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Blockchain and business model innovation: Designing a P2P mortgage lending system

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Abstract. This paper explores P2P lending in the context of mortgage financing. While P2P lending has gained considerable traction in the consumer loan segment, it remains absent for the economically and socially important mortgage sector. Following a design research approach (most specifically, Action Design Research), the paper defines a series of questions about how a sound business model would make P2P mortgage lending feasible from a technical and business perspective. In order to provide an initial answer, a model is developed by providing a theoretical explanation and a partial formalization in Business Process Modelling and Notation (BPMN). The business model introduces artificial intelligence, blockchain/smart contracts and Business-Process-as-a-Service (BPaaS) as its main features. A preliminary evaluation of the model's feasibility and effectiveness is offered, as a way of providing an initial prescriptive theory on a subject (P2P mortgage lending) where academic studies and business applications are basically absent.

Key words: P2P lending, crowdlending, mortgages, business model innovation, blockchain, smart contracts, artificial intelligence, BPaaS.

1 Introduction

Mortgage loans perform a fundamental function in the economy and society as they are, for the majority of people, the only option to owning a home. In a simple mortgage lending model, banks extend mortgage loans by performing their traditional financial intermediation role between depositors and borrowers, receiving a collateral consisting in the property purchased (i.e. a mortgage), and keeping the mortgage debt in their balances. This model, however, became progressively more complex with the introduction of a secondary market, as well as securitization in the form of mortgage-backed securities (MBS), most prominently since the 1970s through U.S. GSE issued MBS [81, 78].

Besides their economic and social significance for households, mortgages proved to be a

sensitive and consequential market by being the main cause behind the 2008 financial crisis and ensuing Great Recession years [77, 27]. A blend of lax screening in the context of housing credit expansion plus systemic risks inside a securitization trend, exposed many shortcomings in the mortgage value chain [39, 45].

As the 2008/2009 crisis unfolded, the seeds of a financial disruptive force where planted with the introduction of Bitcoin [58] and its underlying technology: blockchain. In parallel, crowdfunding and online P2P lending have grown over the course of this decade, reaching unexpected levels[1]. This P2P lending expansion has to some extent complemented bank lending by offering an alternative finance option to high risk sectors underserved by banks [72]. The mortgage sector, however, has been mostly alien to P2P lending.

The purpose of this study is to explore how a blockchain/smart contract-based P2P mortgage lending system would look like. It is the claim of this paper that blockchain, more than just a new technology, is actually a new framework for conducting business processes: in other words, an example of business model innovation [62]. Following the design research paradigm, the paper sketches a new business model for mortgage lending, with the purpose of answering the following research question:

> ***RQ:*** *How could a new business model make mortgage P2P lending viable?*

This main research question is decomposed into three sub-research questions, covering different aspects and stages in the process of mortgage origination. The first issue to be addressed refers to the business processes that take place from a mortgage application until the borrower's creditworthiness assessment (underwriting), focusing in the information asymmetries between borrowers and lenders in a P2P framework, as well as optimal assessment methods. Thus, the first sub-research question is the following:

> ***RQ1:*** *How to handle information flows between borrowers and lenders in a P2P mortgage lending system, such that underwriting could be performed in a sound way?*

The second aspect to be addressed pertains to the actual funding of a mortgage loan. Under a traditional mortgage lending system, banks perform their financial intermediation function, channeling funds from savers to borrowers. Under a P2P lending system, however, financial flows from lenders to borrowers have to be channeled in an effective and efficient way. Therefore, the second sub-research question is defined as follows:

> ***RQ2:*** *What framework could handle efficiently and effectively the financial flow of funds from lenders to borrowers in a P2P mortgage lending system?*

The final issue, and one of the elements that differentiates mortgage lending from consumer

[1] In 2009, [11] predicted a P2P lending market size of USD 10 billion after one decade. In fact, at the end of 2016 it had already reached USD 34.5 billion [94].

lending, is the mortgage itself as a collateral. In online P2P lending, borrowers and lenders can be matched on a one to one basis, because the loan amount is relatively small. Mortgage loans, in contrast, usually go by the hundreds of thousands, such that syndicating the loan among several lenders becomes almost a necessity. In that scenario, the assignation of a single mortgage deed between several lenders becomes a question:

> ***RQ3:*** *Who should be the holder of the mortgage deed under a P2P lending system?*

The rest of this paper shall be structured as follows. Section 2 will cover background literature in order to provide the conceptual context of the problem. Section 3 will explain the research methodology used. Sections 4, 5 and 6 will design a model for answering the three sub-research questions posed. Section 7 will offer a preliminary evaluation of the proposed model, and Section 8 will conclude, pointing out to limitations and suggesting future research directions.

2 Background Literature

In this section, we shall refer to previous work covering the main theoretical context of the research question. The section will be divided into 3 sub-sections, each one developing a specific dimension of the problem.

2.1 P2P lending

2.1.1 P2P lending and financial intermediation

Peer-to-peer lending is a method and system where borrowers and lenders directly interact with each other, with minimal involvement of financial intermediaries like banks. In traditional lending, banks take deposits from households and channel them to economic agents requiring capital. This role of banks has been justified by a theory of financial intermediation based on transaction costs [73], asymmetry of information [14, 4], risk management and participation costs [2, 3]

During the last two decades, with the surge of electronic marketplaces, a *disintermediation* process has taken place [60, 22, 64, 47], with some authors describing an intermediation/disintermediation/reintermediation cycle [20, 21], where some traditional intermediaries, after being disenfranchised as a consequence of technological innovations, find new ways to compete by leveraging these innovations. Financial disintermediation has been noticed in several fields, notably P2P lending [16, 11] and virtual currencies [66].

2.1.2 Information asymmetries and credit assessment models

Besides its characterization as a financial disintermediation process, P2P lending has been claimed to reduce information asymmetries between borrowers and lenders. Two researches about *Prosper*, one of the biggest P2P loan platform in U.S., show how microlenders, in order to mitigate the adverse selection problem present when choosing whom to fund, give weight to soft information signaled through friendships [49] or provided by group leaders acting as intermediaries [11]. An important outcome of this enhanced availability of soft information based on online relationships, is that borrower's credit conditions are improved; both in relation to the likelihood of receiving a loan as well as of its terms [48, 91].

Lenders in P2P platforms benefit from the information that is signaled through reputation systems and credit history. But beyond that, and more importantly, the increased soft and hard information gathered through P2P systems enables more sophisticated creditworthiness assessments by means of data analytics [29, 89, 50]. Artificial intelligence (AI) and, more specifically, data analytics based on artificial neural networks (ANN) have been shown to provide highly sophisticated and accurate assessments on creditworthiness and default likelihood. [19] show how an ANN credit score model outperforms a linear regression model in screening for default loans, while [92], in a research performed over an n=10,649 data set of a major P2P lending platform, find an ANN method to have a 78.6% accuracy rate for creditworthiness evaluation.

