CRM and AI in Time of Crisis

Michelle Lu
Navid Mojir

Working Paper 22-035

CRM and AI in Time of Crisis

Michelle Lu
McGill University

Navid Mojir
Harvard Business School

Working Paper 22-035

Funding for this research was provided in part by Harvard Business School.

CRM and AI in Time of Crisis

Michelle Lu

Desautels Faculty of Management, McGill University, michelle.lu@mcgill.ca

Navid Mojir

Harvard Business School, nmojir@hbs.edu

January 2021

A crisis can affect the incentives of various players within a firm's multi-layered sales and marketing organization (e.g., headquarters and branches of a bank). Such shifts can result in sales decisions against the firm's best interests. Motivated by the backlash to the Paycheck Protection Program and the subsequent adoption of artificial intelligence (AI) in the banking industry during the COVID-19 pandemic, we develop a model of decision authority allocation between headquarters and branches, then examine the impact of AI on decision authority and intra-organizational conflicts. Our model reveals how an increased concentration of decision authority at headquarters during a crisis can push the bank to focus on its largest clients and explains why such a strategy might not be beneficial. Furthermore, using AI does not always help the firm. When it replaces the branch's due diligence efforts (e.g., Fintech firms), AI can mitigate intra-organizational conflict and enhance resource allocation. Yet when AI supplements the branch's due diligence efforts (e.g., traditional banks), the branch might decrease its efforts and thus lower the bank's information about the branch's clients. AI can thus create new conflicts of interest and result in decision authority becoming concentrated at headquarters. This effect of AI is exacerbated during a crisis. Our findings have important implications for both practitioners and policy-makers that apply beyond the COVID-19 crisis.

Key words: customer relationship management; CRM; artificial intelligence; AI; decision authority; intra-organizational conflict; B2B marketing; COVID-19 pandemic; crisis marketing

1. Introduction

In response to the economic downturn and historically high unemployment rates during the COVID-19 pandemic, Congress approved the Paycheck Protection Program (PPP) as part of the Coronavirus Aid, Relief, and Economic Security Act (the CARES Act, March 2020). PPP was a \$349 billion support package, later expanded to \$669 billion in its second round. The program was designed to alleviate the pandemic's negative economic consequences on small businesses, which compose the majority of companies in the US. Typically, they are more credit-constrained than larger companies (Humphries et al. 2020). Small businesses that met the size criteria of the U.S. Small Business Administration (SBA) could apply for loans through designated banks, and the SBA would fully forgive the loan if they used the funds mainly to keep their employees on the payroll (U.S. Small Business Administration 2020). A significant public backlash followed the first round of PPP when news media revealed that many large corporations, including about 180 public companies, had applied for and in some cases received PPP loans using certain loopholes in the program (Sherman 2020). A class-action lawsuit accused four of the largest US banks, who acted as intermediaries to distribute the funds, of prioritizing their most significant customers (Egan 2020). Publicly available data about the allocation of loans showed that more than half of PPP funds went to larger businesses (O'Connell et al. 2020).

To mitigate the fund allocation issues in the first round of PPP, some of the major banks tried to develop or fine-tune artificial intelligence (AI) solutions to automate the application and allocation processes (Sawers 2020). The SBA also approved a set of Fintech companies to participate in the second round of PPP. These companies usually use automated allocation algorithms (Netzer et al. 2019; Chen et al. 2019). In addition, Google tried to develop AI solutions to simplify the application and fund allocation process for smaller businesses (Wiggers 2020).

This research aims to understand how the banks' internal dynamics influenced the controversial outcome of the PPP. We also explain why prioritizing large clients is not in the banks' best interest. We then investigate whether and how AI might improve sales decisions and discuss the managerial and policy insights of our findings.

Our explanation recognizes that like many other companies, banks organize their sales and marketing functions based on the size and significance of their clients; they serve larger clients through headquarters and smaller ones through branches (Wieczner and Morris 2020). Headquarters and branches take into account the value of each transaction and a client's ongoing relationship with the bank when making loan decisions. While branches generally serve a significant role in collecting information and performing due diligence for the bank's smaller clients, during a crisis when the bank allocates the government's "free money," such due diligence loses its relevance, changing the internal dynamic of decision making and decision authority (i.e., the right to decide resource allocations) within the bank. Such shifts in decision authority result in smaller clients receiving fewer resources.

We follow Aghion and Tirole's (1997) approach to develop a model that captures the tradeoff at headquarters between motivating branches to acquire information about the creditworthiness of their clients and retaining control over the allocation of resources. An inherent conflict between headquarters and branches stems from the desire at headquarters for more information about the clients at the branches, while branches are reluctant to acquire more information given the cost of its acquisition. Our model highlights how a shift in the incentive structure during a crisis can exacerbate this conflict such that funds are denied to some branch clients with good future business prospects. Such conflicts between headquarters and branches could be costly for the bank from the perspective of customer relationship management.

Given that banks rely heavily on local information to make loan decisions, particularly small business loans, they need branches to gather and process that information. Yet the bank's strategic decisions and allocation of its more substantial loans remain in the control of headquarters. In this division of labor and decision authority, each of the organization's entities will seek to maximize its own payoff. When there is no crisis, the bank allocates its own funds and is therefore cautious about the risk of default. To incentivize the branch to acquire more information, headquarters may prefer to delegate decision authority to the branches, achieving a balanced distribution of decision authority between branches and headquarters in equilibrium. This balanced allocation of decision authority results in a diverse clientele base and allocates funds to clients at branches and headquarters, benefiting the bank's overall payoff.

During a crisis, however, the bank allocates the government's funds instead of its own. In many cases, including the COVID-19 crisis, loan forgiveness programs free the bank from concerns about the payback of loans. Information acquired by the branches to assess the default risk of their clients is thus no longer pertinent, and decision authority shifts to headquarters; more resources are allocated to clients at headquarters. While this new allocation is optimal from the perspective of headquarters, it is not optimal overall because it ignores the value of the future business of clients at the branches (i.e., the value of customer relationships). In other words, during a crisis, banks tend to behave myopically towards the branches' clients.

We show that during a crisis, the value of business-specific default risk information drops as economic conditions deteriorate, and the drop rate is more drastic in hard-hit areas. This drop in the information value occurs because, during a crisis, the role of default information only pertains to predicting the client relationship value and not the loan principal loss. With the drastic drop in information value, the incentive to acquire information also drops, pushing headquarters to rely less on client-specific information and more on macro-level signals. As a result, the branch loses its strategic role and thereby its decision authority; small businesses in hard-hit areas then receive less funding. This reliance on macro-level signals can explain the findings of empirical studies that suggest hard-hit areas are less likely to receive PPP funding (Granja et al. 2020).

The COVID-19 economic crisis has also encouraged the use of artificial intelligence (AI) or financial intermediaries that employ AI. Over the years, AI technologies have gained traction in augmenting organizational decision-making processes due to their superior speed, scalability, and efficiency advantages (Aghion et al. 2019). Many lenders in the Fintech industry use automated processes and AI (Netzer et al. 2019, Luo et al. 2019, Fuster et al. 2019, Chen et al. 2019). During the COVID-19 pandemic, social-distancing and work-from-home measures made the automation of many decision-making tasks even more salient, shining a spotlight on AI (Walsh 2020). In the latter part of our paper, we extend our framework to provide insights into the potential role that AI can play in customer relationship management during a crisis. More particularly, we consider two different potential functions of AI: *Augmentation AI* or AI as a supplement to the branch's due diligence efforts, and *Replacement AI* or AI as a replacement for the branch's due diligence efforts.

The academic literature to date has largely emphasized the role of AI in cutting data processing and prediction costs. In contrast, we explore how AI influences intra-organizational dynamics. We argue that Replacement AI can improve the allocation of resources by reducing internal conflicts of interest among different players within organizations. The branches have a higher risk tolerance for their own clients and therefore prove less willing to perform due diligence as thorough as headquarters demands. Replacement AI can offer another avenue for headquarters to predict the default risk of the smaller businesses that are typically clients at the branches. This new avenue moves some of the branches' functions to headquarters and practically integrates branches and headquarters, hence resolving the inherent conflict of interest between the two.

The introduction of augmentation AI, on the other hand, may introduce a new conflict of interest in an organization, causing decision authority to concentrate at headquarters.

When using augmentation AI, the branch would prefer to reduce its due diligence effort and rely on the AI, which may potentially decrease the amount of information generated about the branch's client. The branch strategically weighs in its costly efforts in addition to overall informativeness, whereas headquarters cares about overall informativeness. Since augmentation AI is deployed at the discretion of the decision maker (more likely headquarters during a crisis), resource allocation with augmentation AI is less efficient during a crisis.

Overall, the efficacy of AI depends on two elements: 1) its relative prediction power (i.e., how accurately it can predict a client's value); and 2) its relative efficiency in resolving organizational conflicts in resource allocation. Whether replacement AI can be more effective than augmentation AI depends on the tradeoff between these two factors.

Studying the performance of banks during the COVID-19 crisis is a worthwhile endeavor,[1] yet we believe this paper contributes to a broader set of research streams. First, we add to the literature focusing on an organization's internal dynamics in marketing decisions. Simester and Zhang (2010) study the effects of internal conflicts of interest on product design. Simester and Zhang (2014) explore the role of internal lobbying of sales reps in collecting demand information and pricing. Dukes and Zhu (2019) study how customer service organizations (CSOs) use a tiered organizational structure to control redress costs and Lim and Ham (2014) examine delegation of decision authority and pricing. In this paper, we focus on the effect of intra-organizational strategic interactions on customer relationship management. We explain how a crisis could affect customer relationships by changing the incentive structure of different players within the organization.

Second, we contribute to a growing literature on AI in organizations. Most work on this topic has focused on AI technology as a way to reduce the cost of prediction (Agrawal et al. 2018, 2019b, Aghion et al. 2019, Athey et al. 2020), automation and strategic replacement of human labor (Acemoglu and Restrepo 2018b,a, 2020, Agrawal et al. 2019a), and empirical measurement of efficiency gains using AI (Netzer et al. 2019, Luo et al. 2019).[2] In this paper, however, we show that AI can improve or impair a firm's marketing decisions and customer relationships, depending on its role in mitigating or aggravating intra-organizational conflicts.

[1] According to the U.S. government data, the banking industry had \$17.9 trillion in assets and a net income of \$237 billion in 2018. Congress had allocated \$669 billion to the PPP, roughly three times the net income of the banking industry in 2018.

[2] An exception is a paper by Dogan et al. (2018), which touches on organizational issues not in the context of crisis or CRM.

Since such conflicts are exacerbated in a crisis, certain AI functions (i.e., Replacement AI) can help manage customer relationships during a crisis, while others (i.e., Augmentation AI) could potentially hurt customer relationships.

Third, most papers that study marketing during a crisis focus on pricing and advertising issues, including the effect on consumers' price elasticity (Van Heerde et al. 2013), shift in consumption decisions (Lamey et al. 2012, Dutt and Padmanabhan 2011), and effectiveness of advertising (Peers et al. 2017, Steenkamp and Fang 2011, Srinivasan et al. 2011, Frösén et al. 2016, Edeling and Fischer 2016, Deleersnyder et al. 2009). We add to this literature by exploring CRM issues, particularly in a B2B context, during a crisis. Although our focus falls on the banking industry during the COVID-19 crisis, the issue of changing intra-organizational dynamics during a crisis is not limited to the banking industry or the COVID-19 crisis. Similar government interventions have occurred during previous financial crises in banking and other industries through financial stimulus packages or other means (e.g., the provocation of the Defense Production Act). Our broader message in this paper is that clients are usually prioritized depending on the sales organization's internal dynamics. A change in the incentive structure of the sales organization can affect the prioritization of the clients in ways that might not necessarily benefit the seller's long-term profitability.

Finally, our paper offers a marketing perspective on (mis)allocation of government relief funds during crises. Many papers in finance and economics literature explore the default risk of bailout loans (Giné and Kanz 2017), financial characteristics of crisis loan recipients (Beck et al. 2018, Cong et al. 2019), effect of crisis loans on the economy (Coleman and Feler 2015, Giannetti and Simonov 2013), and investment decisions of firms that receive crisis loans (Acharya et al. 2019, Benmelech and Bergman 2012). Established reasons for banks to misallocate crisis loans so far include the evergreening of nonperforming loans (Acharya et al. 2019, Giannetti and Simonov 2013), relational lending (Beck et al. 2018), cash hoarding (Benmelech and Bergman 2012), allocation inefficiency (Coleman and Feler 2015), and falling victim to moral hazard (Giné and Kanz 2017). Our paper provides a novel marketing explanation for the misallocation of crisis loans that builds on the nature of banks' internal sales organization.

Our findings have implications for both managers and policymakers. For managers and board members, we highlight the importance of decision authority within the organization, the changes brought by a crisis, and the importance of long-term business relationships with all clients, especially in the context of crisis. We emphasize the need to avoid myopia during a crisis and show the double-edged nature of AI in managing customer relationships. For policymakers, we highlight the importance of the internal dynamics of intermediary organizations in policy implementation. Ignoring such dynamics could result in undesirable policy outcomes.

The paper proceeds as follows. Section 2 presents a model describing the internal dynamics and allocation of decision authority in a bank. Section 3 analyzes the causes of the controversial fund allocations under the PPP program. Section 4 investigates the potential uses of artificial intelligence and their implications in addressing allocation ineffectiveness. We conclude in Section 5.

2. A Model of CRM in a Bank

In this section, we model loan decisions in a bank, taking into account a multi-layered decision-making process. We follow Aghion and Tirole (1997) in developing our model of decision rights in banks, which we then extend in Section 4 to include different AI functions.

A bank receives multiple requests for funding and must decide how to allocate its limited financial resources among different applicants. The bank's decision-making unit comprises its headquarters and a branch. Denote the total value of loans issued at headquarters level as E and at the branch level as e. The total value of loans $E+e$ is subject to a resource constraint, i.e., $E+e \leq w$, where $w \in (0,1]$. Both headquarters and branch consider two factors when deciding about commercial loan applications: payback potential, and the potential for future business (i.e., relationship value).

First, the bank wants to give loans to applicants who will be around in the future and will be able to pay back, meaning that loan applicants return the principal (E or e) and pay the associated fees and interests $f(E)$ or $f(e)$. The fee structure $f(\cdot)$ is assumed to be a concave and increasing function in loan values. Therefore, the bank is interested in assessing the likelihood that the applicants survive and pay back. We categorize factors that affect this likelihood into two main groups: macro-level factors, which we denote by μ, and business-specific factors, which we indicate by d. Macro-level factors pertain to market or industry-level economic conditions common across all businesses in the same sector or local economy. These factors are known to both the branch and headquarters. A business survives these market-level conditions with probability $\mu \in [0,1]$. For example, during the economic crisis caused by the COVID-19 pandemic, it could be estimated that restaurants in a particular area would survive with a probability of μ. Conditional on being among businesses that survive market-level shocks, each company has its own specific risk of defaulting on its financial obligations. This company-specific probability of default, $d \in [0,1]$, is not common knowledge and requires due diligence to be revealed. In our previous example, due diligence on the loan application of a restaurant within a particular area can reveal the probability that the restaurant is among those that will survive without defaulting on its obligations.

Second, the bank considers future business potential when making lending decisions. This "investment in the relationship" is a common factor in business decisions across various B2B markets and lending criteria for the bank. Given a client pays back, the more resources the bank devotes to a client, the higher the likelihood that the relationship survives, and the higher the long-term value to the bank, in, for example, the purchase of other financial services. To capture this aspect, without loss of generality, we assume the probability that headquarters or the branch keeps the relationship with their clients to be E and e, respectively.

