TL*}. \tag{C.5}$$

It results from (C.3) and (C.5) that $\lim_{\varepsilon \to 0} V_1^{TL}(c^{TL}, \tau_S^{TL} + \varepsilon) = V_0^{TL}(c^{TL}, \tau_S^{TL})$. Given (i) and (ii), this implies that $V^{TL}(c^{TL}, \tau^{TL})$ is continuous and strictly increasing on $\left[0, \tau_F^{TL}\right]$ by connecting $V_0^{TL}(c^{TL}, \tau^{TL})$ and $V_1^{TL}(c^{TL}, \tau^{TL})$ at τ_S^{TL}.

□

It results from the application of the intermediate value theorem that there exists a single value $0 < \underline{\tau}^{TL} < \tau_F^{TL}$ such that $V^{TL}(c^{TL}, \underline{\tau}^{TL}) = u(1)$ and a single value $0 < \overline{\tau}^{TL} < \tau_F^{TL}$ such that $V^{TL}(c^{TL}, \overline{\tau}^{TL}) = V^B(c^B, \tau_F^B)$. Given that $V^B(c^B, \tau_F^B) > u(1)$ (Lemma 1 in Appendix A), we finally deduce that $\overline{\tau}^{TL} > \underline{\tau}^{TL}$.

References

Allen, F. and D. Gale (2004) "Financial intermediaries and markets" *Econometrica* **72**, 1023- 61.

Allen, F., Gu, X. and J. Jagtiani (2021) "A survey of fintech research and policy discussion" *Review of Corporate Finance* **1**, 259-339.

Arnold, I.J. and S.E. van Ewijk (2011) "Can pure play internet banking sur- vive the credit crisis?" *Journal of Banking & Finance* **35**, 783-93.

Arslanian, H. and F. Fischer (2019) "The rise of fintech" in *The future of finance: The impact of FinTech, AI, and crypto on financial services* by H. Arslanian and F. Fischer, Eds., Springer, 25-56.

Basak, S. and D. Cuoco (1998) "An equilibrium model with restricted stock market participation" *The Review of Financial Studies* **11**, 309-41.

Chiorazzo, V., D'Apice, V., DeYoung, R. and P. Morelli (2018) "Is the traditional banking model a survivor?" *Journal of Banking & Finance* **97**, 238-56.

Diamond, D.W. (1997) "Liquidity, banks, and markets" *Journal of Political Economy* **105**, 928–56.

Diamond, D.W. and P.H. Dybvig (1983) "Bank runs, deposit insurance, and liquidity" *Journal of Political Economy* **91**, 401-19.

Gale, D. and P. Gottardi (2020) "A general equilibrium theory of banks' capital structure" *Journal of Economic Theory* **186**, 104995.

He, Z., Huang, J. and J. Zhou, J. (2020) "Open banking: Credit market competition when borrowers own the data" NBER working paper number 28118.

He, Z. and A. Krishnamurthy (2013) "Intermediary asset pricing" *American Economic Review* **103**, 732-70.

Kučinskas, S. (2019) "Aggregate risk and efficiency of mutual funds" *Journal of Banking & Finance* **101**, 1-11.

Mankiw, N.G. and S.P. Zeldes (1991) "The consumption of stockholders and nonstockholders" *Journal of Financial Economics* **29**, 97–112.

Marini, F. (2005) "Banks, financial markets, and social welfare" *Journal of Banking & Finance* **29**, 2557-75.

Parlour, C.A., Rajan, U. and H. Zhu (2022) "When fintech competes for payment flows" *The Review of Financial Studies* **35**, 4985-5024.

Philippon, T. (2016) "The fintech opportunity" NBER working paper number 22476.

Tang, H. (2019) "Peer-to-peer lenders versus banks: Substitutes or complements?" *The Review of Financial Studies* **32**, 1900-38.

Thakor, A.V. (2020) "Fintech and banking: What do we know?" *Journal of Financial Intermediation* **41**, 100833.

Vives, X. (2019) "Digital disruption in banking" *Annual Review of Financial Economics* **11**, 243-72.