Data analytics methods other than ANN have also been studied. [38] propose an instance-based data-driven investment decision-making framework to quantify loan risk in P2P lending. [44] compare models based on decision trees (DT), support vector machine (SVM) and ANN, finding similar prediction performances. Some studies focus on aspects other than the method or model of data analytics. [93] analyze the predictability power of different sorts of data, finding that social network and loan information are more important than credit rating for predicting default; [34] find also a significant value in social media information for creditworthiness screening and default deterrence. [76], on the other hand, study a different outcome variable: while most literature researches default predictability of different data analytics models and methods, the authors focus on profit predictability, showing that data mining techniques are able to identify the most profitable loans (i.e. loans with the best return/risk ratio), rather than simply predict the likelihood of default.

2.2 Mortgage financing

Mortgage loans differ from other types of debt instruments in several ways, but mostly due to their being guaranteed by real estate as collateral. In contracts with most loans, where the dispossession or bankruptcy of the debtor might turn the debt to be uncollectible, in a mortgage loan the property under lien can be seized and sold to satisfy the credit with

priority. Also, the mortgage follows the property, such that the lender can seize it even if ownership has been transferred [59]. Another legal principle in the mortgage market is the "mortgage follows the note" rule, which roughly means that the mortgage deed (the lien) is necessarily attached to the debt itself [42, 31].

Mortgage financing has been studied from many perspectives, most prominently in the last decade, regarding mortgage-backed securities (MBS) and their role in the 2008 financial crisis and ensuing Great Recession [56, 27, 63]. For this paper's research questions, we shall refer to literature covering the topics of inefficiencies in the mortgage origination process and accessibility to mortgage financing (which are the main problems to be addressed by the artifact whose design is proposed); and the role of Fintech in the mortgage market (from which a solution should emerge).

2.2.1 Mortgage origination inefficiencies

[67] studies efficiency in the context of the whole U.S. financial industry. The analysis, based in financial intermediation theory, concludes that, despite information technology, the cost of intermediation relative to the production of assets and liquidity services has increased in the last decades to its maximum historical levels. More specifically, [24] studies efficiency in the mortgage supply chain, stating that due to high marketing costs and an obsolete, paper-based technology for origination, lower and moderate income households are underserved by the banks that have the largest share of the mortgage segment. [52] find a positive correlation between efficiency and credit supply for the mortgage market between 1999 and 2008, while banks with higher market power tended to restrict that credit supply. In contrast, they find that the more efficient banks used technology indiscriminately in order to increase mortgage credit supply, at the expense of credit quality. These results, tying both credit supply expansion and credit risk to efficiency, are consistent with the "lax screening" hypothesis, according to which faster originations are to a great extent due to insufficient or unsound creditworthiness assessments.

2.2.2 Accessibility issues

Lax screening is just one side of the coin regarding unsound mortgage underwriting: the "false positive" side. It is understandably associated with the irresponsible credit expansion of the real estate bubble market years. But after the 2008-2009 shock and following recession, the other side of the coin has also become prominent; applicants who should have access to mortgage financing are improperly qualified at too high-risk levels or outright rejected ("false negative") because relevant soft-information, such as level of education, is not rightfully considered. In fact, those with college and advanced degrees might be at a great disadvantage, as student debt burden has soared and constitutes one of the biggest

obstacles in the path for homeownership and social ladder climbing, most particularly for the millennial generation [80]. [15] observe that high student debt has been associated with tightening of mortgage eligibility, particularly during the Great Recession years. For instance, they note that *"while student loan borrowers aged 25 (or 30) used to have average credit scores comparable to those without student debt, by 2012 they had considerable lower credit scores"* [p. 16]. A similar conclusion is reached by [12], who state that those with high student debt burden are significantly and substantially more prone to either return to living with parents or to delay moving away from them, while [26], in a short article for the Federal Reserve Bank of Cleveland, show a strikingly inverse trend in the decade 2005-2015, between the percentage of student loans and of mortgage loans among young people (18-30 years old). The same inverse correlation between, on the one hand, high student debt, and on the other hand homeownership/mortgage acquisition/amount of mortgage debt among youths, is found by [41], though to a lesser extent. For the UK market, [5] finds that increased student debt levels delay first-time homeownership.

2.2.3 Fintech and the mortgage market

Among research on Fintech in the mortgage industry, it stands out a recent Federal Reserve Bank of New York (FDBNY) report covering data from 2010 to 2016 [30]. The authors find a mostly positive role for Fintech lenders in the mortgage market. Fintech mortgage lenders, defined as those who provide an origination process that can be entirely completed online, are able on average to cut mortgage origination times by 20%. Also, contrary to the lax screening hypothesis, default rates on Fintech lenders were about 25% lower than those of traditional lenders. This enhanced efficiency is based, according to the authors, on an ability to automate, simplify and speed up each step of the mortgage origination process, as well as centralized underwriting operations. On the negative side, they find that an automated mortgage underwriting, mostly based on hard information and without personal interaction, might result in a less effective borrower screening and credit rationing. [17] address organizational innovation in the mortgage market, reflected in the increased share of "shadow banks" (i.e. non-depository lenders) on the mortgage market. Their assessment of this growth points towards increased regulatory burden on traditional banks as the main reason, and technological innovation as a secondary cause. [36] refer to mortgage innovation in the context of what is called the "Fintech revolution", mentioning features like alternative credit scores built on mobile usage data, mortgage approvals based on data mining, and the incorporation of an applicant's level of education for creditworthiness assessment.

2.3 Blockchain technology and business model innovation

2.3.1 Blockchain and the financial industry

Since its very beginning, blockchain technology has been closely intertwined with Fintech. After all, the bitcoin crypto-currency (its first application) is above all a financial innovation: a "peer-to-peer electronic cash system" was its original description [58]. Among the several areas of application for distributed ledger technology (DLT), the financial industry stands out as the clearest one [84, 83, 51].

A study by [65] argues that blockchain technology has the potential of being applied in financial areas such as transaction processing, government cash management, commercial bank ledgers, and clearing and settlement of financial assets. [37] characterize blockchain as a Fintech 2.0 innovation, focusing on the backend underlying technology for the financial industry and not in its application scenarios. The authors consider that blockchain offers a solution to problems like efficiency bottlenecks, transaction lag, fraud and operation risks. In the particular area of credit information systems, they note the potential uses of blockchain for information ownership and data sharing. Of particular interest is the analysis made in [53], where it is argued that blockchain is more than a new ICT technology that can be applied by banks. Based on financial intermediation theory and New Institutional Economics, the authors consider that blockchain will decentralize and disintermediate several areas of banking activity, such that *"while banking itself may not fundamentally change, banks might"* [p. 279].