To reflect the incentive structure in a bank, we consider that headquarters receives future business value V_H from its client and v_H from the branch's client while incurring $\kappa_1 E$ and $\kappa_2 e$ when principal losses E and e occur. Similarly, the branch receives future business value v_B from its client and V_B from headquarters' client while incurring $\kappa_1 e$ and $\kappa_2 E$ when principal losses occur. We assume that $\frac{V_B}{V_H} < \frac{\kappa_2}{\kappa_1} \leq 1$ and $\frac{v_H}{v_B} < \frac{\kappa_2}{\kappa_1} \leq 1$ such that one's client generates more benefits and responsibility on its own than on its counterparty, and the counterparty will not seek risks by taking advantage of shouldering less responsibility. To reduce the number of parameters, let us make a normalization by setting $H \equiv \frac{V_H}{\kappa_1}$, $B \equiv \frac{v_B}{\kappa_1}$, $\alpha \equiv \frac{V_B}{V_H}\frac{\kappa_1}{\kappa_2}$, and $\beta \equiv \frac{v_H}{v_B}\frac{\kappa_1}{\kappa_2}$. Hence, the headquarters' client generates a normalized business value H to headquarters and βB to the branch, whereas the branch's client generates a normalized business value B to the branch and αH to headquarters. Here, $\alpha, \beta \in (0,1)$ are congruence parameters as in Aghion and Tirole (1997), measuring one's stake in the other's business.

Default Risks and Information Acquisition The bank must assess the default risks of loan applicants. Consider d^H and d^B to be the default risk of a typical headquarters' and branch's applicant, respectively. Headquarters and the branch need to predict default risks of their clients by acquiring and analyzing related information.

There are essential differences between headquarters and the branch when assessing the default risk of their clients. Headquarters' clients are usually larger public companies for which information about financial standing is publicly available. Furthermore, these clients typically follow good bookkeeping practices (e.g., generally accepted accounting principles, GAAP), making the due diligence process much more streamlined and standard (Cetorelli and Strahan 2006). The branch's clients, however, are typically smaller private businesses. Public and structured information about such companies is rarely available, and the branch plays an important role in gathering information about them locally (Gilje et al. 2016). These factors result in a lower cost per unit of the loan for headquarters' clients (Bolton et al. 2016). Therefore, without loss of generality, we assume that it is effortless to discover d^H (i.e., d^H is known), whereas it is costly for the branch to unravel d^B.

Let us suppose d^B is unknown initially, and $d^B \in \{d_l^B, d_h^B\}$ with prior beliefs λ and $1-\lambda$, where d_l^B represents a low default risk and d_h^B represents a high default risk. We denote the expected default risk $d_0^B = \lambda d_l^B + (1-\lambda) d_h^B$. The branch exerts effort $q \in [0,1]$ to acquire default information with a convex cost $g(q)$, where $g(0) = 0$, $g' > 0$ and $g'(1) = \infty$. With probability q, a perfect signal about d^B is drawn; with probability $1-q$, no signal is generated. We also assume the signal is verifiable and observable to both headquarters and the branch. Hence, the more effort the branch exerts to conduct due diligence, the more likely the default risk of its loan applicants become transparent.

Assumption 1 – resource scarcity: $\psi^H \geq \frac{1}{f'(w)+1+H}$.

Here, ψ^H represents the payback probability of headquarters' client (i.e., $\psi^H = \mu(1-d^H)$). Assumption 1 eliminates a trivial situation that the branch's clients are allocated untapped resources.

Moreover, to avoid the possibility that managing expected loss dominantly contributes to customer diversity, we make the following assumption.

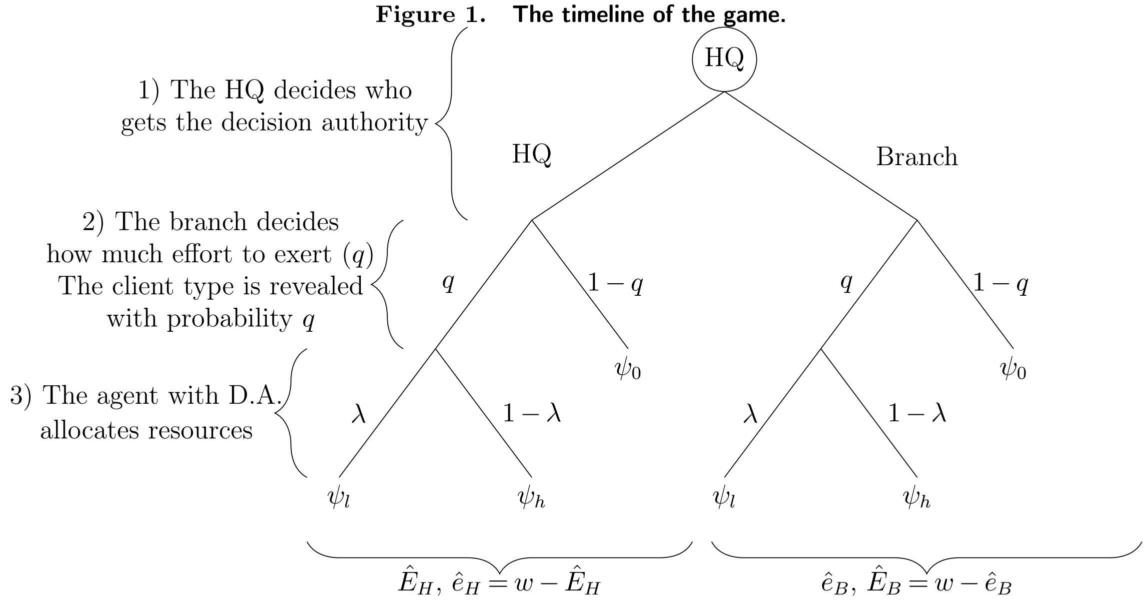
Assumption 2 – importance of CRM: $\frac{f'(w)+2}{f'(0)+2} \leq \frac{1-\psi^H}{1-\psi^B} \leq \frac{f'(0)+2}{f'(w)+2}$.

This assumption enables us to capture the importance of managing both future customer relationships and loan-specific net benefits.

Decision Authority The decision authority in our context refers to the priority right of allocating funds to one's clients. The priority right is critical because resources are generally limited. That is, the budget constraint $E + e \leq w$ is binding. Consider a pool of loan applications from clients at headquarters and the branch. When headquarters has the decision authority, it allocates funds to its clients before allocating resources to the branch's clients and vice versa when the branch has the decision authority.

The Timeline of the Game In the first stage, headquarters allocates the decision rights. In the second stage, the branch decides on the effort in acquiring information about its loan applicants. Then a signal about d^B is revealed at the end of this stage. In Stage 3, the party that owns the decision authority allocates resources and the counterpart obtains the remaining resources.

Figure 1. The timeline of the game.



Two Dimensions of Organizational Conflicts We distinguish between two different potential types of conflict that could arise between headquarters and the branch. First, conditional on the information about the branch's client type, the branch and headquarters might allocate resources differently. For example, if no information is available about the branch's client, its loan might be funded under the branch's authority, but not headquarters' authority. We call this type of disagreement between the branch and headquarters that results in different resource allocation outcomes *misalignment in resource allocation* or *resource allocation conflict*. Second, headquarters and branch have different preferences when collecting information about the branch's clients. Whereas headquarters always (weakly) prefers more information to less, the branch is thrifty with information, because due diligence is costly to the branch. We consider diverging preferences between headquarters and branch for information acquisition *misalignment in information acquisition* or *information acquisition conflict*. Of course, the two dimensions of organizational conflict are intertwined. We distinguish these two dimensions to articulate the intuition behind our findings later on.

3. An Analysis of CRM in Non-Crisis and Crisis Time

We analyze the model under two different scenarios; when the bank is lending out its own resources (i.e., the non-crisis scenario) and when the bank is lending out government funds, similar to what happened during the COVID-19 crisis (i.e., the crisis scenario). Throughout our analysis, we address three main issues: First, who will have decision authority? Second, what is the equilibrium level of the branch's effort to reveal the idiosyncratic default risk of its clients? Third, what is the equilibrium client portfolio? Here, since we do not make any functional form assumptions, our major focus is to compare equilibrium outcomes under different scenarios.

3.1. Baseline: Non-Crisis Time

We use backward induction and start the analysis with the payoffs in the last stage, where the party who has the decision authority allocates the resources. The information revealed by the last stage can take three possible values, depending on the true type of the branch client and whether the branch's effort is fruitful in revealing it: $\psi^B \in \{\psi_l^B, \psi_h^B, \psi_0^B\}$. Here, ψ_l^B and ψ_h^B represent the payback probabilities of a low- and high-risk client, respectively, while ψ_0^B represents the expected value of the branch client's payback probability for cases where the client type is not revealed. Conditional on ψ^B, we can write headquarters and branch's payoff as follows:

$$U = \underbrace{\psi^H \cdot f(E)}_{\text{direct payoff}} + \underbrace{\left(E\psi^H \cdot H + e\psi^B \cdot \alpha H\right)}_{\text{future business values}} - \underbrace{\left((1-\psi^H) \cdot E + (1-\psi^B) \cdot e\right)}_{\text{principal loss}}, \tag{1}$$

$$u = \psi^B \cdot f(e) + \left(e\psi^H \cdot B + E\psi^H \cdot \beta B\right) - \left((1-\psi^B) \cdot e + (1-\psi^H) \cdot E\right). \tag{2}$$

In the above equations, the first part of each payoff function is the direct payoff from fees and interests $f(\cdot)$ if the client pays back, continues the business in the future and does not default, which happens with probability ψ^j, $j \in \{H, B\}$. The second part denotes the expected value of the future business generated by a loan portfolio $\{E, e\}$. More specifically, if headquarters' client receives a loan of value E, with probability $E\psi^H$, the client will pay back the loan in the next period and continue its relationship with the bank, which will yield a business value of H to headquarters and βB to the branch. Similarly, suppose the branch client receives a loan value of e. The client will remain solvent and continue its relationship with the bank with probability $e\psi^B$. This relationship would provide a value of B to the branch and αH to headquarters. The third summand in each payoff function measures the expected loss of principals for the loan portfolio $\{E, e\}$. With probability $1-\psi^j$, the business does not survive or defaults, imposing a loss of E (e) to headquarters (branch).[3]

Decision authority in our context refers to the priority rights to allocate resources, w. The party who holds the decision authority determines the level of resources allocated to its clients to maximize its payoff in equation (1) or (2), subject to the binding budget constraint $E + e = w$. The counterpart's clients will be allocated the remaining resources (if any).

To explore the effect of holding the decision authority on the allocation of resources, let $\left(\hat{E}_H, \hat{e}_H\right)$ and $\left(\hat{E}_B, \hat{e}_B\right)$ represent the equilibrium loan portfolios for the non-crisis scenario under headquarters and the branch authority in the last stage, respectively. The following lemma examines the relationship between the decision authority and the resource allocation conditional on ψ^B.

Lemma 1. *(Decision Authority and Resource Allocation) Under Assumption 1,*

- *Holding the decision authority leads to a higher proportion of resources allocated to the decision-maker's client, i.e.,* $\hat{E}_H(\psi^B) \geq \hat{E}_B(\psi^B)$ *while* $\hat{e}_B(\psi^B) \geq \hat{e}_H(\psi^B)$, *for all* $\psi^B \in \{\psi^B_l, \psi^B_h, \psi^B_0\}$.
- *Under headquarters' authority, headquarters allocates resources to the branch if* $\psi^B/\psi^H \equiv \psi > \frac{f'(w)+1+H}{1+\alpha H} \equiv \underline{\psi}_H$*; whereas under the branch's authority, the branch allocates resources to its clients if* $\psi > \frac{1+\beta B}{f'(0)+1+B} \equiv \underline{\psi}_B$*. Moreover, the threshold for the relative payback probability under the branch authority is lower, i.e.,* $\underline{\psi}_B < \underline{\psi}_H$.

[3] We assume that the bank cannot hold collateral to guarantee payment of the principal and fees if the client goes bankrupt. Alternatively, one can assume the default risk that we consider in our model has been adjusted for collateral risk. Moreover, the default can affect the branch and headquarters asymmetrically. Such asymmetry would not qualitatively affect our results.

All proofs are presented in the Appendix. Lemma 1 highlights the value of holding the decision authority when corporate resources are scarce; the decision-maker's clients will compose a larger share of the client portfolio.

Moreover, the fact that headquarters' risk tolerance for the branch's clients is lower than that of the branch gives rise to a conflict of interest in the level of information needed (i.e., information acquisition conflict).

Information Environment Before moving to the second stage of information acquisition, we discuss the information environment of interest. The incentive for information acquisition is determined by the final resource allocation. We focus on the case in which headquarters and the branch have agreeing interests in knowing the branch's client payback probability to allocate any resources to the branch (i.e., without information, both would allocate all the resources to headquarters' clients). That is, we make the following assumption:

Assumption 3 – aligned incentives in information acquisition when there is no crisis: $\psi_0 \leq \underline{\psi}_j < \psi_l, \forall j \in \{H, B\}$, where $\psi_0 \equiv \psi_0^B/\psi^H$ and $\psi_l \equiv \psi_l^B/\psi^H$.

In essence, we examine a similar environment as in Agrawal et al. (2018). Focusing on this case helps us understand (1) the impact of information acquisition on resource allocation; (2) how the crisis and ensuing government programs affect the incentive alignment between headquarters and the branch. This condition also suggests that absent any strategic interplay, information itself is always valuable as it improves headquarters' decision-making, and the branch and headquarters share aligned incentives.

Hereafter, Assumption $1-3$ apply throughout the paper.

Information Acquisition Next, we move to the second stage and analyze information acquisition by the branch. In the above information environment and under j's authority, for $j \in \{H, B\}$, the branch chooses effort q_j in acquiring information that maximizes its expected payoff:

$$\hat{q}_j = \arg\max_{q\in[0,1]} \mathbb{E}\left[\hat{u}_j\left(\psi^B, q\right)\right] = q\lambda \cdot \hat{u}_j(\psi_l^B) + q(1-\lambda)\cdot \hat{u}_j(\psi_h^B) + (1-q)\cdot \hat{u}_j(\psi_0^B) - g(q). \quad (3)$$

Here, $\hat{u}_j(\psi_l^B)$ and $\hat{u}_j(\psi_h^B)$ denote the equilibrium payoff to the branch if its client is a low-risk or a high-risk one, respectively. If no information is revealed, we denote its equilibrium payoff as $\hat{u}_j(\psi_0^B)$.

If a positive equilibrium exists, $\hat{q}_j$ solves the following first-order condition:

$$\mathcal{J}(\hat{u}_j, \psi^B) \equiv \lambda \hat{u}_j(\psi_l^B) + (1-\lambda)\hat{u}_j(\psi_h^B) - \hat{u}_j(\psi_0^B) = g'(\hat{q}_j) \tag{4}$$

The left-hand side of the above equation corresponds to the Jensen gap $\mathcal{J}(\hat{u}_j, \psi^B)$, which represents the difference between the branch's expected equilibrium payoff once it gets to know the client type versus the equilibrium payoff if it does not know that information. Hence, $\mathcal{J}(\hat{u}_j, \psi^B)$ measures the value of information to the branch. The sign of $\mathcal{J}(\hat{u}_j, \psi^B)$ suggests whether information benefits the branch or not. Only when $\mathcal{J}(\hat{u}_j, \psi^B) > 0$ will the branch exert effort to acquire information about its client type. Moreover, the size of $\mathcal{J}(\hat{u}_j, \psi^B)$ measures the information value. The larger the information value (the Jensen gap $\mathcal{J}(\hat{u}_j, \psi^B)$), the higher the branch's incentive to acquire information.