2.3.2 Blockchain-based business model innovation

During the last decade, business model innovation has been defined and explained by different (and competing) paradigms and schools [33]. One of them, the *Activity System* school (aka *IESE/Wharton school*), defines a business model as a set of activities, resources and capabilities (held within the firm or across its boundaries), that allow a firm to create value and appropriate a share of it [95, 96]. Therefore, a modification in the distribution of these activities, resources and capabilities aimed to generate and appropriate economic value, would traduce into business model innovation. Based on those observations, it is a proposition of this paper that blockchain technology, by generating disintermediation in financial services, constitutes a significant way of business model innovation. Blockchain technology as a way of business model innovation is explored in the conceptual framework developed in [35]. By introducing new ways of decentralization and delegation of processes into "autonomous interacting pieces of code" (i.e. smart contracts), blockchain challenges trust establishing intermediaries such as banks, as well as incumbent business models. Business logic, understood as market mechanisms and corresponding decision making and

instrumental processes, can be coded into smart contracts, a concept originally proposed by [82], but which regained notoriousness with the Ethereum platform [18]. These smart contracts function as an "automatable and enforceable agreement" [23], having the capacity to replace trust intermediaries in some circumstances. [74] use the business model concept as a departing point in order to develop a proposed blockchain network ontology. They define a business model as a structural template that describes the business logic behind value creation and its delivery (in this sense, they are close to the *Cognitive* school, aka *Cass* school [6, 33].

2.3.3 Blockchain as a form of Business-Process-as-a-Service (BPaaS)

The concept of Business-Process-as-a-Service (BPaaS) has been coined in the context of cloud services [87], being an extension of the traditional cloud services stack of Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS) [90]. [1] defines BPaaS as a special instance of the SaaS model in which enterprise cloud suppliers provide methods for modeling, utilizing, customizing and executing business processes. Under this model, *"cloud consumers (or clients) can rely on and access pre-defined process descriptions, customize these processes according to the current needs, and remotely execute the processes in the cloud"* [pp. 398-399].

An important feature of the BPaaS model is its firm boundaries-crossing structure. One the one hand, BPaaS is not simply an additional layer over the traditional cloud stack, entirely allocated to the cloud provider, but rather spans the provider, the consumer and third parties [7]. On the other hand, BPaaS can be configured by mixing services from different providers into a single business process structure, which is in turn offered to clients by the firm as its own service [13].

A similar functionality to that of BPaaS can be attributed to blockchain technology in relation to business process management. By encoding business logic into smart contracts that can be triggered by events originating in different network players, blockchain has the potential of offering a sort of distributed cloud service. As it is explained in several papers [88, 32, 55, 70], for business processes where several organizations or players have to take part, blockchain can act as a choreography monitor by recording the process execution status for each player, and checking through smart contracts that interactions between them conform to a pre-defined model. It also performs the role of an active mediator among players, by coordinating collaborative process execution, also through smart contracts. Most specifically, in [32] the authors develop a procedure for depicting business processes workflows in BPMN and Petri nets, and then coding them in Solidity, the Ethereum programing language.

3 Research Method

3.1 Action Design Research

The present study follows the Action Design Research methodology (ADR), as exposed in [75]. ADR is a confluence of both Design Science Research (DSR), frequently used in the Information Systems discipline [54, 40], and Action Research (AR), a method initially suggested by [46], which combines theory generation with problem solving in organizational contexts [8].

As [40] explain, DSR is a problem-solving paradigm that *"seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished"* [p. 76]. The goal of DSR is twofold: solving a practical problem and generating theory, both through the creation of an IT artifact [9].

The IT artifact itself can be a *construct, model, method* or *instantiation*, and its creation follows two general stages: *design/building* and *evaluation* [54, 40]. Though traditional DSR suggests a sequenced procedure (first desing/build, then evaluate), recent literature have questioned this structure as too rigid, particularly when the research is performed in organizational contexts. It is thus observed that evaluation can be parallel and intermingled with the design stage [9, 86], as well as that several design/evaluation iterations should be performed as the artifact is developed [75].

ADR is particularly adequate when design research is undertaken to solve a perceived problem in organizational contexts: in other words, when in order to address a problem within an organization, an IT artifact is designed, built and evaluated [71]. In the particular case of this study, the research is being conducted in the organizational context of an Israel-based startup company, which is developing a blockchain-based mortgage lending platform.

The problem to be solved, therefore, does not reside within the organization itself: rather, the startup is being developed with the goal of designing, building and instantiating an IT artifact that will solve a perceived problem in the mortgage industry. While this goal is purely practical, it does not exclude theory generation as a by-product. In fact, the *"lean startup"* entrepreneurship method [69, 57, 28], followed by the startup that provides the context of this study, closely resembles the ADR paradigm in that IT artifact design/building, evaluation, and organizational intervention are concurrent and intermingled [75].

3.2 Model building

The very first step in design research is the identification of a problem to be solved. For this study, the problem is rendered into the research main question and sub-questions. Each sub-question addresses a specific phase in mortgage origination, and how this phase should be structured for a mortgage crowdlending system to work effectively and efficiency.

Consequently, the answer to each of these sub-questions will be provided by an artifact *model*. As [40] explain, models *"aid problem and solution understanding and frequently represent the connection between problem and solution components enabling exploration of the effects of design decisions and changes in the real world"* [p. 78-79]. Each of these models will consist on a proposed workflow solution that will describe in terms of structures and processes, how information and financial flows, as well as legal rights are to be handled in a mortgage crowdlending system. The group of these models provides the artifact's blueprint.

In this sense, the present study proceeds by stages from textual descriptions about structures and process, through workflow depictions using Business Process Modelling and Notation (BPMN).

3.3 Evaluation

The second general stage of DSR is the *evaluation* of the proposed artifact. Without evaluating the artifact, the design research cannot be properly said to be complete. The evaluation needs to cover two aspects, which correspond to the twofold goal of DSR: whether the artifact is useful in addressing the perceived problem, and whether the creation of the artifact generates new knowledge.

A full evaluation of an artifact should include its instantiation, i.e. the functioning artifact operating in the real world. Evaluation of instantiations allow to assess the artifact's suitability for its intended purpose [40, 9, 68]. For the ADR here undertaken, a full evaluation of the artifact's instantiation would imply an assessment of its performance on the real world, i.e. whether or not the proposed mortgage crowdlending system addresses, in an effective and efficient way, the issues briefly described in the literature background: information asymmetries, difficulties to access mortgage financing, soundness of artificial intelligence powered underwriting, etc. In other words, a full DSR evaluation would require for the artifact to be already in the market.

However, as literature on DSR has observed, the evaluation of the artifact is conducted through several iterations, which cover not only its final instantiation, but also its preliminary design/blueprint in terms of models and methods. In this sense, a distinction is made

between *ex-ante* and *ex-post* evaluations [79, 86]. *Ex-ante* evaluations are made over the artifact's model before it is instantiated.

Ex-ante evaluations are required due to the emergent nature of IT artifacts. As [79] point out, design decisions relate to the prescriptive knowledge generated by an emergent design theory, and these decisions *"have to be justified and validated by means of evaluations long before an IT artifact has been put into use"* [p. 385].

Given that the objective of this paper is to design and propose an artifact's model and method for mortgage crowdlending, the assessment presented constitutes an ex-ante evaluation of the corresponding blueprint. It represents the first step in the ADR which should be completed when the artifact is fully instantiated by its introduction in the market. At that final stage, an *ex-post* evaluation is to be conducted.

4 Information flows and mortgage underwriting

In this and the next two sections, the sub-research questions are addressed in the following manner: first, the specific problem behind the question shall be defined and described; second, a solution to the problem will be exposed; and third, this solution will be formally modelled in a way that can be instantiated by a specific business model/IT artifact.

4.1 Problem setting

One of the main challenges that P2P lending in general has to cope with is that posed by information asymmetries. The information necessary to soundly assess creditworthiness is asymmetrically distributed between borrowers and lenders: for the latter, it is challenging to gather the right amount and quality of borrower's data. Financial institutions like banks handle this with accumulated knowledge and through experience-tested business processes. Part of this knowledge is tacit [61] and cannot be easily formalized in a set of rules. Acquiring and applying this knowledge outside a firm's boundary, as it is supposed to be done under a P2P disintermediation framework, implies very high participation costs as defined by [2]: *"the costs of learning about effectively using markets as well as participating in them on a day to day basis"* [p. 1462].

P2P lending systems handle information asymmetries in several ways, one of them being reputation systems. In P2P lending platforms like *Prosper* and *Lending Club*, as borrowers take and duly repay loans (or not), they build a reputation that signals creditworthiness levels. Such a tool is not feasible for mortgage lending, as loans are usually taken once in a lifetime and they can last for up to 30 years. Thus, lenders in a mortgage P2P system, would require different tools to properly gather borrowers' data and assess creditworthiness.

This difficulty effectively obstructs home loan borrowers' access to alternative financing under a P2P system. While, as exposed in the previously quoted FRBNY report, Fintech mortgage lenders have been successful in reducing origination times and default rates, the innovative element of these Fintech lenders lies solely in the digitization of the process, not in the expansion of financial sourcing through a P2P framework [30]. The claimed complementarity of P2P lending to address the underserved high risk/high return segment [72], does not seem to take place in the mortgage sector.

The case of student debt burdened borrowers, frequent among millennials, calls for special attention. Their credit scores are downgraded by their financial situation, even in cases where their true creditworthiness is in fact better, which causes them to be incorrectly rejected (a false negative, or Type II error). Soft information, which would allow more sophisticated underwriting with the help of AI and ANN assessment, is not sufficiently considered in traditional banking underwriting. As mentioned by [30], Fintech mortgage lenders are offering innovative, more powerful tools for creditworthiness assessment. Also, AI creditworthiness assessment tools are already being used in P2P consumer lending. The question is, therefore, how to design a system that would benefit from AI assisted underwriting, already used in Fintech mortgage (non-P2P) lending and P2P (non-mortgage) lending.

4.2 Proposed solution

The solution proposed in this paper implies a degree of financial *reintermediation* [21]. This reintermediation would take place by offering prospective borrowers a tool for efficiently providing both hard and soft information, and offering prospective lenders a tool for soundly assessing creditworthiness and risk levels.

These tools would be instantiated in an online based platform that would offer easy digitization and AI/ANN powered creditworthiness and risk assessment. This can be structured in different ways: the same platform could offer information uploading and mortgage application functionality *and* AI powered underwriting. *Or*, these tools could be provided by different platforms under a collaborative framework.

The model here presented, proposes a framework where each functionality can be outsourced to a different platform. This way, companies currently offering AI/ANN creditworthiness assessments in the context of consumer or non-P2P mortgage lending, would provide their resources and capabilities for the mortgage value-chain, as a service: in other words, they would operate under the BPaaS model.

All the processes inputs and outputs would be stored in a permissioned distributed ledger (blockchain), while digital versions of the paper documents (employer letters, education certificates, payment slips, property appraisal reports) can be stored in a distributed file

database like the InterPlanetary File System (IPFS) [10], where they would be identified by a unique hash code. This way, any entity taking part in the mortgage origination stage, or even in further servicing, would access the same source of information.

Once all borrower's information is collected (hard and soft) and the property appraisal is digitally available, an AI tool would perform a creditworthiness and risk assessment and make a pre-approval decision. This stage, therefore, begins with a mortgage application and finishes with a decision regarding pre-approval, made by an AI/ARR artificial agent. If the application is rejected, the process finishes. If it is pre-approved, the process moves to a second stage: crowdlending.

4.3 Model formalization

4.3.1 Process steps list

The process steps list for the application/underwriting stage goes as follows:

1. Borrower uploads information into Application Platform.
2. Borrower applies for a specific property and a specific loan amount.
3. Application Platform identifies digitally uploaded documents with unique hash ID.
4. Application Platform creates and consolidates digital file.
5. Appraiser uploads digital property appraisal report in Application Platform.
6. Application Platform transfer digital file to Underwriting Platform.
7. Underwriting Platform analyses digital file with AI/ANN powered tool.
8. Underwriting Platform makes pre-approval decision, which defines interest rate, loan period, terms and risk level.
9. If loan is pre-approved, Application Platform sends loan to crowdlending.
10. If loan is rejected, Application Platform finishes the procedure.

4.3.2 BPMN diagram

The corresponding BMPN diagram is depicted in Figure 1.