Observation 1. Shifting the decision authority to the branch increases its incentive for information acquisition, i.e., $\hat{q}_B > \hat{q}_H$ because $\mathcal{J}(\hat{u}_B, \psi^B) > \mathcal{J}(\hat{u}_H, \psi^B) > 0$.

Notice that $\mathcal{J}(\hat{u}_j, \psi^B)$ is always positive, regardless which party holds decision authority. Under headquarters' authority, the revelation of good news strictly improves the branch's payoff while the revelation of bad news will not worsen it. Under the branch's authority, the convexity of its equilibrium payoff $\hat{u}_B(\psi)$ suggests that the branch is better off with information. Intuitively, the branch can utilize the information to its benefit.

Decision Authority In the first stage, headquarters decides to allocate decision authority, considering its strategic impact on information acquisition and resource allocation. Under j's authority, headquarters' expected payoff is as follows,

$$\begin{aligned}
\mathbb{E}\left[\hat{U}_j\left(\psi^B, \hat{q}_j\right)\right] &= \hat{q}_j \lambda \cdot \hat{U}_j(\psi_l) + \hat{q}_j(1-\lambda) \cdot \hat{U}_j(\psi_h) + (1-\hat{q}_j) \cdot \hat{U}_j(\psi_0) \\
&= \hat{q}_j \cdot \Big(\lambda \cdot \hat{U}_j(\psi_l) + (1-\lambda) \cdot \hat{U}_j(\psi_h) - \hat{U}_j(\psi_0)\Big) + \hat{U}_j(\psi_0) \\
&\equiv \hat{q}_j \cdot \mathcal{J}\left(\hat{U}_j, \psi^B\right) + \hat{U}_j(\psi_0)
\end{aligned} \tag{5}$$

Under j's authority, additional information benefits headquarters if the difference between the above expected payoff $\mathbb{E}\left[\hat{U}_j\left(\psi^B, \hat{q}_j\right)\right]$ and the payoff with no information $\hat{U}_j(\psi_0)$ is positive. This difference represents the value of information to headquarters, which is equivalent to $\hat{q}_j \cdot \mathcal{J}\left(\hat{U}_j, \psi^B\right)$ according to equation (5).

Again, additional information benefits headquarters if and only if headquarters' Jensen gap $\mathcal{J}\left(\hat{U}_j, \psi^B\right)$ is positive. Under its own authority, headquarters is better off with additional information as it can optimally utilize the information to improve the allocation, especially if there is good news (i.e., the branch client is low risk). Nonetheless, good news may not necessarily benefit headquarters under the branch's authority due to the loss of control over the resource allocation.

Observation 2. $\mathcal{J}\left(\hat{U}_B, \psi^B\right) \geq 0 \Leftrightarrow \hat{U}_B(\psi_l^B) \geq \hat{U}_H(\psi_0^B) \Leftrightarrow \psi_l \equiv \frac{\psi_l^B}{\psi^H} \geq \frac{f(w)/w+1+H}{1+\alpha H}$, *which always exists under Assumption 1. Moreover,* $\mathcal{J}\left(\hat{U}_H, \psi^B\right) > \mathcal{J}\left(\hat{U}_B, \psi^B\right)$.

For information to be useful for headquarters, it must be the case that headquarters' payoff under the branch's authority, knowing that the branch's client is low risk, is higher than its payoff under its own authority without that information. Otherwise, there will be no clear benefit for headquarters to delegate its authority. Put differently, to rationalize the delegation, the default risk of a low-risk branch client should be sufficiently low that headquarters find it beneficial to allocate funds to the branch's low-risk clients.

Observation 1 and 2 together reveal one of headquarters' fundamental tradeoffs in allocating the decision authority: balancing the branch's incentive to acquire information with loss of control over resource allocation.

Headquarters allocates the decision authority to maximize its expected payoff, $\mathbb{E}\left[\hat{U}_j\left(\psi^B, \hat{q}_j\right)\right]$. Under the information environment laid out as Assumption 3, headquarters will receive all the resources if there is no information, irrespective of who holds the decision authority (i.e., $\hat{U}_H(\psi_0^B) = \hat{U}_B(\psi_0^B)$). Given $\hat{q}_j = g'^{-1}\left(\mathcal{J}\left(\hat{u}_j, \psi^B\right)\right)$, we can rewrite the problem of the decision authority allocation as an information maximization problem. The following proposition formally describes the equivalence of the two problems.

Proposition 1. *Headquarters' decision authority allocation problem is equivalent to the choice of the party that yields the highest scaled joint Jensen gap:* $g'^{-1}\left(\mathcal{J}\left(\hat{u}_j, \psi^B\right)\right) \cdot \mathcal{J}\left(\hat{U}_j, \psi^B\right)$.

One implication of the above proposition is that headquarters takes into account the joint information values even if it aims to maximize its own payoff. This stems from headquarters' considerations for managing relative payback risks and incentivizing the branch to collect local information for better decision-making. As a result, the client portfolio is diversified (i.e., includes both the branch and headquarters clients). Nonetheless, later we show how a crisis and the ensuing government programs can change this diversified client portfolio by altering the value of information.

3.2. CRM In Crisis Time

This section analyzes the bank's allocation of decision authority and resources as well as the branch's information acquisition efforts during a crisis. Although payback risks are critical factors for lending decisions when headquarters and the branch use their own funds, they lose their relevance during the crisis when the bank acts merely as the distributor of government funds. This moral hazard incentive causes unintended consequences. To see this, we rewrite headquarters and branches' profit-maximization problems under their authority, respectively:

$$\max_{E\in[0,w]} U = f(E) + E\cdot\psi^H H + (w-E)\cdot\psi^B\alpha H, \tag{6}$$

$$\max_{e\in[0,w]} u = f(e) + e\cdot\psi^B B + (w-e)\cdot\psi^H\beta B. \tag{7}$$

Compared to the non-crisis scenario (Section 3.1), the government's relief programs change the payoff functions in two ways. First, consistent with the government's compensation plans for intermediary entities during crises, the headquarters and branch earn fees regardless of whether the client pays back the loan or not. Second, with the government's "free" money, the principal loss is no longer a concern in awarding loans. This incentive change leaves the business value of keeping a client's relationship as the only factor that makes information about the clients' payback probability valuable, affecting the equilibrium loan compositions.

As before, we start by analyzing the effect of decision authority on resource allocation. Let $\left(\tilde{E}_H, \tilde{e}_H, \underline{\tilde{\psi}}_H\right)$ and $\left(\tilde{E}_B, \tilde{e}_B, \underline{\tilde{\psi}}_B\right)$ be the loan portfolios and minimal relative payback probabilities to allocate resources to the branch under headquarters' and the branch's authority for the crisis scenario. The next lemma compares these values with those in the non-crisis scenario.

Lemma 2. *(Decision Authority and Resource Allocation in a Crisis)*

- *Compared with non-crisis scenario, more loans are funneled towards the decision maker's clients during a crisis, i.e.,* $\tilde{E}_H(\psi^B) \geq \hat{E}_H(\psi^B)$ *while* $\tilde{e}_B(\psi^B) \geq \hat{e}_B(\psi^B)$*, for all* $\psi^B \in \{\psi_l^B, \psi_h^B, \psi_0^B\}$.

- *Compared with non-crisis scenario, the discrepancy between the branch and headquarters' criteria to allocate positive resources to the branch clients is enlarged, i.e.,* $\underline{\tilde{\psi}}_B < \underline{\psi}_B < \underline{\psi}_H < \underline{\tilde{\psi}}_H$*, where* $\underline{\tilde{\psi}}_B \equiv \beta - \frac{f'(0)}{B\psi^H}$ *and* $\underline{\tilde{\psi}}_H \equiv \frac{1}{\alpha}\left(\frac{f'(w)}{H\psi^H}+1\right)$.

Headquarters (branch) is more stringent (lenient) towards the branch client under its own (the branch's) authority during a crisis than in the non-crisis time (i.e., $\underline{\tilde{\psi}}_H > \underline{\psi}_H$ while $\underline{\tilde{\psi}}_B < \underline{\psi}_B$). Since payback losses do not matter with forgivable loan programs, the headquarters (branch) has less incentive to allocate resources to the counterparty's clients to balance payback risks, thereby requiring higher (accepting lower) payback probability from the branch client.

Consequently, a conflict of interest in information acquisition arises. If $\underline{\tilde{\psi}}_B \le \psi_0$ and $\psi_l \le \underline{\tilde{\psi}}_H$ (which is a feasible case), the branch would allocate positive resources to its clients without any information about their default risk, while headquarters would not allocate any resources to the branch's clients even if they are low risk. In such a scenario, the shift in decision authority would change the resource allocation. Such an enlarged misaligned incentive not only affects the branch's incentive for due diligence but also headquarters' allocation of decision authority.

Similar to the non-crisis scenario, during a crisis, the branch's effort for information acquisition in the second stage, denoted as $\tilde{q}_j$, is determined by the Jensen gap $\mathcal{J}\left(\tilde{u}_j, \psi^B\right)$. The only relevant cutoff for $\mathcal{J}\left(\tilde{u}_B, \psi^B\right)$ is $\underline{\tilde{\psi}}_B$, and the only pertinent cutoff for $\mathcal{J}\left(\tilde{u}_H, \psi^B\right)$ is $\underline{\tilde{\psi}}_H$. We separate discussions on $\tilde{q}_j$ by decision authority.

Observation 3A. (Under Headquarters' Authority)

- *Since* $\mathcal{J}\left(\tilde{u}_H, \psi^B\right) < \mathcal{J}\left(\hat{u}_H, \psi^B\right)$, $0 \le \tilde{q}_H < \hat{q}_H$ *always holds. That is, the branch's effort during a crisis is lower compared to that when there is no crisis.*
- *Moreover,* $\tilde{q}_H = 0$ *for* $\psi_l \le \underline{\tilde{\psi}}_H$*. That is, the branch completely shirks as information does not influence headquarters' decision.*

Observation 3B. (Under the Branch's Authority)

- *If the branch's incentive is still aligned with headquarters, i.e.,* $\psi_0 \le \underline{\tilde{\psi}}_B < \psi_l$*, then* $\tilde{q}_B > \hat{q}_B$ *as* $\mathcal{J}\left(\tilde{u}_B, \psi^B\right) > \mathcal{J}\left(\hat{u}_B, \psi^B\right)$.
- *If the branch's incentive is misaligned with the headquarters, i.e.,* $\psi_0 > \underline{\tilde{\psi}}_B$*, incentive misalignment reduces the branch's effort compared with the above case of aligned*

incentive. Moreover, shifting the decision authority to the branch can reduce its effort, i.e., $\tilde{q}_H > \tilde{q}_B$*, which happens for* $\tilde{q}_H > 0$ *and* $\lambda < \frac{\Delta\tilde{u}(\psi_0^B)-\Delta\tilde{u}(\psi_h^B)}{\Delta\tilde{u}(\psi_l^B)-\Delta\tilde{u}(\psi_h^B)}$*, where* $\Delta\tilde{u} = \tilde{u}_B - \tilde{u}_H$*.*

Depending on the level of incentive alignment between headquarters and the branch in information acquisition, delegating the decision authority to the branch could have contrasting effects on the branch's effort to acquire information. When incentives are aligned, delegating decision authority to the branch increases its incentive to acquire information. In contrast, when incentives are misaligned, the branch may shirk from acquiring information as it allocates resources to its clients by default (i.e., without having any information about the client type).

Let us turn to headquarters' considerations.

Observation 4. $\tilde{U}_H(\psi_0^B) \geq \tilde{U}_B(\psi^B)$ *for all* $\psi^B \in \{\psi_l^B, \psi_h^B, \psi_0^B\}$*. Moreover,* $\mathcal{J}(\tilde{U}_H;\psi^B) > \mathcal{J}(\hat{U}_H;\psi^B)$*.*

In the non-crisis scenario (Section 3.1), headquarters' allocation of decision authority balances the tradeoff between the branch's increased incentive for information acquisition and the loss of control over resource allocation. The crisis and the government's forgivable loan programs unintentionally cause an incentive misalignment among an otherwise aligned set of players within the bank. This misalignment worsens headquarters' payoff due to the loss of control and potentially reduces the branch's information acquisition effort. Even when incentives are aligned, due to a more extreme loan composition (Lemma 2), headquarters ends up with a smaller payoff under the branch's authority for all states (compared with default payoff under its authority), making the loss of control more unappealing for headquarters. As a result, headquarters is more likely to retain the decision authority during a crisis, reducing the branch's information acquisition effort.

Proposition 2. *During a crisis, headquarters is always better off holding the decision authority.*

- *For* $\psi_l \leq \underline{\tilde{\psi}}_H$*, headquarters allocate all resources to its clients regardless of the risk type of the branch's clients. No information is generated, i.e.,* $\tilde{q}_H = 0$*.*

- *For $\psi_l > \underline{\tilde{\psi}}_H$, headquarters allocates positive resources $\tilde{e}_H(\psi_l^B) > 0$ to the branch only when the branch's clients are low risks. The branch exerts effort $\tilde{q}_H > 0$ to acquire information.*

The finding of Proposition 2 is consistent with empirical evidence suggesting that larger bank clients are more likely to get government funds during the COVID-19 crisis and explains this phenomenon as rooted in the internal dynamics of the bank. It also makes the importance of considering the internal dynamics of intermediary organizations in policy-making more salient as ignoring such dynamics could cause unintended inefficiencies that derail policy objectives. Besides the shift towards headquarters' clients during a crisis, there would also be a shift towards heavier reliance on risk factors common across businesses in the same area or industry (the following corollary).

Corollary 1. *As μ decreases, $\tilde{E}$ increases and $\tilde{e}$ decreases during the crisis while μ has no impact on $\hat{E}$ and $\hat{e}$ in when there is no crisis. Moreover, $\frac{\partial \mathcal{J}(\tilde{U}_H, \psi^B)}{\partial \mu} \geq 0$, increasing in μ during a crisis while $\frac{\partial \mathcal{J}(\hat{U}_j, \psi^B)}{\partial \mu} \geq 0$, which is constant in μ when there is no crisis.*

The above corollary has two significant implications. First, during a crisis, economic conditions have a disproportionate impact on small and large businesses. For areas or industries with worse economic conditions (i.e., as μ decreases), headquarters would be more likely to funnel funds to larger businesses. The same disproportionate effect does not appear when there is no crisis. In line with the empirical finding in Granja et al. (2020) that harder-hit areas are less likely to receive government funds during the COVID-19 crisis, we suggest that this phenomenon is more severe for small businesses.

Furthermore, during a crisis, the value of knowing idiosyncratic default information drops as economic conditions worsen, and the rate of drop is more drastic in hard-hit areas during the crisis because now the role of default information only pertains to predicting the client relationship value. With the drastic drop in the value of information, the incentive to acquire information also drops, pushing headquarters to rely less on the branch to acquire information. As a result, the branch loses its strategic role and decision authority, resulting in small businesses in hard-hit areas receiving less funding.

3.3. The First-Best Resource Allocation and Allocation Bias

In the previous section, we demonstrated that the moral hazard incentive that stems from the government's "free money" during a crisis consequentially alters the internal dynamics between headquarters and the branch, leading to the concentration of decision authority at headquarters' level and a more extreme resource allocation compared to the non-crisis time. While the shift in headquarters' strategy is optimal from its own perspective, it is not clear whether the optimal crisis strategy would benefit the entire organization (e.g., the bank's shareholders).