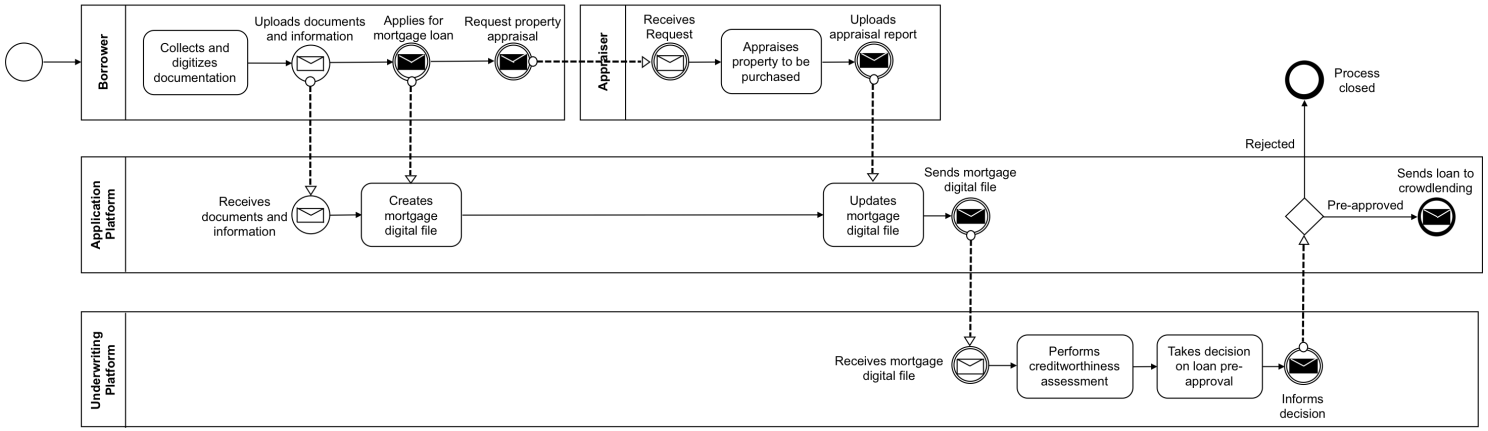

Figure 1: Application and underwriting flow

5 Financial flows and mortgage crowdlending

5.1 Problem setting

Even after a mortgage loan application has been pre-approved by an artificial intelligence system, there remains a crucial issue to be solved under a P2P framework: how to fund the loan. The simplest solution would be to match borrowers and lenders in a one-to-one (121) way: one individual would fund the whole loan requested by one borrower. This scheme, however, is unfeasible with mortgage loans: their amount is significantly higher than the typical P2P consumer loan. Consequently, the *double coincidence of wants problem* [43] becomes very difficult to solve. This problem is non-existent when the traditional financial intermediation function performed by banks is present, because banks buffer financial resources in amounts far higher than individual loans. But under a P2P system, no buffering is in principle available.

A second issue, derived from the absence of financial buffering in pure P2P systems, is the time that can take to find the lender (or lenders, if the loan is syndicated). An excessive period of time between pre-approval of a loan and its complete funding might make the seller to change her mind or simply avoid altogether prospective buyers that apply through P2P mortgage lending.

A final issue is how to handle financial flows under a P2P system: does the lending platform creates escrow accounts where lenders deposit fiat currency? In that case, the whole point of disintermediating mortgage origination (i.e. not using banks) is lost, and the question surges on whether full disintermediation is feasible or even desirable. If alternative financial flows are used in the form of cryptocurrencies, a new problem surges: how to cope with their high price volatility.

5.2 Proposed solution

The solution proposed for handling the double coincidence of wants problem has already being insinuated: for a P2P mortgage lending system to properly work, the loan has to be syndicated among several lenders. In other words, P2P mortgage lending cannot be done under a simple 121 model, but has to be structured under a multiple-to-one (M21) framework: P2P lending has thus to become crowdlending.

Most specifically, under the model here proposed, pre-approved mortgage loans would be "sliced" into sub-units. For efficient functioning of the system, slices would be standardized: they would be of equal amounts and, as they are created from the same loan, equal risk level. For instance, if an individual intends to purchase a house whose price is USD 234,567, and the required down-payment fraction is 30%, the loan amount would then be

USD 164,196.90. However, for efficiency reasons, the sub-unit amount is standardized, say, at USD 10,000 per slice. Under this constrain, the loan would be sliced into 16 equal units and the remainder of USD 4,196.90 would be added to the down-payment. Such pre-approved loan slices would then be placed for funding in the crowdlending platform. In this way, the double coincidence of wants problem would be greatly reduced.

How are these pre-approved slices going to be funded? The proposed model is to channel the funds through crypto-currency flows, managed by smart contracts. The smart contracts would perform the escrow function of holding the amounts funded by each individual lender and, after the last slice is funded, automatically transferring the funds in order to close the property purchase. In other words, the crowdlending business logic would be embedded into these smart contracts. The only intermediary between the lenders and the borrowers, as far as financial flows are concerned, would be software and code.

However, under such a model, the time and volatility related problems have to be tackled. It is proposed for the cryptocurrency volatility problem to be addressed in the following way: first, by fixing the loan amount in fiat currency, even if the individual funding is made in cryptocurrency. This way, any exchange rate would be reflected in a change in the required amount of crypto for each individual slice funding, but the price in fiat currency would be the same.

Second, a leeway can be coded into the smart contract, such that the individual lender is required to send, say, 10% more crypto over the applicable exchange rate. If the relative price of crypto decreases in relation to the currency in which the loan is denominated, but it does so by less than 10%, the slice would still be considered funded; if the decrease is more than 10%, the smart contract would automatically send the invested crypto to the individual lender and the slice funding would be unsuccessful. If the crowdlending is successfully completed (i.e. all slices are funded) the remainder from the 10% leeway would be reintegrated to the lenders' wallets.

Third, after the last slice is funded, the smart contract would automatically send funds for liquidation into fiat currency. The corresponding liquidated amount would then be placed into a traditional escrow account. This measure is required to address the volatility problem between the moment that the final slice is funded and the day the mortgage and property sale is actually closed. Indeed, complete financial disintermediation in the form of totally excluding banks does not seem possible (or, for that matter, desirable). The borrower's down-payment would also be deposited into that escrow account, at the start of crowdlending stage.

A final constrain of the model would be a limited funding period. After a specific amount of time of, say, 30 days, if the pre-approved mortgage loan is not successfully funded, the smart contract would stop and close the crowdlending process, reintegrating all invested cryptocurrency to individual lenders.

5.3 Model formalization

5.3.1 Process steps list

The process steps list for the application/underwriting stage goes as follows (for ease of exposition, the number of lenders and slices is limited to 3):

1. Borrower deposits down-payment in financial partner escrow account.

2. Crowdlending platform receives pre-approved loan information.

3. Crowdlending platform list pre-approved loan and divides it into 3 slices.

4. Lender A funds slice 1.

5. Lender B funds slice 2.

6. Lender C funds slice 3.

7. If full funding is reached within time allotted, Crowdlending platform liquidates crypto-currency with financial partner escrow account.

8. If full funding is not reached within time allotted, Crowdlending platform reintegrates crypto-currency to lenders 1, 2 and 3.

9. If full funding is not reached within time allotted, Financial Partner reintegrates down-payment to borrower.

5.3.2 BPMN diagram

The corresponding BMPN diagram is depicted in Figure 2. Given that there is no general BPMN notation for financial flows (besides compensation events, which are not relevant to this model), these are depicted as tasks linked by sequence flows.

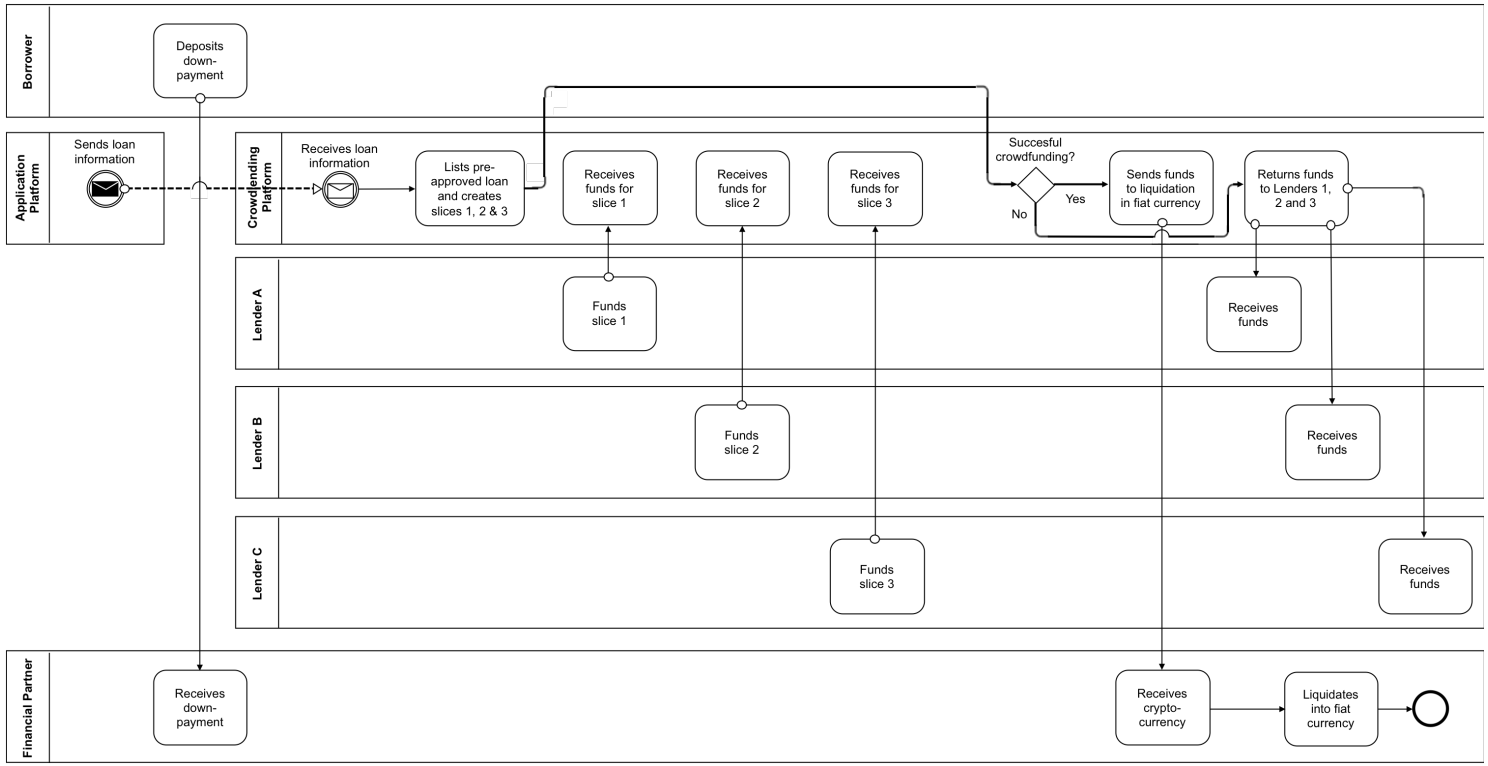

Figure 2: Crowdlending flow

6 Mortgage deed assignment

6.1 Problem setting

As referred in the background literature section, mortgage loans differ from other type of loans in that, by definition, they are guaranteed by the purchased property as a collateral. This collateral is what is properly called a mortgage. As a principle, the mortgage follows the property: even if the borrower/debtor sells the property to a third party who does not owe anything to the lender, the latter can seize and foreclose the property to this third party to satisfy his credit in case of default by the borrower. Also, the mortgage follows the note: if the lender sells her credit against the borrower to a third party, the latter would automatically become the new mortgage holder.

Under a traditional mortgage lending model, where a bank extends a loan to a borrower, the system functions in a straightforward way. The lending bank holds the mortgage deed until the loan full repayment or until it sells it in the secondary market. However, in a crowdlending system, where the loan is syndicated among several lenders, the question arises about who should hold the mortgage. Could the mortgage deed be assigned to a group of individuals?

This scenario would generate considerable complexity. If closing a mortgage loan is itself already a paperwork loaded event, with several actors involved, a closing that includes several lenders would only increase the difficulty. Additionally, assigning a single mortgage deed to a plurality of lenders, would make difficult, if not impossible, to trade it in a secondary market, as a full consent of all lenders would be required.

6.2 Proposed solution

The proposed answer to the third sub-research question, *"who should hold the mortgage deed?"*, is taken from traditional mortgage securitization: a special purpose vehicle (SPV) should hold the mortgage. More specifically, after the loan is fully funded by a certain number of lenders, the mortgage deed is assigned to an SPV which acts as a trustee. The assignment of the collateral rights is pre-coded in the funding smart contract. The SPV then issues a security share for each funded loan slice. This share, in fact, would be equivalent to a traditional MBS (although some differences shall be pointed out in Section 7).

The SPV would be acting at mortgage closing on behalf of the individual lenders. It could manage loan servicing, either directly or by outsourcing it to servicing companies. At this stage, individual lenders could trade their loan slices, as SPV security shares, in the secondary market. In case of a foreclosure is needed, the SPV would also act on behalf of

the lenders, whether they are the original ones or those who acquired the slices in secondary trading. Notice that the mortgage deed as such is not traded in the secondary market, but rather the SPV shares representing the loan slices.

6.3 Model formalization

Since the sub-research question to be answered is who would hold the mortgage deed in a P2P mortgage lending system, the model formalization of the last origination stage will focus on the deed assignment, covering also the financial flow from the Financial Partner to the Seller, and the SPV shares assignment to the lenders. It will not include all the details and entities involved in the closing event in order to avoid unnecessary complexities. In any case, it needs to be noticed that the steps listed and depicted in BMPN take place at the closing event.

6.3.1 Process steps list

1. Financial Partner sends funds held on escrow (down-payment plus liquidated crypto-currency) to Seller.

2. Crowdlending Platform assigns mortgage deed rights to SPV, sending all loan and funding process information (this includes loan amount and period, interest rate, risk level, number of slices, amount of each slice, and identity of each lender).

3. SPV assigns security shares to individual lenders, according to the number of loan slices funded.

6.3.2 BPMN diagram

The corresponding BMPN diagram is depicted in Figure 3.