To investigate this question, we start by defining the first-best resource allocation as a fully informed allocation that maximizes the overall payoff of an integrated organization. We then construct a measure of departure from the first-best allocation, which signifies the degree of resource allocation bias, and compare the bias measure between crisis and non-crisis scenarios. We use allocation bias and departure from the first-best interchangeably.

3.3.1. The First-Best Allocation Consider the sum of headquarters and branch payoffs:

$$\begin{aligned} U+u &= f(E)+f(e)+\psi^H E(H+\beta B)+\psi^B e(B+\alpha H) \\ &\quad -\mathbb{I}_{\text{non-crisis}}\left((1-\psi^H)(2E+f(E))+(1-\psi^B)(2e+f(e))\right), \end{aligned} \tag{8}$$

where $\mathbb{I}_{\text{non-crisis}}$ is an indicator function denoting non-crisis scenario.

For a loan composition (E,e), the marginal rate of substitution (MRS) between E unit of funding to headquarters' clients and e unit of funding to the branch's client is:

$$\Gamma(E,e) \equiv \frac{\partial(U+u)/\partial E}{\partial(U+u)/\partial e} = \frac{f'(E)+\psi^H(H+\beta B)-\mathbb{I}_{\text{non-crisis}}(1-\psi^H)(2+f'(E))}{f'(e)+\psi^B(B+\alpha H)-\mathbb{I}_{\text{non-crisis}}(1-\psi^B)(2+f'(e))}. \tag{9}$$

Let $\left(E^*(\psi^B), e^*(\psi^B)\right)$ stand for the optimal loan portfolio that maximizes the total payoff in the true state $\psi^B \in \{\psi^B_l, \psi^B_h\}$, subject to the resource constraint, $E+e \le w$. Then $\Gamma\left(E^*(\psi^B), e^*(\psi^B); \psi^B\right)$ reflects the MRS for the first-best allocation. Hereafter, we use $\Gamma^*(\psi^B)$ for notational simplicity. To illustrate, consider the interior equilibrium allocation, the first-best MRS should equalize the marginal expected payoffs from headquarters and the branch such that $\Gamma^* = 1$. $\Gamma(E,e) > 1$ indicates insufficient (excessive) resource allocation to headquarters (branch) as the marginal expected payoff from headquarters is larger than that from the branch; the bank should allocate more loans to headquarters. Vice versa for $\Gamma(E,e) < 1$.

To be consistent with previous notations for non-crisis and crisis scenarios, for later analysis, we use $\hat{\Gamma}$ to denote $\Gamma(\mathbb{I}_{\text{non-crisis}} = 1)$ and $\tilde{\Gamma}$ to denote $\Gamma(\mathbb{I}_{\text{non-crisis}} = 0)$, respectively.

3.3.2. An Enlarged Allocation Bias During Crisis To examine allocation bias resulting from a loan portfolio $\{E, e\}$, we construct a measure of the distance between $\Gamma(E, e; \psi^B)$ and $\Gamma^*(\psi^B)$ given the true state $\psi^B \in \{\psi_l^B, \psi_h^B\}$, as follows:

$$\mathcal{D}(E, e; \psi^B) \equiv \left| \Gamma(E, e; \psi^B) - \Gamma^*(\psi^B) \right|. \tag{10}$$

We interpret allocation bias as the departure from the first-best: the smaller the bias, the more effective the resource allocation. We use $\hat{\mathcal{D}}$ and $\tilde{\mathcal{D}}$ to represent allocation bias in the non-crisis and crisis scenarios.

During a crisis, a more considerable departure from the first-best allocation arises. To show this, in the following proposition, we compare the distance between first-best and equilibrium allocation in crisis and non-crisis scenarios conditional on the true value of the default risk of the branch client.

Proposition 3. *The equilibrium loan allocation departs further from the first-best allocation during crisis time compared with non-crisis time. That is,* $\hat{\mathcal{D}}\left(\hat{E}_j(\psi^B), \hat{e}_j(\psi^B); \psi^B\right) \leq \tilde{\mathcal{D}}\left(\tilde{E}_H(\psi^B), \tilde{e}_H(\psi^B); \psi^B\right)$ *for all* $\psi^B \in \{\psi_l^B, \psi_h^B\}$ *and* $j = \{H, B\}$.

Under the non-crisis scenario (Section 3.1), the need to manage default risks results in a more diverse client portfolio (i.e., both the branch and headquarters clients are sufficiently funded). The optimal amount of loans $\{E, e\}$ reflects the relative default risk between headquarters and the branch's clients. As the default risk for a branch client decreases relative to that of headquarters', for example, its share of loans increases. Unless the relative default risk is extreme, the loans' distribution covers both headquarters and the branch's clients. This more diverse client portfolio, in turn, is better aligned with the first-best allocation of resources. During a crisis (Section 3.2), however, the government's "free money" cancels out the payback concern, leading to a skewed loan composition toward headquarters' clients even when relative default risks are moderate.

4. Can Artificial Intelligence Enhance the Client Portfolio?

This section analyzes the potential role of AI in managing client relationships and resolving inefficiencies that arise from a conflict of interest between headquarters and the branch as exacerbated during a crisis. The potential role of AI in addressing the issue of intra-organizational conflict of interest is particularly important because, unlike humans, an AI algorithm has no strategic incentives.

We consider AI as an algorithm that collects and analyzes information about the branch's client to provide a prediction of the client's default risk. We denote the performance of an AI algorithm by ρ. With probability ρ, a perfect signal about $d^B \in \{d^B_l, d^B_h\}$ (or equivalently, $\psi^B \in \{\psi^B_l, \psi^B_h\}$) is drawn. With probability $1-\rho$, the AI will yield no signal. Loosely following the taxonomy in the literature, we classify and model AI by its function and implications on the organization – *Augmentation* and *Replacement*.

Augmentation AI includes any use of artificial intelligence that augments information acquisition about the branch client's default risk. The branch can still exert effort to collect information about its client's default risk; however, the AI *supplements* that information and *augments* the branch's effort. With augmentation AI, after the first stage in which headquarters assigns the decision authority, the party with decision authority should now decide whether to use AI or not. The rest of the game then unfolds as before.

Replacement AI includes any usage of AI that completely replaces the human information gathering and decision making as it practically *replaces* the branch's role in its capacity to predict the default risk of its client. Because the AI algorithm does not have any autonomy or self-serving strategic incentives, it functions entirely at headquarters' leisure. Therefore, in this case, decision authority loses its strategic role, and we practically have a unitary decision-maker that integrates headquarters and the branch's clients and obtains the sum of their payoffs.

While Fintech companies are the most likely users of replacement AI (Luo et al. 2019, Chen et al. 2019), traditional banks are more likely to use augmentation AI (Zhang 2018; Jakšič and Marinč 2019; Sawers 2020). That is because, in many cases, Fintech companies do not have staff allocated to perform due diligence for loan applications (Fuster et al. 2019; Netzer et al. 2019). As traditional banks increase their reliance on the AI technology, they might also gradually move towards using replacement AI.

We analyze AI under non-crisis and crisis scenarios. To provide managerial insights, throughout our analysis, we seek to investigate which AI function would come closest to the first-best and how each function affects the total amount of information generated about the branch client's creditworthiness. To provide policy insights, we also explore the impact of each AI function on the client portfolio (i.e., the share of the branch clients) and the likelihood of harder-hit areas receiving funding.

4.1. AI in Non-Crisis Time

In this section, we analyze the role of AI when there is no crisis. We first focus on augmentation AI, and then extend our analysis to replacement AI before comparing the two.

4.1.1. Augmentation AI The primary role of augmentation AI is to help predict the branch's client default risk in the second stage of information acquisition. Thus, upon reaching the last stage of resource allocation, the equilibrium outcome described in Lemma 1 would apply.

In the second stage, the branch decides how much effort to exert to reveal its client default risk in the presence of augmentation AI. Consistent with our notation in the previous section, let $\hat{u}_j$ denote the non-crisis equilibrium end payoff. We can write the branch's expected payoff under j's decision authority and with augmentation AI:

$$\mathbb{E}\left[\hat{u}_j^{Aug.}\right] = \lambda(\rho+(1-\rho)q)\cdot\hat{u}_j(\psi_l^B)+(1-\lambda)\left(\rho+(1-\rho)q\right)\cdot\hat{u}_j(\psi_h^B)+(1-q)(1-\rho)\cdot\hat{u}_j(\psi_0^B)-g(q). \tag{11}$$

Notice that $\rho=0$ also corresponds to the case in which no AI is in use.

The equilibrium effort with augmentation AI, $\hat{q}_j^{Aug.}$, is determined by the following first-order condition:

$$(1-\rho)\cdot\mathcal{J}(\hat{u}_j,\psi^B)=g'(\hat{q}_j^{Aug.}) \tag{12}$$

Equation (12) suggests that augmentation AI can reduce the branch's effort. Moreover, increased informativeness of AI (a larger ρ) decreases the branch's incentive to acquire information. This outcome is similar to what Athey et al. (2020) consider "falling asleep at the wheel." This crowding-out effect happens because the AI substitutes the branch's role in predicting default risks.

This effect suggests that augmentation AI may not necessarily improve the bank's knowledge of the branch's client creditworthiness. Let us define the probability that the branch's client type is revealed with augmentation AI as "augmented informativeness," and denote it with $\hat{\rho}_j^{Aug.} \equiv \rho + (1-\rho)\hat{q}_j^{Aug.}$, under j's authority. The case of $\rho = 0$ corresponds to the level of informativeness with no AI, i.e., $\hat{\rho}_j^{Aug.} = \hat{q}_j$. Compared to the no-AI case, using augmentation AI increases informativeness about the branch's client (i.e., reduce uncertainty about the branch client type) when $\hat{\rho}_j^{Aug.} > \hat{q}_j$, which can be further specified as:

$$\rho + (1-\rho)g'^{-1}\left((1-\rho)\mathcal{J}(\hat{u}_j, \psi^B)\right) > g'^{-1}\left(\mathcal{J}(\hat{u}_j, \psi^B)\right) \tag{13}$$

where $g'^{-1}(\cdot)$ is an increasing and concave function.

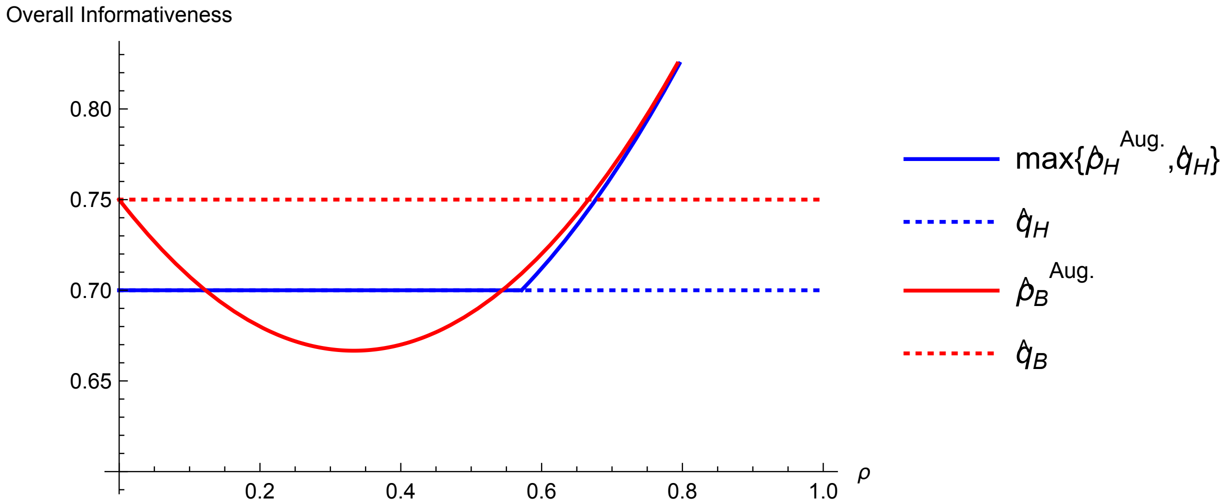
Building on the above inequality, the following Lemma elaborates on the conditions under which augmentation AI can result in increased informativeness.

Lemma 3. *Denote function $g'^{-1}(\cdot)$ as $z(\cdot)$ and the cutoff $\mathcal{J}^*$ that satisfies $\mathcal{J}^* = \frac{1-z(\mathcal{J}^*)}{z'(\mathcal{J}^*)}$. Compared to the no-AI case,*

- *when $\mathcal{J}(\hat{u}_j, \psi^B) < \mathcal{J}^*$, augmented informativeness $\hat{\rho}_j^{Aug.}$ is increasing in AI performance, ρ. That is, augmentation AI always increases informativeness.*
- *when $\mathcal{J}(\hat{u}_j, \psi^B) \geq \mathcal{J}^*$, $\hat{\rho}_j^{Aug.}$ first decreases and then increases in ρ. Augmentation AI can increase informativeness only when its performance is sufficiently strong, i.e., $\rho > 1 - \frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_j, \psi^B)}$.*

Augmented informativeness relies on both AI performance and the branch's effort. Though stronger AI performance increases augmented informativeness, it strictly crowds out the branch's effort. Hence, whether augmented informativeness improves from the no-AI scenario is determined by the strengths of the two countervailing forces of AI performance and the crowding-out effect. Strong AI performance renders the branch's effort no longer critical. Despite a worsened coupling crowd-out effect, overall informativeness is improved. When the AI performance is not strong enough, and the branch's effort still matters, whether the crowding-out effect dominates AI performance depends on the branch's incentive to substitute its costly effort with AI. Equation (12) implies that the marginal cost of exerting effort when $\mathcal{J}(\hat{u}_j, \psi^B)$ is high is much larger than when $\mathcal{J}(\hat{u}_j, \psi^B)$ is low, owning to the convexity of the information acquisition costs. Thus, for a large $\mathcal{J}(\hat{u}_j, \psi^B)$, the branch is more incentivized to reduce its costly effort and rely more on AI inputs, resulting in a more severe

Figure 2. **Decreased Overall Informativeness under the Branch's Authority with Augmentation AI**



crowding-out effect. Therefore, when $\mathcal{J}(\hat{u}_j, \psi^B) < \mathcal{J}^*$, the crowding-out effect is weak so that AI performance always dominates. For $\mathcal{J}(\hat{u}_j, \psi^B) \geq \mathcal{J}^*$, as the AI performance increases, the overall level of information decreases initially due to the dominant crowding-out effect. Finally, as AI performance increases, this direct effect overpowers its crowding-out effect on the branch's effort, resulting in higher overall informativeness. The red line in Figure 2 illustrates this point (also this is the second point in Lemma 3).

These findings suggest that the advent of augmentation AI may introduce a new conflict of interest within an organization about using augmentation AI. When it comes to whether to use augmentation AI, headquarters cares about the overall informativeness; whereas the branch weighs in its costly efforts in addition to overall informativeness. Hence, headquarters does not always find it beneficial to use AI, but the branch will always find it beneficial to use augmentation AI, irrespective of its performance (i.e., $\mathbb{E}\left[\hat{u}_B(\hat{q}_B^{Aug.})\right]$ is increasing in ρ).

Figure 2 illustrates the possibility of such a conflict. Absent AI, the branch's authority always leads to higher informativeness compared to headquarters' authority (i.e., the red and blue dotted lines). With augmentation AI, however, AI will not be used under headquarters' authority until it has a strong performance and leads to higher overall informativeness (i.e., the piece-wise blue line). Under the branch's authority, AI is always in use even when it decreases overall informativeness, and sometimes may even result in lower informativeness compared to that under headquarters' authority. Such a discrepancy has an important implication for the allocation of decision authority, which we analyze next.