7 Evaluation

7.1 Preliminary considerations

As [79] observe *"a researcher could present intermediate products of a DSR process to the research community in order to build consensus on the relevance, novelty, and importance of a chosen problem domain, to discuss design objectives and features,* [or] *to disseminate*

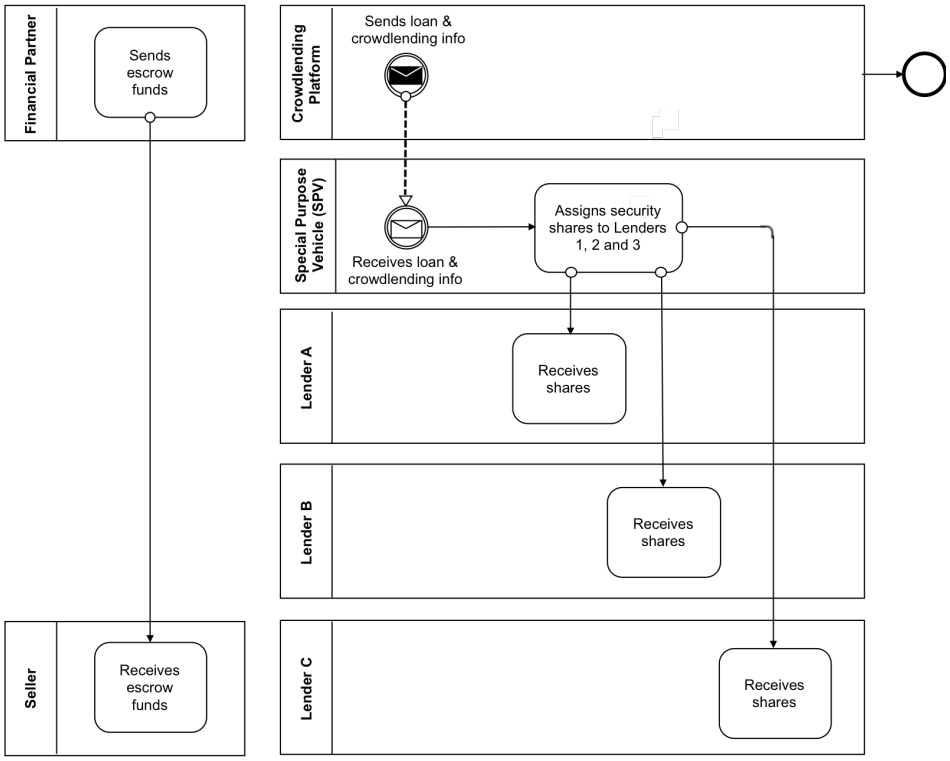

Figure 3: Mortgage assignment, SPV shares assignment and financial flow to the Seller

an initial blueprint of an IT artifact" [p. 386]. The theoretical explorations and models formalized in the previous sections are offered with this purpose.

The referred authors propose a DSR evaluation pattern based on a *design-evaluate-construct-evaluate* pattern, in which *ex-ante* evaluations validate the design of an artifact, while *ex-post* evaluations validate its instances and use. To this end, they identify four sequential evaluations, of which the first two belong to the *ex-ante* phase, while the last ones take place *ex-post*. Figure 4 partially reproduces the table presented in their paper, covering the first two evaluations activities and criteria.

In this section, both Evaluation 1 and 2 will be performed, covering some of the criteria and methods listed in Table 1. The goal of this first evaluation is twofold. First, to assess if the proposed ADR project is important for practice, is novel and adds to the existing knowledge base. Second, to assess whether or not the proposed model actually progresses towards addressing the problems stated in previous sections [79]. To this end, an assessment under the criteria of feasibility will be made initially: in other words, it will be judged whether the model presented can be instantiated. Then, it will be evaluated whether the instantiated model might successfully address the problems and issues stated in previous sections, as well as the practical consequences of doing so.

7.2 Practical and theoretical relevance and novelty

This paper addresses a clear gap in financial research: there are basically no published academic papers studying P2P lending in the mortgage sector[2]. This gap might reflect the absence of P2P mortgage lending platforms in the market. The FRBNY report on Fintech in the mortgage sector, does not mention a single Fintech company offering P2P lending as an alternative for financing [30]. In this context, this study offers a first explorative approach on how P2P lending could be implemented in the mortgage sector. It does so by designing a preliminary model, which incorporates current technologies such as distributed ledger technology and smart contracts (blockchain), artificial intelligence, and artificial neural networks. Given the lack of empirical data about P2P mortgage lending, this study offers a preliminary exploration on how an alternative financial source (P2P lending) could be applicable in an economically and social relevant sector of the financial industry (mortgages).

[2] A search conducted in Google Scholar on May 12, 2018, for papers with the words "P2P" and "mortgage" in their title, returned a single paper [85]. The paper's abstract, however, does not contain the word "mortgage". As the original text is in Chinese, the authors of the present study were not able to determine the extent to which that research actually covered mortgages. To our knowledge, the only other paper mentioning both concepts in its title is the already quoted article by [31], which has a legal approach and does not address the origination process.

Activity	Input	Output (mandatory)	Eval. Criteria (exemplary)	Eval. Methods (exemplary)
Eval 1	Problem statement/ Observation of a problem Research need Design objectives Design theory Existing solution to a practical problem	Justified problem statement Justified research gap Justified design objectives	Applicability, suitability, importance, novelty, (economic) feasibility	Literature review, review of practitioner initiatives, expert interview, focus groups, survey
Eval 2	Design specification Design objectives Stakeholders of the design specification Design tool/ design methodology	Validated design specification Justified design tool/ methodology	Feasibility, accessibility, understandability, clarity, simplicity, elegance, completeness, level of detail, internal consistency, applicability, operationality,	Mathematical proof, logical reasoning, demonstration, simulation, benchmarking, survey, expert interview, focus group

Figure 4: Table of DSR evaluation activities and evaluation criteria

7.3 Design research progress

7.3.1 Feasibility's of model instantiation

This paper has presented, after a first iterative exploration, a model of a P2P lending system for the mortgage loans sector. A judgement regarding the feasibility of its future instantiation in an IT artifact depends on two related issues: whether each sub-model can be instantiated as such, and whether they can be integrated.

The information flows and underwriting model presented on Section 4 relies on two capabilities: digitization of borrower's information, and use of artificial intelligence and artificial neural networks for creditworthiness assessment. Digitization has been already shown to be successful in the mortgage sector by Fintech lenders such as *Quicken Loans* with its *Rocket Mortgage* tool, while AI/ANN underwriting is already being used in the consumer lending sector, as mentioned in Section 2.

The feasibility of instantiating the model presented in Section 5 depends to a great extent on the capability of smart contracts to properly embed the crowdlending business logic proposed. Our preliminary evaluation is that the business logic is simple enough to be successfully coded, following methods like the one presented in [32] where BPMN workflows are first translated into Petri nets language, and then coded into in Solidity, the Ethereum programing language.