Taking into account the strategic effect of decision authority on augmented informativeness and resource allocation, headquarters allocates the decision authority to maximize the expected payoff (see equation 5): $\mathbb{E}\hat{U}_H^{Aug.} = \max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\} \cdot \mathcal{J}\left(\hat{U}_H, \psi^H\right) + \hat{U}_H(\psi_0^B)$ vs. $\mathbb{E}\hat{U}_B^{Aug.} = \hat{\rho}_B^{Aug.} \cdot \mathcal{J}\left(\hat{U}_B, \psi^B\right) + \hat{U}_B(\psi_0^B)$. Considering that $\hat{U}_H\left(\psi_0^B\right) = \hat{U}_B\left(\psi_0^B\right)$ (see Assumption 3), headquarters' decision authority allocation problem reduces down to choosing the maximum between $\max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\} \cdot \mathcal{J}\left(\hat{U}_H, \psi^H\right)$, and $\hat{\rho}_B^{Aug.} \cdot \mathcal{J}\left(\hat{U}_B, \psi^B\right)$. We can write the condition for allocating the decision authority to the branch as:

$$\frac{\hat{\rho}_B^{Aug.} - \max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\}}{\max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\}} - \frac{\mathcal{J}\left(\hat{U}_H, \psi^B\right) - \mathcal{J}\left(\hat{U}_B, \psi^B\right)}{\mathcal{J}\left(\hat{U}_B, \psi^B\right)} > 0 \tag{14}$$

The above equation, again, suggests the key tradeoff in delegating decision authority as shown in Section 3.1. The first argument represents the potential increase in informativeness after yielding decision authority to the branch. The second argument represents the loss of payoff that arises from relinquishing control to the branch, or how much more headquarters could have obtained by withholding the authority, i.e., $\mathcal{J}\left(\hat{U}_H, \psi^B\right) > \mathcal{J}\left(\hat{U}_B, \psi^B\right)$. As shown in Lemma 3, yielding the decision authority to the branch when the branch has access to augmentation AI would not necessarily increase the overall informativeness; the presence of augmentation AI can reduce the likelihood of the branch obtaining the decision authority. The next proposition formally examines the impact of the augmentation AI on decision authority compared with the no-AI case.

Proposition 4. *(Decision Authority with Augmentation AI)*
Compared with the no-AI case,

- *augmentation AI reduces the likelihood of the branch obtaining the decision authority, irrespective of AI performance and the branch's incentive for information acquisition;*
- *when AI performance is strong, headquarters always holds the decision authority.*

Consider the case that headquarters is indifferent whether to hold or delegate decision authority without AI. All else being equal, with the advent of AI technology, headquarters would strictly prefer to retain decision authority because the informativeness from yielding the decision authority to the branch decreases, i.e., $\left(\hat{\rho}_B^{Aug.} - \max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\}\right) < \hat{q}_B - \hat{q}_H$. Furthermore, as discussed in Lemma 3, strong AI performance marginalizes the branch's importance in predicting its clients' default risks. Hence, headquarters does not need to sacrifice control to gain more information.

Overall, the advent of AI technology increases the concentration of decision authority at headquarters. Augmentation AI reduces headquarters' reliance on the branch's effort to acquire information. Even worse, it may increase the misalignment in information acquisition. Nevertheless, the conflict can be resolved if headquarters can always decide whether or not to implement augmentation AI.

4.1.2. Replacement AI With replacement AI, decision authority loses its strategic role. An AI algorithm can be deployed to generate information and allocate resources such that the total organization payoff $U + u$ is maximized conditional on information collected. Consider the information environment in Assumption 3. Under replacement AI, the integrated entity preserves the same aligned incentive.[4] With probability ρ, the AI generates an informative signal about the branch's client (i.e., $\psi^B \in \{\psi_l^B, \psi_h^B\}$), and achieves the first-best allocation. With probability $1-\rho$, there will be no informative signal, and no resources will be allocated to the branch's client.[5]

4.1.3. The Effectiveness of Augmentation vs. Replacement AI In this section, we compare the resource allocation effectiveness of augmentation and replacement AI. We use the departure from the first-best allocation, which we developed in section 3.3.1, to measure allocation inefficiency. With augmentation AI, allocation efficiency depends on whether headquarters or the branch holds decision authority. Let us denote the overall informativeness under j's authority, for $j \in \{H, B\}$, as $\hat{\rho}_j^{\prime Aug.}$. Under headquarters' authority, headquarters uses augmentation AI if $\hat{\rho}_H^{Aug.} \geq \hat{q}_H$, thus, $\hat{\rho}_H^{\prime Aug.} = max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\}$. In contrast, the branch always uses augmentation AI under own authority, hence, $\hat{\rho}_B^{\prime Aug.} = \hat{\rho}_B^{Aug.}$.

We compare AI effectiveness for each of the branch client's true type. If the branch client is high risk, i.e., $\psi^B = \psi_h^B$, under both augmentation and replacement AI, all the resources will be allocated to headquarters' client, irrespective of whether an informative signal is drawn. Such an allocation achieves the first-best. Hence, the effectiveness of augmentation and replacement AI is the same.

[4] Formally, the integrated organization is better off with all resources allocated to headquarters' client when $f'(w) - \psi f'(0) + (H + \beta B) - \psi(\alpha H + B) + 2 - 2\psi \geq 0 \Leftrightarrow \psi \leq \frac{f'(w)+H+\beta B+2}{f'(0)+\alpha H+B+2} \equiv \underline{\psi}_I$. $\underline{\psi}_I$ stands for the minimal payback probability that the integrated organization requires to allocate positive resources to the branch. It is straightforward to verify that $\underline{\psi}_B < \underline{\psi}_I < \underline{\psi}_H$.

[5] Note that in this case, the branch does not exist anymore, as the AI has replaced it. This is similar to what we see in Fintech companies (Luo et al. 2019, Fuster et al. 2019). Therefore, here the branch client refers to smaller businesses that would've been served by the branch, had it existed.

Therefore, to obtain the conditions for replacement AI to be more effective than augmentation AI, we turn to the case in which the branch client is low risk, i.e., $\psi^B = \psi_l^B$. In this case, with the availability of augmentation AI, the party who holds the decision authority allocates $\left(\hat{E}_j(\psi_l^B), \hat{e}_j(\psi_l^B)\right)$ if an informative signal is generated, which happens with probability $\hat{\rho}_j'^{Aug.}$. Otherwise, all resources are allocated to headquarters' clients.

Two factors contribute to the expected allocation bias. First, conditional on receiving information, the departure from the first-best allocation results from the organizational conflict in resource allocation. We denote such a departure as $\hat{\mathcal{D}}_j\left(\psi_l^B\right) \equiv \left|\hat{\Gamma}\left(\hat{E}_j\left(\psi_l^B\right), \hat{e}_j(\psi_l^B); \psi_l^B\right) - \Gamma^*\left(\psi_l^B\right)\right|$. The larger the conflict, the further distance between the decision maker's self-serving allocation and the first-best one. The second source of departure from the first-best is attributed to headquarters' uninformed self-serving resource allocation. We denote this departure as $\hat{\mathcal{D}}_j^{\emptyset}\left(\psi_l^B\right) \equiv \left|\hat{\Gamma}\left(w, 0; \psi_l^B\right) - \Gamma^*\left(\psi_l^B\right)\right|$. Thus, given the true type $\psi^B = \psi_l^B$, the expected bias of augmentation AI under j's authority can be specified as follows:

$$\mathbb{E}\hat{\mathcal{D}}_j^{Aug.}\left(\psi_l^B\right) \equiv \hat{\rho}_j'^{Aug.} \cdot \hat{\mathcal{D}}_j\left(\psi_l^B\right) + \left(1 - \hat{\rho}_j'^{Aug.}\right) \cdot \hat{\mathcal{D}}_j^{\emptyset}\left(\psi_l^B\right) \tag{15}$$

With replacement AI, the first-best allocation is achieved whenever replacement AI is informative. If AI is uninformative, it allocates all resources to headquarters' clients. Therefore, the sole reason for the departure from the first-best under replacement AI lies in uninformed allocation. Similarly, we denote the departure because of no information as $\hat{\mathcal{D}}^{\emptyset}(\psi_l^B) \equiv \left|\hat{\Gamma}(w, 0; \psi_l^B) - \Gamma^*(\psi_l^B)\right|$. Notice that in the non-crisis scenario when the integrated entity and headquarters have the same incentive for information, $\hat{\mathcal{D}}^{\emptyset}(\psi_l^B) = \hat{\mathcal{D}}_j^{\emptyset}(\psi_l^B)$. Thus, the effectiveness of replacement AI can be written as:

$$\mathbb{E}\hat{\mathcal{D}}^{Rep.}\left(\psi_l^B\right) \equiv (1 - \rho) \cdot \hat{\mathcal{D}}^{\emptyset}\left(\psi_l^B\right) \tag{16}$$

A comparison of the expected distance under augmentation AI (equation (15)) and replacement AI (equation (16)) reveals that the relative effectiveness of the two AI functions depends on the extent of augmented informativeness and the departure from the first-best. Proposition 5 presents a formal comparison between the effectiveness of the two AI functions.

Proposition 5. *When there is no crisis, replacement AI is more effective than augmentation AI under j's authority if and only if*

$$\frac{\rho}{\hat{\rho}_j^{\prime Aug.}} + \frac{\hat{\mathcal{D}}_j(\psi_l^B)}{\hat{\mathcal{D}}^{\emptyset}(\psi_l^B)} > 1, \tag{17}$$

where $\hat{\rho}_H^{\prime Aug.} = \max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\}$ *and* $\hat{\rho}_B^{\prime Aug.} = \hat{\rho}_B^{Aug.}$.

Proposition 5 reveals that the condition for replacement AI being more informative than augmentation AI can be separated into two factors: the relative informativeness in predicting the default risk and the relative efficiency in resolving the incentive misalignment within an organization. The relative efficiency in resolving organization misalignment depends on the size of inefficiency. The numerator in the second term represents the distance between the first-best and the actual allocation with informative augmentation or no AI. Because augmentation AI is employed by a strategic party with private interest, even if it is informative, it generates bias that reflects the misalignment between the first-best and decision maker's self-serving incentive. The larger the bias, the more powerful replacement AI should be to overcome it; however, replacement AI also causes bias when it is uninformative. The denominator in the second term measures the departure from first-best allocation with uninformative replacement AI. Hence, the relative efficiency of replacement AI in resolving incentive misalignment is normalized by its own bias caused by uninformativeness.

4.2. AI in Crisis Time

In this section, we focus on whether and how using AI could impact fund allocation during a crisis. We start by comparing augmentation AI in times of crisis and non-crisis time, then extend this analysis to replacement AI before comparing the two.

4.2.1. Augmentation AI First, the advent of augmentation AI will not shift the decision authority during a crisis. When there is a crisis, holding decision authority always benefits headquarters regardless of the branch client type or its knowledge of the branch client type (see Observation 4). We examine augmentation AI under headquarters' authority.

In the last stage of resource allocation, the equilibrium outcome described in Proposition 2 still applies. In the second stage, the branch's information acquisition, we focus our analysis on the more interesting case of $\psi_l > \underline{\tilde{\psi}}_H$, in which information still matters to headquarters during a crisis (the second case stated in Proposition 2).[6] In this case, even though headquarters finds the information valuable, it will not delegate decision authority to the branch due to an increased incentive misalignment in resource allocation. Nonetheless, with the assistance of augmentation AI, headquarters can improve the resource allocation with augmented informativeness $\tilde{\rho}_H^{Aug.} \equiv \rho + (1-\rho)\tilde{q}_H^{Aug.}$ if $\tilde{\rho}_H^{Aug.} > \tilde{q}_H$, where $\tilde{q}_H^{Aug.}$ is determined in equation (12) by replacing $\hat{u}_H$ with $\tilde{u}_H$.

Following the findings in Section 4.1.3, we specify the expected distance between headquarters' self-serving and the first-best MRS based on the two sources of distance. First, conditional on receiving an informative signal, headquarters can make an informed decision. The distance between its self-serving and the first-best MRS is attributed to the extent of the organizational conflict in resource allocation. Following equation (10), let us denote such a distance as $\tilde{\mathcal{D}}_H\left(\psi^B\right) \equiv \left|\tilde{\Gamma}\left(\tilde{E}_H\left(\psi^B\right), \tilde{e}_H\left(\psi^B\right); \psi^B\right) - \tilde{\Gamma}^*\left(\psi^B\right)\right|$, for $\psi^B \in \left\{\psi_l^B, \psi_h^B\right\}$. Second, if no information is revealed, headquarters allocates all resources to its clients based on the prior belief. The distance reflects both factors of missing information and the organizational conflict. That is, we denote $\tilde{\mathcal{D}}_H^{\emptyset}\left(\psi^B\right) \equiv \left|\tilde{\Gamma}\left(w, 0; \psi^B\right) - \tilde{\Gamma}^*\left(\psi^B\right)\right|$, for $\psi^B \in \left\{\psi_l^B, \psi_h^B\right\}$. Similar to equation (15), the expected distance under augmentation AI, given the true state ψ^B, can be specified as follows:

$$\begin{aligned} \mathbb{E}\tilde{\mathcal{D}}_H^{Aug.}\left(\psi^B\right) \equiv & \max\left\{\tilde{\rho}_H^{Aug.}, \tilde{q}_H\right\} \cdot \tilde{\mathcal{D}}_H\left(\psi^B\right) + \\ & \left(1 - \max\left\{\tilde{\rho}_H^{Aug.}, \tilde{q}_H\right\}\right) \cdot \tilde{\mathcal{D}}_H^{\emptyset}\left(\psi^B\right), \quad \text{for } \psi^B \in \left\{\psi_l^B, \psi_h^B\right\} \end{aligned} \tag{18}$$

Because augmentation AI still reflects the incentive of the decision maker, it has no direct impact on ex-post allocation bias. We observe the following relation regarding ex-post allocation biases.

Lemma 4. *For all* $\psi^B \in \left\{\psi_l^B, \psi_h^B\right\}$, $\tilde{\mathcal{D}}_H^{\emptyset}\left(\psi^B\right) \geq \max\{\hat{\mathcal{D}}_j^{\emptyset}\left(\psi^B\right), \tilde{\mathcal{D}}_H\left(\psi^B\right)\} \geq \min\{\hat{\mathcal{D}}_j^{\emptyset}\left(\psi^B\right), \tilde{\mathcal{D}}_H\left(\psi^B\right)\} \geq \hat{\mathcal{D}}_j\left(\psi^B\right)$. *Therefore, augmentation AI aggravates the expected allocation bias during crisis time, i.e.,* $\mathbb{E}\tilde{\mathcal{D}}_H^{Aug.}\left(\psi^B\right) \geq \mathbb{E}\hat{\mathcal{D}}_j^{Aug.}\left(\psi^B\right)$ *for all* $j \in \{H, B\}$.

[6] On the contrary, if $\psi_l \leq \underline{\tilde{\psi}}_H$, then according to Proposition 2, information has no value to headquarters because it will allocate all the resources to its clients, regardless of the branch's client default risk. Then headquarters will not use augmentation AI to gain information.

First, an uninformed allocation causes a larger bias compared to an informed one, i.e., $\tilde{\mathcal{D}}_H^{\emptyset} \geq \tilde{\mathcal{D}}_H$ and $\hat{\mathcal{D}}_j^{\emptyset} \geq \hat{\mathcal{D}}_j$. Moreover, comparing allocation ineffectiveness resulted from an uninformed allocation between crisis and non-crisis time, crisis aggravates ineffectiveness, i.e., $\tilde{\mathcal{D}}_H^{\emptyset} \geq \hat{\mathcal{D}}_j^{\emptyset}$. The uninformed decision leads all resources to headquarters. Such an extreme allocation departs further from the first-best in a crisis as the first best allocation is more balanced in crisis than non-crisis time when paybacks no longer matter. Last, Proposition 3 suggests that conditional on receiving information, headquarters' private interests in crisis time result in a larger allocation bias compared with non-crisis time, i.e., $\tilde{\mathcal{D}}_H \geq \hat{\mathcal{D}}_j$. These observations lead to the conclusion that the expected allocation bias under augmentation AI is more severe during a crisis.