Regarding the model presented in Section 6 the question is not so much whether it can be technically instantiated, but rather on its legal feasibility. The key aspect is the possibility of legally assigning the mortgage deed to an SPV as proposed. This will in turn depend on the applicable law for each jurisdiction. However, it is beyond the scope of this study to conduct a preliminary legal analysis of this issue, although it is clearly an aspect that has to be thoroughly analyzed before the system can be introduced in the market.

The integration of the three models is an essential aspect for the feasibility of the system. One possible solution is for a single business entity to manage all of them. Our approach to this question is instead an interorganizational collaboration, such that the platforms could be operated by different entities. In particular, the crowdlending, smart contracts powered platform may outsource the application and underwriting stage to a different platform, and in turn integrate itself with a financial institution that would handle the mortgage closing and SPV. Under this framework, crowdlending would function under the Business-Process-as-a-Service (BPaaS) paradigm.

7.3.2 Addressing mortgage financing problems and issues

The following following issues shall be covered in relation to the model's progress: A) Efficiency in mortgage origination; B) Accessibility to mortgage financing for underserved population segments; C) Information asymmetries and lax screening; and D) Sub-prime loan implications.

If efficiency is operationalized in terms of the duration of mortgage origination, the model presented in this paper does not constitute necessarily an improvement: the very distributed nature of crowdlending, where funds are sourced from many individuals, might in fact prolong the origination process. On the other hand, if the model is successful in improving financial access for underserved segments, its market size should increase and so its liquidity levels (measured in how many individual lenders would be willing to fund loan sub-units). In turn, higher liquidity levels should translate into shorter crowdfunding times.

Perhaps the single most important value generation criteria for testing this model is whether it improves mortgage finance accessibility for underserved segments. By "underserved", we do not mean sub-prime (aka "NINJA": no income, no job, no assets) borrowers, but "false negative" applicants: i.e. those whose true creditworthiness level is misjudged under the traditional system. Our preliminary evaluation is as follows:

The proposed model would increase access to finance by making a better use of relevant soft information about applicants. First, because it will benefit from sophisticated AI/ARR based data analytics. And second (and even more important), because individual lenders will be able to directly assess the applicant's circumstances. This reflects the two-staged loan approval method of the model. In the first stage, an algorithm based assessment is made on the loan application (which already assess soft information that might be relevant, like education level), and a pre-approval decision is made. Then, on the second stage, the final approval is actually given by the crowd: if all slices are funded within the allotted time, that counts as a final approval; if they are not, the application is in fact rejected. During this second stage, the borrower can provide as much information as she wants, and make her case. Lenders then can decide on grounds that are not purely financial, in the same way that individual investors might decide to fund a project in a crowdfunding platform like *Kickstarter*.

However, does not this system actually imply lax screening? Are not professional loan officers far better equipped than individual lenders to assess whether a loan should be approved? These questions should be evaluated also by considering the two staged approval model. Individual lenders will only find listed in the crowdlending platform pre-assessed loans. In other words, they will not be able to fund any application whatsoever, but only those that, under pre-defined criteria, have already been vetted. The model addresses information asymmetries between borrowers and lenders by pre-qualifying loan applications,

and creating incentives for the borrower to signal its creditworthiness during crowdlending phase.

Finally, is not this a system that might systematically address the high risk, sub-prime loan segment? Our evaluation is that, in fact, it might be so. But, on the other hand, there is a crucial difference between a sub-prime mortgage loan issued by a bank and one crowdfunded by individuals: in the former case, the bank makes use of depositor's money; in the latter, individuals lend their own. The principal-agent duty present in the banks-depositors relationship [25] is therefore absent. If an individual cannot be legally forbidden to risk his money in a casino, the legal constrains regarding funding higher risk loans, when that funding is directly done by individuals and not through financial intermediaries, should be far more flexible.

This circumstance, nonetheless, requires close monitoring or even restricting secondary trading of SPV security shares derived by mortgage loan slices, when the latter's risk level is above certain threshold. As previously mentioned, these security shares resemble traditional MBS. The difference is that while MBS are composed of tranches from hundreds of mortgages, the SPV shares would, at least under the simple model proposed, be composed only from single mortgages. In other words, the securitization of mortgage financing would take place at the very origination phase.

8 Conclusion

This paper has developed and formalized a business model for P2P lending in the mortgage sector, following an Action Design Research methodology. The proposed model is a preliminary stage in a longer research project, which shall conclude with an instantiation of the model and, after its introduction to market, an evaluation of it. The study delves into blockchain technology, artificial intelligence and business model innovation in order to explore how a feasible and effective P2P mortgage lending system would be like.

Three sub-research questions and one main research question are addressed. The first sub-research question, regarding information flows between borrowers and lenders, is answered by proposing a two-platform based system, where one platform manages collection of information regarding the borrower (soft and hard) and the property (appraisal), and another performs underwriting by means of an AI/ANN. This system, while enhancing efficiency in the collection and management of data, reduces information asymmetries between borrowers and lenders by vetting loan applications and defining risks levels and setting loan terms.

The second sub-research question is answered by presenting a crowdfunding model for financial flows, where lenders can fund sub-units of pre-approved loans. The mechanism is

based on blockchain technology, more specifically the smart contract functionality. It is the crowdlending itself that counts as the final approval of the loan application. The funding of the loan is done under a highly disintermediated framework, where smart contracts perform the role of *active mediators*.

The third sub-research question gets its answer in the figure of a Special Purpose Vehicle (SPV), similar to those already used for mortgage-backed securities (MBS).

Thus, how could a new business model make viable mortgage P2P lending? This paper's view is that distributed ledger technology and smart contracts, by facilitating the execution of inter-organizational or inter-personal standardized business processes, allow for effective mortgage crowdlending mechanisms to take place.

This study has several limitations. The first is given by the very preliminary nature of the research, where only a theoretically based model is presented. No empirical evaluation of the model was possible at this stage. Another limitation is that the study covers only the origination portion of the mortgage value chain: the servicing of a crowdlending generated loan is not covered. Also, the dynamics of a secondary market for the SPV security shares are not explored.

Future research could cover these issues. Most avenues and opportunities for research shall open, nonetheless, once the model is instantiated and tested in the real world. A particularly interesting empirical evaluation would be to test whether a crowdlending model actually targets the sub-prime segment. Demographic implications can also be studied: are millennials more open to alternative mortgage financing, even controlling for risk levels?

Different approaches to P2P mortgage lending could be explored. While this study has proposed a multiple-to-one (M21) model where multiple lenders fund sub-units of an individual loan; a multiple-to-multiple (M2M) model where slices coming from different pre-approved loans are bundled into "funding packages" for individual investors can be also explored. Such a system would resemble, even more, traditional MBS.

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