4.2.2. Replacement AI As discussed in Section 4.1.3, with replacement AI, missing information is the cause of allocation bias. An uninformative replacement AI allocates resources based on the prior belief, resulting in a distance $\tilde{\mathcal{D}}^{\emptyset}\left(\psi^B\right) \equiv \left|\tilde{\Gamma}\left(\tilde{E}^*(\psi_0^B), \tilde{e}^*(\psi_0^B); \psi^B\right) - \tilde{\Gamma}^*\left(\psi^B\right)\right|$, for $\psi^B \in \left\{\psi_l^B, \psi_h^B\right\}$. Thus, the expected allocation bias of replacement AI, given the true state ψ^B, is:

$$\mathbb{E}\tilde{\mathcal{D}}^{Rep.}\left(\psi^B\right) \equiv (1-\rho) \cdot \tilde{\mathcal{D}}^{\emptyset}\left(\psi^B\right), \quad \text{for } \psi^B \in \left\{\psi_l^B, \psi_h^B\right\} \tag{19}$$

Lemma 5. *Whether the expected allocation bias with replacement AI when there is a crisis is higher or lower compared to that when there is no crisis depends on the branch's true client type, i.e.,* $\mathbb{E}\tilde{\mathcal{D}}^{Rep.}\left(\psi_h^B\right) \geq \mathbb{E}\hat{\mathcal{D}}^{Rep.}\left(\psi_h^B\right)$ *always holds while* $\mathbb{E}\tilde{\mathcal{D}}^{Rep.}\left(\psi_l^B\right) \leq \mathbb{E}\hat{\mathcal{D}}^{Rep.}\left(\psi_l^B\right)$ *can arise.*

Consider the case wherein the branch client is high risk, and the bank does not have any information about the client. When there is no crisis, neither headquarters nor the branch will allocate any resources to the branch client, i.e., there is alignment in resource allocation. Similarly, the integrated organization under replacement AI will not allocate any resources to the branch client. Information about the client type will not change the resource allocation, therefore, $\mathbb{E}\hat{\mathcal{D}}^{Rep.}\left(\psi_h^B\right) = 0$. There might be a misalignment in resource allocation between headquarters and the branch during a crisis, however, as payback risk no longer matters. While headquarters will not allocate any resources to the branch's client, the branch might allocate some resources to its client, even though it has no information about its type. The integrated organization under replacement AI would allocate some resources to the branch client as well. In this case, the replacement AI makes the bank worse off by over-allocating resources to the branch client. In effect, the missing information results in $\mathbb{E}\tilde{\mathcal{D}}^{Rep.}\left(\psi_h^B\right) \geq 0$. Such a bias reflects a Type II error, i.e., not rejecting a client that should have been rejected.

Now, consider a case where the branch client is low risk. All else equal, compared with the scenario in which paybacks do matter, without payback concerns, the allocation that reflects the incentive of the integrated entity under replacement AI is more balanced (i.e., include more branch clients), and information has less marginal effect in changing the bank's client portfolio. Hence, it is possible that the allocation bias that results from the missing information is less severe during a crisis. In this case, the bias reflects Type I error, i.e., rejecting a client that should not have been rejected.

4.2.3. The Effectiveness of Augmentation vs. Replacement AI Comparing the effectiveness of augmentation and replacement AI during a crisis, we find that the same two factors that determine the superiority of replacement or augmentation AI when there is no crisis are at play here as well: the (relative) prediction power of AI and its efficiency in resolving organizational conflict. We present a sufficient condition in the following proposition.

Proposition 6. *During a crisis, a sufficient condition for replacement AI to be more effective than augmentation AI is as follows,*

$$\lambda \cdot \left(\tilde{\rho}_H^{\prime Aug.}\left(\frac{\rho}{\tilde{\rho}_H^{\prime Aug.}} + \frac{\tilde{\mathcal{D}}_H(\psi_l^B)}{\tilde{\mathcal{D}}^{\emptyset}(\psi_l^B)}\right) + 1 - \tilde{\rho}_H^{\prime Aug.}\right) + (1-\lambda)\cdot\left(\rho + \frac{\tilde{\mathcal{D}}_H(\psi_h^B)}{\tilde{\mathcal{D}}^{\emptyset}(\psi_h^B)}\right) > 1. \tag{20}$$

where $\tilde{\rho}_H^{\prime Aug.} = \max\left\{\tilde{\rho}_H^{Aug.}, \tilde{q}_H\right\}$.

For large values of λ (when the branch's client is more likely to be low risk), the term in the first bracket of equation (20) is critical. This part is a reminiscent of equation (17). Recall that when there is no crisis, $\hat{\mathcal{D}}_H(\psi_l^B) \leq \hat{\mathcal{D}}^{\emptyset}(\psi_l^B)$ is always the case; when the organization is better aligned, the ineffectiveness in under-allocating resources to the branch that is caused by missing information is always more severe than that caused by conflicting interests in resource allocation. In comparison, when there is a crisis, $\tilde{\mathcal{D}}_H(\psi_l^B) \geq \tilde{\mathcal{D}}^{\emptyset}(\psi_l^B)$ can potentially arise. That is, the branch may receive more resources under uninformative replacement AI than under informative AI with headquarters' authority. This is because the loss of payback concerns has opposite effects on the headquarter's and the integrated entity's incentives under replacement AI: headquarters tends to favor its own clients, while the integrated entity tends to balance the client portfolio. When $\tilde{\mathcal{D}}_H(\psi_l^B) \geq \tilde{\mathcal{D}}^{\emptyset}(\psi_l^B)$, the term in the second bracket of equation (20), i.e., $\rho + \frac{\tilde{\mathcal{D}}_H(\psi_h^B)}{\tilde{\mathcal{D}}^{\emptyset}(\psi_h^B)}$, effectively defines the sufficient condition for replacement AI to be more effective. In sharp contrast, the augmented predictability no longer matters. Hence, the key consideration whether to implement replacement AI over augmentation AI hinges on AI performance and the size of ineffectiveness in over-allocating resources when replacement AI is uninformative. Even when $\tilde{\mathcal{D}}_H(\psi_l^B) < \tilde{\mathcal{D}}^{\emptyset}(\psi_l^B)$, the above consideration becomes critical as λ is small.

Last, we compare the impact of augmentation AI and replacement AI on resource allocation as economic conditions worsen. Since augmentation AI still reflects headquarters' incentive, it is unable to correct the allocation bias in a crisis. As suggested by Corollary 1, as economic conditions worsen, headquarters' clients receive more resources than the branch's clients. In sharp contrast, the next corollary demonstrates that replacement AI can better address the allocation bias in a crisis.

Corollary 2. *With replacement AI,* $\tilde{E}^* > \tilde{e}^* \Leftrightarrow \frac{\partial \tilde{e}^*}{\partial \mu} < 0$.

Corollary 2 suggests that if more resources are allocated to headquarters' clients, when economic conditions worsen, they should receive fewer resources and the branch's clients more. As mentioned earlier, without payback concerns, the integrated entity prefers a more balanced allocation than what headquarters prefers. Such an allocation reflects the first-best allocation that yields a higher value client portfolio to the entire organization.

5. Conclusions

We focused on the banking industry during the COVID-19 pandemic and explained why banks might prioritize their largest clients during a crisis, then revealed why such a focus might not be in the bank's best interest. Our explanation centered around the allocation of decision authority between headquarters and branches and the conflict of interest between them: headquarters would like branches to collect more information about their clients than they are willing to. It also highlighted the shift in banks' internal dynamics during a crisis given that government's "free money" results in a lack of concern for payback, reduces the importance of the branch's information, and concentrates the decision authority at headquarters. This concentration creates an oversight of branch clients' relationships, reducing the resources allocated to branches.

We also explored the potential role of AI in alleviating the increased intra-organizational conflict arising from a crisis. While using AI to replace branches' due diligence efforts could benefit both the bank and its smaller clients, AI as a supplement (i.e., Augmentation AI) would not necessarily benefit the bank. Augmentation AI could encourage the branch to reduce its efforts and instead rely on AI, reducing the bank's total information about its smaller clients and the resources it would allocate to them.

One implication of our findings for managers and board members is that they might need to reevaluate the effectiveness of their company's sales organization during a crisis. A sales organization that serves the company's interests well when there is no crisis might fail to do so when a crisis hits. While our model addressed the banking industry during COVID-19 pandemic, our findings have broader implications. Both managers and policymakers must scrutinize similar government interventions that affect the sales organization's incentive structure and the allocation of the decision authority to avoid unintended consequences. More broadly, our work highlights the importance of the allocation of decision authority within the sales organization and its impact on customer relationship management.

Our findings also imply that managers should approach using AI technologies with caution. AI technologies can reduce information processing and prediction costs; however, that is not all they do. They can also change the incentive structure of different players in sales organizations and affect the conflict of interest within an organization. Considering such effects is the key to choosing the right AI function.

While our model captures the fundamental effects on on customer relationship management of changing a sales organization's internal dynamics, what causes such a change in our setting is government intervention, which decreases the value of due diligence about a firm's clients. Future research can expand on the mechanism through which the internal dynamics of the sales organization changes. Furthermore, even though we focused on changes in the sales organization's dynamics due to a crisis, even when there is no crisis, heterogeneity across different firms' sales organizations would imply different efficacy levels for different

AI functions across organizations. Future research can explore the relationship between the structure of sales organization and the efficacy of different AI functions.

Acknowledgments

The authors thank participants at the 2020 Conference on Artificial Intelligence, Machine Learning, and Business Analytics. Comments from Sriya Anbil, Rajiv Lal, and Das Narayandas were very helpful and are appreciated. Lia Yin provided excellent research assistance for this project.

Appendix. Proofs

Proof of Lemma 1. We show the proof of the lemma by establishing the following result.

Denote $\psi \equiv \psi^B/\psi^H$ and under Assumption 1,

- when $\psi \le \underline{\psi}_B$, $\hat{e}_H = \hat{e}_B = 0$, where $\underline{\psi}_B \equiv \frac{1+\beta B}{f'(0)+1+B}$.
- when $\underline{\psi}_B < \psi \le \underline{\psi}_H$, $\hat{e}_H = 0$ while $\hat{e}_B > 0$, where $\underline{\psi}_H \equiv \frac{f'(w)+1+H}{1+\alpha H}$. More specifically, there exists $\overline{\psi}_B \equiv \frac{1+\beta B}{f'(w)+1+B}$ such that

  —when $\psi < \overline{\psi}_B$, $\hat{e}_B$ is determined by

$$f'(\hat{e}_B) + B(1-\beta\psi^H/\psi^B) + (1-\psi^H/\psi^B) = 0; \tag{21}$$

  —when $\psi \ge \overline{\psi}_B$, $\hat{e}_B = w$.

- When $\underline{\psi}_H < \psi \le f'(w)+1+H$, $\hat{e}_H > 0$ while $\hat{e}_B = w$. More specifically,

  —if $\alpha < \frac{f'(0)-f'(w)}{H(f'(w)+1+H)}$, $\hat{e}_H = w - \hat{E}_H \in (0,w)$, where $\hat{E}_H$ is determined by

$$f'(\hat{E}_H) + H(1-\alpha\psi^B/\psi^H) + (1-\psi^B/\psi^H) = 0; \tag{22}$$

  —if $\alpha \ge \frac{f'(0)-f'(w)}{H(f'(w)+1+H)}$, there exists $\overline{\psi}_H \equiv \frac{f'(0)+1+H}{1+\alpha H}$ such that $\hat{e}_H = w$ can arise when $\psi \ge \overline{\psi}_H$.

Under headquarters' authority, headquarters allocates all funds to its clients if $f'(w) + H(1-\alpha\psi^B/\psi^H) + (1-\psi^B/\psi^H) \ge 0 \Leftrightarrow \psi^B/\psi^H \le \frac{f'(w)+1+H}{1+\alpha H} \equiv \underline{\psi}_H$. Then for $\psi \equiv \psi^B/\psi^H > \underline{\psi}_H$, $\hat{e}_H > 0$. Under the branch's authority, the branch allocates no funds to its clients if $f'(0) + B(1-\beta\psi^H/\psi^B) + (1-\psi^H/\psi^B) \le 0 \Leftrightarrow \psi^B/\psi^H \le \frac{1+\beta B}{f'(0)+1+B} \equiv \underline{\psi}_B$. Then for $\psi > \underline{\psi}_B$, $\hat{e}_B > 0$. Moreover, $\underline{\psi}_B < \underline{\psi}_H \Leftrightarrow \frac{1+\beta B}{f'(0)+1+B} < \frac{f'(w)+1+H}{1+\alpha H} \Leftrightarrow \underline{\psi}_H \Leftrightarrow \frac{1+\beta B}{f'(0)+1+B} < 1 < \frac{f'(w)+1+H}{1+\alpha H}$, which always holds.

Under headquarters' authority, headquarters allocates all funds to the branch's clients if $f'(0) + H(1-\alpha\psi^B/\psi^H) + (1-\psi^B/\psi^H) \ge 0 \Leftrightarrow \psi \ge \frac{f'(0)+1+H}{1+\alpha H} \equiv \overline{\psi}_H$. Then for $\psi < \overline{\psi}_H$, $\hat{e}_H < w$. Under Assumption 1, $\psi_B/\psi_H \le f'(w)+1+H$. Then $\hat{e}_H = w$ does not exist if $\overline{\psi}_H > f'(w)+1+H \Leftrightarrow \frac{f'(0)+1+H}{1+\alpha H} > f'(w)+1+H \Leftrightarrow \frac{f'(0)-f'(w)}{H(f'(w)+1+H)} > \alpha$. Under the branch's authority, the branch allocates all funds to its clients if $f'(w) + B(1-\beta\psi^H/\psi^B) + (1-\psi^H/\psi^B) \ge 0 \Leftrightarrow \psi \ge \frac{1+\beta B}{f'(w)+1+B} \equiv \overline{\psi}_B$. Moreover, $\overline{\psi}_B < 1 < \underline{\psi}_H$.

In all of the cases above, $\hat{e}_B \ge \hat{e}_H$. Then $\hat{E}_H = w - \hat{e}_H \ge w - \hat{e}_B = \hat{E}_B$.

Proof of Observation 2. Under Assumption 3, $\hat{E}_H(\psi_0^B) = w$. According to Lemma 1, $\hat{E}_B(\psi_l^B) = 0$. Then $\hat{U}_B(\psi_l^B) = w(\psi_l^B\alpha H - 1 + \psi_l^B)$ while $\hat{U}_H(\psi_0^B) = \psi^H f(w) + w(\psi^H H - 1 + \psi^H)$. $\hat{U}_B(\psi_l^B) \ge \hat{U}_H(\psi_0^B) \Leftrightarrow \psi_l^B(1+\alpha H) \ge \psi^H(f(w)/w + 1 + H) \Leftrightarrow \psi_l \equiv \frac{\psi_l^B}{\psi^H} \ge \frac{f(w)/w+1+H}{1+\alpha H}$. Under Assumption 1 that $\psi^H \ge \frac{1}{f'(w)+1+H}$, $\psi_l \le f'(w)+1+H$ should hold. For the above threshold to exist, $\frac{f(w)/w+1+H}{1+\alpha H} \le f'(w)+1+H \Leftrightarrow \alpha \ge \frac{f(w)/w - f'(w)}{H(f'(w)+1+H)} = 0$. The last equality holds because $f'(w) = \frac{f(w)-f(0)}{w}$ and $f(0) = 0$.

Proof of Lemma 2. We start with the second part. In the crisis, under headquarters' authority, headquarters allocates all resources to its clients if $f'(w)+H(\psi^H-\alpha\psi^B)\geq 0 \Leftrightarrow \psi^B/\psi^H \leq \frac{1}{\alpha}\left(\frac{f'(w)}{H\psi^H}+1\right) \equiv \underline{\tilde{\psi}}_H$. Then when $\psi > \underline{\tilde{\psi}}_H$, $\tilde{e}_H > 0$. Under the branch's authority, the branch allocates all resources to headquarters' clients if $f'(0)+B(\psi^B-\beta\psi^H)\leq 0 \Leftrightarrow \psi^B/\psi^H \leq \beta - \frac{f'(0)}{B\psi^H} \equiv \underline{\tilde{\psi}}_B$. Then when $\psi > \underline{\tilde{\psi}}_B$, $\tilde{e}_B > 0$.

For the first part, we start the analysis with headquarters' authority. In the non-crisis time, when $\psi \leq \underline{\psi}_H$, $\hat{E}_H = w$. When $\underline{\psi}_H < \psi < \overline{\psi}_H \equiv \frac{f'(0)+1+H}{1+\alpha H}$, $\hat{E}_H \in (0,w)$, which is determined by $f'(\hat{E}_H)+H(1-\alpha\psi^B/\psi^H)+(1-\psi^B/\psi^H)=0$. The cutoff $\overline{\psi}_H$ is obtained by setting $f'(0)+H(1-\alpha\psi^B/\psi^H)+(1-\psi^B/\psi^H)>0$. Lastly, when $\psi \geq \overline{\psi}_H$, $\hat{E}_H = 0$. Next, we conduct a similar analysis for the crisis time. When $\psi \leq \underline{\tilde{\psi}}_H$, $\tilde{E}_H = w$. When $\underline{\tilde{\psi}}_H < \psi < \tilde{\overline{\psi}}_H \equiv \frac{1}{\alpha}\left(\frac{f'(0)}{H\psi^H}+1\right)$, $\tilde{E}_H \in (0,w)$, which is determined by $f'(\tilde{E}_H)/\psi^H + H(1-\alpha\psi^B/\psi^H)=0$. The cutoff $\tilde{\overline{\psi}}_H$ is obtained by setting $f'(0)/\psi^H + H(1-\alpha\psi^B/\psi^H) > 0$. Lastly, when $\psi \geq \tilde{\overline{\psi}}_H$, $\tilde{E}_H = 0$. Also notice that $\tilde{\overline{\psi}}_H > \overline{\psi}_H$ holds because $\frac{1}{\alpha}\left(\frac{f'(0)}{H\psi^H}+1\right) > \frac{f'(0)+1+H}{1+\alpha H} \Leftrightarrow 1-\alpha > f'(0)\left(\alpha - \frac{1+\alpha H}{H\psi^H}\right)$, which is always true as $\alpha - \frac{1+\alpha H}{H\psi^H} < 0$.

Next, we compare $\hat{E}_H$ and $\tilde{E}_H$ case by case. When $\psi \leq \underline{\psi}_H$ or $\psi \geq \tilde{\overline{\psi}}_H$, $\hat{E}_H = \tilde{E}_H = w$ or $\hat{E}_H = \tilde{E}_H = 0$, respectively. When $\underline{\psi}_H < \psi \leq \underline{\tilde{\psi}}_H$, $\tilde{E}_H = w$ while $\hat{E}_H \in (0,w)$. So, $\tilde{E}_H > \hat{E}_H$. When $\underline{\tilde{\psi}}_H < \psi < \overline{\psi}_H$, $\tilde{E}_H \in (0,w)$ and $\hat{E}_H \in (0,w)$, then $0 = f'(\tilde{E}_H)+H(1-\alpha\psi) = f'(\hat{E}_H)+H(1-\alpha\psi)+(1-\psi) < f'(\hat{E}_H)+H(1-\alpha\psi) \Leftrightarrow f'(\tilde{E}_H) < f'(\hat{E}_H)$. The first inequality holds because $\psi > \underline{\tilde{\psi}}_H > 1$. As f' is a decreasing function, $\tilde{E}_H > \hat{E}_H$. Lastly, when $\overline{\psi}_H \leq \psi < \tilde{\overline{\psi}}_H$, $\tilde{E}_H \in (0,w)$ and $\hat{E}_H = 0$, then $\tilde{E}_H > \hat{E}_H$ trivially holds. To summarize, $\tilde{E}_H \geq \hat{E}_H$.

We repeat the reasoning to the branch's authority. In the non-crisis time, when $\psi \leq \underline{\psi}_B$, $\hat{e}_B = 0$. When $\underline{\psi}_B < \psi < \overline{\psi}_B \equiv \frac{1+\beta B}{f'(w)+1+B}$, $\hat{e}_B \in (0,w)$, which is determined by $f'(\hat{e}_B)+B(1-\beta\psi^H/\psi^B)+(1-\psi^H/\psi^B)=0$. The cutoff $\overline{\psi}^B$ is obtained by $f'(w)+B(1-\beta\psi^H/\psi^B)+(1-\psi^H/\psi^B)<0$. Lastly, when $\psi \geq \overline{\psi}_B$, $\hat{e}_B = w$. In the crisis time, $\psi \leq \underline{\tilde{\psi}}_B$, $\tilde{e}_B = 0$. When $\underline{\psi}_B < \psi < \tilde{\overline{\psi}}_B \equiv \beta - \frac{f'(w)}{B\psi^H}$, $\tilde{e}_B \in (0,w)$, which is determined by $f'(\hat{e}_B)+B(\psi^B-\beta\psi^H)=0$. The cutoff $\tilde{\overline{\psi}}_B$ is obtained by $f'(w)+B(\psi^B-\beta\psi^H)<0$. Lastly, when $\psi \geq \tilde{\overline{\psi}}_B$, $\tilde{e}_B = w$. Besides $\underline{\tilde{\psi}}_B < \underline{\psi}_B$, we also notice that $\tilde{\overline{\psi}}_B < \overline{\psi}_B$ holds because $\beta - \frac{f'(w)}{B\psi^H} < \frac{1+\beta B}{f'(w)+1+B} \Leftrightarrow f'(w)\left(\beta - \frac{f'(w)+1+B}{B\psi^H}\right) < 1-\beta$, which is true as $\beta - \frac{f'(w)+1+B}{B\psi^H} < 0$.

Again, we compare $\hat{e}_B$ and $\tilde{e}_B$ case by case. When $\psi \leq \underline{\tilde{\psi}}_B$ or $\psi \geq \overline{\psi}_B$, $\hat{e}_B = \tilde{e}_B = 0$ or $\hat{e}_B = \tilde{e}_B = w$, respectively. When $\underline{\tilde{\psi}}_B < \psi \leq \underline{\psi}_B$, $\hat{e}_B = 0$ while $\tilde{e}_B \in (0,w)$. So, $\tilde{e}_B > \hat{e}_B$. When $\underline{\psi}_B < \psi < \tilde{\overline{\psi}}_B$, $\tilde{e}_B \in (0,w)$ and $\hat{e}_B \in (0,w)$, then $0 = f'(\tilde{e}_B)+B(1-\beta/\psi) = f'(\hat{e}_B)+B(1-\beta/\psi)+(1-1/\psi) < f'(\hat{e}_B)+B(1-\beta/\psi) \Leftrightarrow f'(\tilde{e}_B) < f'(\hat{e}_B)$. The first inequality holds because $\psi \leq \tilde{\overline{\psi}}_B < 1$. As f' is a decreasing function, $\tilde{e}_B > \hat{e}_B$. Lastly, when $\tilde{\overline{\psi}}_B \leq \psi < \overline{\psi}_B$, $\hat{e}_B \in (0,w)$ and $\tilde{e}_B = w$, then $\tilde{e}_B > \hat{e}_B$ trivially holds. To summarize, $\tilde{e}_B \geq \hat{e}_B$.

Proof of Observation 4. For $\psi^B = \psi^B_h$ or ψ^B_l, $\tilde{E}_H = w$ delivers the highest payoff to headquarters. For any resource that the branch allocates to headquarters under its authority, headquarters will not obtain a higher payoff. Thus, $\tilde{U}_H(\psi^B_0) \geq \tilde{U}_B(\psi^B)$. For $\psi^B = \psi^B_l$, according to the proof of Lemma 2, $\tilde{E}_B = 0$, $\tilde{U}_B(\psi^B_l) = w\psi^B_l \alpha H$ whereas $\tilde{U}_H(\psi^B_0) = f(w)+w\psi^H H$. $\tilde{U}_H(\psi^B_0) - \tilde{U}_B(\psi^B_l) = f(w)+wH(\psi^H - \psi^B_l\alpha) > 0 \Leftrightarrow \frac{f(w)}{\psi^H wH} + 1 - \alpha\psi_l > 0$ holds for all α. It is sufficient to show that $\frac{f(w)}{\psi^H wH}+1 > \psi_l$. Notice that $\psi_l \leq \frac{1}{\psi^H}$. Hence, so long as $\frac{f(w)}{\psi^H wH}+1 > \frac{1}{\psi^H}$, the result holds. It is indeed the case because $\frac{f(w)}{\psi^H wH}+1 > \frac{1}{\psi^H} \Leftrightarrow \psi^H > 1 - \frac{f(w)}{wH}$ and $1 - \frac{f(w)}{wH} < f'(w)+1+H$.

Proof of Corollary 1. For the interior solution $\tilde{E}_H \in (0,w)$, $\tilde{E}_H$ is determined by $f'(\tilde{E}_H) + H(\psi^H - \alpha\psi^B) = 0 \Leftrightarrow f'(\tilde{E}_H) = \mu H\left(\alpha(1-d^B) - (1-d^H)\right)$. Since f' is a decreasing function, $\tilde{E}_H$ decreases as μ increases. And $\tilde{e}_H = w - \tilde{E}_H$ increases in μ. For $\hat{E}_H \in (0,w)$, $\hat{E}_H$ is determined by $f' + H(1 - \alpha\psi^B/\psi^H) + (1 - \psi^B/\psi^H)$, where $\psi^B/\psi^H = (1-d^B)/(1-d^H) = 0$, which is independent of μ. For $\hat{e}_B \in (0,w)$, $\hat{e}_B$ is determined by $f' + B(1 - \beta\psi^H/\psi^B) + (1 - \psi^H/\psi^B) = 0$. Again, the first-order condition is independent of μ.

Let us specify $\mathcal{J}\left(\tilde{U}_H, \psi^B\right) = \lambda\tilde{U}_H(\psi_l^B) + (1-\lambda)\tilde{U}_H(w) - \tilde{U}_H(w) = \lambda\left(\tilde{U}(\psi_l^B) - \tilde{U}_H(w)\right) = \lambda\left(f(\tilde{E}_H) - f(w) + (w - \tilde{E}_H)\mu H\left(\alpha(1-d^B) - (1-d^H)\right)\right)$. Differentiating $\mathcal{J}\left(\tilde{U}_H, \psi^B\right)$ w.r.t. μ, we obtain $\frac{\mathcal{J}\left(\tilde{U}_H, \psi^B\right)}{\partial\mu} = \lambda(w - \tilde{E}_H)H\left(\alpha(1-d^B) - (1-d^H)\right) > 0$. Since $\tilde{E}_H$ decreases in μ, $\frac{\mathcal{J}\left(\tilde{U}_H, \psi^B\right)}{\partial\mu}$ increases in μ. In the non-crisis time, $\mathcal{J}\left(\hat{U}_j, \psi^B\right) = \lambda\left(\hat{U}(\psi_l^B) - \hat{U}_j(w)\right) = \lambda\psi^H \times M_j$, where $M_j \equiv f(\hat{E}_j) - f(w) + (w - \hat{E}_j)\left((\alpha H + 1)\psi - H - 1\right)$. Since M_j is independent of μ, $\frac{\mathcal{J}\left(\hat{U}_j, \psi^B\right)}{\partial\mu} = \lambda(1-d^H) \times M_j > 0$ and is constant in μ.

For the corner solution, the above claims trivially hold.

Proof of Proposition 3. We first examine $\psi^B = \psi_l^B$. In the non-crisis time, $\hat{E}_H \in [0,w)$. During the crisis, let us consider two cases: *Case 1:* $\psi_l > \underline{\tilde{\psi}}_H$ and *Case 2:* $\psi_l \le \underline{\tilde{\psi}}_H$.

Case 1: $\psi_l > \underline{\tilde{\psi}}_H$. During the crisis, $\tilde{E}_H \in [0,w)$. Suppose $\hat{E}_H \in (0,w)$ and $\tilde{E}_H \in (0,w)$. Then the first-best allocations in both crisis and non-crisis scenarios will not allocate all resources to headquarters. That is, $\tilde{\Gamma}^* \le 1$ and $\hat{\Gamma}^* \le 1$. First, we show that there does not exist a case in which $\tilde{\Gamma}^* < 1$ and $\hat{\Gamma}^* = 1$. We prove by contradiction. $\tilde{\Gamma}^* < 1$ indicates that $f'(0) + \psi^H(H + \beta B) < f'(w) + \psi_l^B(B + \alpha H) \Leftrightarrow f'(0) - f'(w) < \psi_l^B(B + \alpha H) - \psi^H(H + \beta B)$. $\hat{\Gamma}^* = 1$ indicates that $\psi^H f(\hat{E}^*) + \psi^H(H + \beta B) + \psi^H - \psi_l^B = \psi_l^B f'(\hat{e}^*) + \psi_l^B(B + \alpha H) + \psi_l^B - \psi^H \Leftrightarrow \psi^H f(\hat{E}^*) - \psi_l^B f'(\hat{e}^*) + 2(\psi^H - \psi_l^B) = \psi_l^B(B + \alpha H) - \psi^H(H + \beta B)$. Hence, $f'(0) - f'(w) < \psi^H f(\hat{E}^*) - \psi_l^B f'(\hat{e}^*) + 2(\psi^H - \psi_l^B)$, which does not hold because $f'(0) - f'(w) > f(\hat{E}^*) - f'(\hat{e}^*)$ and $\psi^H - \psi_l^B < 0$.

Second, we show $\tilde{\Gamma}(\tilde{E}_H, \tilde{e}_H) < 1$ and $\hat{\Gamma}(\hat{E}_H, \hat{e}_H) < 1$. $\tilde{\Gamma}(\tilde{E}_H, \tilde{e}_H) = \frac{f'(\tilde{E}_H) + \psi^H(H + \beta B)}{f'(\tilde{e}_H) + \psi^B(B + \alpha H)} < 1 \Leftrightarrow f'(\tilde{E}_H) + H(\psi^H - \psi^B\alpha) < f'(\tilde{e}_H) + B(\psi^B - \psi^H\beta)$, which always holds. This is because the LHS equals to zero according to the first-order condition, and the RHS is positive because $f'(\tilde{e}_H) + B(\psi^B - \psi^H\beta) > f'(\tilde{e}_B) + B(\psi^B - \psi^H\beta) = 0$ for $\tilde{e}_H < \tilde{e}_B$. Similarly, $\hat{\Gamma}(\hat{E}_H, \hat{e}_H) = \frac{\psi^H f'(\hat{E}_H) + \psi^H(H + \beta B) - (\psi^B - \psi^H)}{\psi^B f'(\hat{e}_H) + \psi^B(B + \alpha H) + \psi^B - \psi^H} < 1 \Leftrightarrow \psi^H f'(\hat{E}_H) + H(\psi^H - \alpha\psi^B) - (\psi^B - \psi^H) < \psi^B f'(\hat{e}_H) + B(\psi^B - \beta\psi^H) + \psi^B - \psi^H$, which always holds. Again, the LHS is zero according to the first-order condition. And the RHS is positive because $\hat{e}_H < \hat{e}_B$.

Next, we show $\tilde{\Gamma}(\tilde{E}_H, \tilde{e}_H) < \hat{\Gamma}(\hat{E}_H, \hat{e}_H)$. $\hat{\Gamma}(\hat{E}_H, \hat{e}_H) > \frac{\partial(\hat{U} + \hat{u})/\partial\hat{E}_H - \psi^H - \psi_l^B}{\partial(\hat{U} + \hat{u})/\partial\hat{e}_H - \psi^H - \psi_l^B}$ and $\tilde{\Gamma}(\tilde{E}_H, \tilde{e}_H) = \frac{\partial(\tilde{U} + \tilde{u})}{\partial\tilde{E}_H} / \frac{\partial(\tilde{U} + \tilde{u})}{\partial\tilde{e}_H}$. For notational simplicity, we omit the subscripts. First, we show that the numerators $\frac{\partial(\tilde{U} + \tilde{u})}{\partial\tilde{E}} = \frac{\partial(\hat{U} + \hat{u})}{\partial\hat{E}} - \psi^H - \psi_l^B$. The optimal allocations under headquarters' authority lead to unit MRS, that is $\frac{\partial\hat{U}}{\partial\hat{E}} = \frac{\partial\hat{U}}{\partial\hat{e}}$ and $\frac{\partial\tilde{U}}{\partial\tilde{E}} = \frac{\partial\tilde{U}}{\partial\tilde{e}}$. Notice that $\frac{\partial\hat{U}}{\partial\hat{e}} - \frac{\partial\tilde{U}}{\partial\tilde{e}} = \psi_l^B$, which leads to $\frac{\partial\hat{U}}{\partial\hat{E}} - \frac{\partial\tilde{U}}{\partial\tilde{E}} = \psi_l^B$. In addition, $\frac{\partial\hat{u}}{\partial\hat{E}} - \frac{\partial\tilde{u}}{\partial\tilde{E}} = \psi^H$. Hence, $\frac{\partial(\hat{U} + \hat{u})}{\partial\hat{E}} - \frac{\partial(\tilde{U} + \tilde{u})}{\partial\tilde{E}} = \psi^H + \psi_l^B$. Next, we show that the denominators $\frac{\partial(\tilde{U} + \tilde{u})}{\partial\tilde{e}} > \frac{\partial(\hat{U} + \hat{u})}{\partial\hat{e}} - \psi^H - \psi_l^B \Leftrightarrow f'(\tilde{e}) > \psi_l^B f'(\hat{e}) + \psi_l^B - \psi^H$. Moreover, $\psi_l^B - \psi^H = \frac{\partial\hat{U}}{\partial\hat{E}} - \frac{\partial\tilde{U}}{\partial\tilde{E}} - \left(\frac{\partial\hat{u}}{\partial\hat{E}} - \frac{\partial\tilde{u}}{\partial\tilde{E}}\right) = \psi^H f'(\hat{E}) + \psi^H - f'(\tilde{E}) - \psi^H$. Thus, the last inequality is equivalent to $\psi_l^B f'(\hat{e}) + \psi^H f'(\hat{E}) < f'(\tilde{e}) + f'(\tilde{E})$, which is sufficient to show $f'(\hat{E}) + f'(w - \hat{E}) < f'(\tilde{E}) + f'(w - \tilde{E})$. Notice that $\hat{E} < \tilde{E} \Leftrightarrow w - \hat{E} > w - \tilde{E}$ and $\hat{E} + \tilde{E} > w \Leftrightarrow \hat{E} > w - \tilde{E}$ and $\tilde{E} > w - \hat{E}$. Since convexity implies increasing difference, we have $\max\left\{f'(\hat{E}), f'(w - \hat{E})\right\} - f'(\tilde{E}) < f'(w - \tilde{E}) - \min\left\{f'(\hat{E}), f'(w - \hat{E})\right\} \Leftrightarrow f'(\hat{E}) + f'(w - \hat{E}) < f'(\tilde{E}) + f'(w - \tilde{E})$.

In the last step, we compare $\left|\hat{\Gamma}^* - \hat{\Gamma}(\hat{E}_H, \hat{e}_H)\right|$ and $\left|\tilde{\Gamma}^* - \tilde{\Gamma}(\tilde{E}_H, \tilde{e}_H)\right|$. Consider $\hat{\Gamma}^* = \tilde{\Gamma}^* = 1$. Then it is immediate that $1 - \hat{\Gamma}(\hat{E}_H, \hat{e}_H) < 1 - \tilde{\Gamma}(\tilde{E}_H, \tilde{e}_H)$. Consider $\hat{\Gamma}^* < 1$ and $\tilde{\Gamma}^* = 1$. Since $\hat{\Gamma}^* > \hat{\Gamma}(\hat{E}_H, \hat{e}_H)$, $\hat{\Gamma}^* - \hat{\Gamma}(\hat{E}_H, \hat{e}_H) < 1 - \tilde{\Gamma}(\tilde{E}_H, \tilde{e}_H)$. Consider $\hat{\Gamma}^* < 1$ and $\tilde{\Gamma}^* < 1$. The first-best allocation leads to all resources for the branch. Any allocation with a higher proportion of the branch-level loans departs less from the first-best.

Suppose $\hat{E}_H = 0$ and $\tilde{E}_H \in (0, w)$. In this case, the first-best allocation in the non-crisis time allocates all resources to the branch, and $\hat{\Gamma}^* - \hat{\Gamma}(\hat{E}_H, \hat{e}_H) = 0$. Hence, $\tilde{\Gamma}^* - \tilde{\Gamma}(\tilde{E}_H, \tilde{e}_H) \geq 0 = \hat{\Gamma}^* - \hat{\Gamma}(\hat{E}_H, \hat{e}_H)$. Suppose $\hat{E}_H = \tilde{E}_H = 0$. Then the first-best allocations in the non-crisis and crisis time allocate all resources to the branch. Hence, the proposition trivially holds.

Case 2: $\psi_l \leq \underline{\tilde{\psi}}_H$. In this case, headquarter receives all resources. Then $\tilde{\Gamma}(w, 0) > \tilde{\Gamma}(\tilde{E}_H, \tilde{e}_H)$, where $\tilde{E}_H$ defined in *Case 1.* Hence, $\tilde{\Gamma}^* - \tilde{\Gamma}(w, 0) > \tilde{\Gamma}^* - \tilde{\Gamma}(\tilde{E}, \tilde{e}) > \hat{\Gamma}^* - \hat{\Gamma}(\hat{E}_H, \hat{e}_H)$.

The fact that in equilibrium the branch obtains the authority implies that $g'(\mathcal{J}(\hat{u}_B, \psi^B)) \cdot \mathcal{J}(\hat{U}_B, \psi^B) > g'(\mathcal{J}(\hat{u}_B, \psi^B)) \cdot \mathcal{J}(\hat{U}_B, \psi^B) \Leftrightarrow g'(\lambda(\hat{u}_B(\psi_l^B) - \hat{u}_B(\psi_h^B))) \cdot (\hat{U}_B(\psi_l^B) - \hat{U}_B(\psi_h^B)) > g'(\lambda(\hat{u}_H(\psi_l^B) - \hat{u}_H(\psi_h^B))) \cdot (\hat{U}_H(\psi_l^B) - \hat{U}_H(\psi_h^B))$. Given ψ_h^B, all resources are allocated to headquarters. Thus, $\hat{u}_B(\psi_h^B) = \hat{u}_H(\psi_h^B)$ and $\hat{U}_B(\psi_h^B) = \hat{U}_H(\psi_h^B)$. For notational simplicity, we use l and m to denote $\hat{u}_B(\psi_h^B)$ and $\hat{U}_B(\psi_h^B)$, respectively. With a little abuse of notation, we drop ψ_l^B in the bracket. Consider a monotone transformation, then we have $(\hat{u}_B - l) \cdot (\hat{U}_B - m) > (\hat{u}_H - l) \cdot (\hat{U}_H - m)$. This inequality implies that $\frac{\hat{u}_B - l}{\hat{U}_H - m} > \frac{\hat{u}_H - l}{\hat{U}_B - m} \Leftrightarrow \frac{\hat{u}_B - \hat{U}_H - l + m}{\hat{U}_H - m} > \frac{\hat{u}_H - \hat{U}_B - l + m}{\hat{U}_B - m}$. Since $\hat{U}_H - m > \hat{U}_B - m$, for the inequality to hold, it must be that $\hat{u}_B - \hat{U}_H - l + m > \hat{u}_H - \hat{U}_B - l + m \Leftrightarrow \hat{u}_B + \hat{U}_B > \hat{u}_H + \hat{U}_H$. Hence, under the equilibrium in which the branch obtains authority, the equilibrium allocation is closer to the first-best allocation compared with the equilibrium in which headquarters obtains authority.

Lastly, we examine $\psi^B = \psi_h^B$. In this case, $\hat{E}_H = \hat{E}_B = w$. In the non-crisis time, the first-best allocation leads to all resources at the branch level, and $\hat{\Gamma}^* - \hat{\Gamma}(\hat{E}_H, \hat{e}_H) = 0$. Hence, $\tilde{\Gamma}^* - \tilde{\Gamma}(\tilde{E}_H, \tilde{e}_H) \geq 0 = \hat{\Gamma}^* - \hat{\Gamma}(\hat{E}_H, \hat{e}_H)$.

Proof of Lemma 3. For notational simplicity, we denote the function $g'^{-1}(\cdot)$ as $z(\cdot)$ and $\mathcal{J}(\hat{u}_j, \psi^B)$ as $\mathcal{J}$. Let us first check the two extremes of inequality (13). When $\rho = 0$, $LHS = \hat{\rho}_j^{Aug.} = z(\mathcal{J}) = \hat{q}_j = RHS$. When $\rho = 1$, $LHS = 1 + z(0) > z(J) = RHS$. Since RHS is independent of ρ, we examine the property of LHS by differentiating it w.r.t. ρ. That is, $\partial \hat{\rho}_j^{Aug.}/\partial \rho = 1 - z((1-\rho)\mathcal{J}) - (1-\rho)\mathcal{J} \cdot z'((1-\rho)\mathcal{J})$.

Denote $\tilde{\mathcal{J}} \equiv (1-\rho)\mathcal{J}$, $\partial \hat{\rho}_j^{Aug.}/\partial \rho > 0 \Leftrightarrow \tilde{\mathcal{J}} < \frac{1 - z(\tilde{\mathcal{J}})}{z'(\tilde{\mathcal{J}})}$. For any log-concave function z, $\frac{1 - z(\tilde{\mathcal{J}})}{z'(\tilde{\mathcal{J}})}$ is monotonically decreasing. If there exists a cutoff $\mathcal{J}^*$ s.t. $\mathcal{J}^* = \frac{1 - z(\mathcal{J}^*)}{z'(\mathcal{J}^*)} \Leftrightarrow \partial \hat{\rho}_j^{Aug.}/\partial \rho = 0$, that cutoff $\mathcal{J}^*$ is unique. Therefore, when $(1-\rho)\mathcal{J} < \mathcal{J}^*$, $\partial \hat{\rho}_j^{Aug.}/\partial \rho > 0$; while $(1-\rho)\mathcal{J} \geq \mathcal{J}^*$, $\partial \hat{\rho}_j^{Aug.}/\partial \rho \leq 0$. Moreover, $(1-\rho)\mathcal{J} < \mathcal{J}^* \Leftrightarrow \rho > 1 - \frac{\mathcal{J}^*}{\mathcal{J}}$. If $\frac{\mathcal{J}^*}{\mathcal{J}} > 1 \Leftrightarrow \mathcal{J} < \mathcal{J}^*$, $\rho > 1 - \frac{\mathcal{J}^*}{\mathcal{J}}$ always holds, which implies $\partial \hat{\rho}_j^{Aug.}/\partial \rho > 0$. On the other hand, for $\mathcal{J} \geq \mathcal{J}^*$, $\partial \hat{\rho}_j^{Aug.}/\partial \rho > 0$ when $\rho > 1 - \frac{\mathcal{J}^*}{\mathcal{J}}$ and $\partial \hat{\rho}_j^{Aug.}/\partial \rho \leq 0$ when $\rho \leq 1 - \frac{\mathcal{J}^*}{\mathcal{J}}$.

Proof of Proposition 4. Consider the condition under which headquarters is indifferent between holding and delegating the decision authority with the absence of augmentation AI: $\frac{\hat{q}_B}{\hat{q}_H} = \frac{\mathcal{J}(\hat{U}_H, \psi^B)}{\mathcal{J}(\hat{U}_B, \psi^B)}$. In the presence of augmentation AI, suppose $\hat{\rho}_H^{Aug.} \leq \hat{q}_H$. Then $\hat{\rho}_B^{Aug.} < \hat{q}_B$. This is because $\hat{\rho}_H^{Aug.} \leq \hat{q}_H$ suggests that $\mathcal{J}(\hat{u}_H, \psi^B) > \mathcal{J}^*$ and $\rho \leq 1 - \frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_H, \psi^B)}$ according to Lemma 3. Shifting the decision authority to the branch leads to $\mathcal{J}(\hat{u}_B, \psi^B) > \mathcal{J}(\hat{u}_H, \psi^B) > \mathcal{J}^*$ and $\rho \leq 1 - \frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_H, \psi^B)} < 1 - \frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_B, \psi^B)}$. Thus, $\hat{\rho}_B^{Aug.} < \hat{q}_B$. It follows that

$\frac{\hat{\rho}_B^{Aug.}}{\max\left\{\hat{\rho}_H^{Aug.},\hat{q}_H\right\}} < \frac{\mathcal{J}(\hat{U}_H,\psi^B)}{\mathcal{J}(\hat{U}_B,\psi^B)}$, which means all else equal, headquarters keeps the decision authority when augmentation AI is available.

Suppose $\hat{\rho}_H^{Aug.} > \hat{q}_H$. It suggests that either (1) $\mathcal{J}(\hat{u}_H,\psi^B) \geq \mathcal{J}^*$ and $\rho > 1-\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_H,\psi^B)}$ or (2) $\mathcal{J}(\hat{u}_H,\psi^B) < \mathcal{J}^*$. We first examine the first case. Recall $\mathcal{J}(\hat{u}_B,\psi^B) > \mathcal{J}(\hat{u}_H,\psi^B) > \mathcal{J}^*$ and $1-\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_H,\psi^B)} < 1-\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_B,\psi^B)}$. For $1-\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_H,\psi^B)} < \rho < 1-\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_B,\psi^B)}$, $\hat{\rho}_B^{Aug.} < \hat{q}_B$ according to Lemma 3. Then, again, $\frac{\hat{\rho}_B^{Aug.}}{\max\left\{\hat{\rho}_H^{Aug.},\hat{q}_H\right\}} < \frac{\hat{q}_B}{\hat{q}_H} = \frac{\mathcal{J}(\hat{U}_H,\psi^B)}{\mathcal{J}(\hat{U}_B,\psi^B)}$. For $\rho \geq 1-\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_B,\psi^B)}$, we show that all else equal, $\hat{\rho}_B^{Aug.} - \hat{\rho}_H^{Aug.} \leq \hat{q}_B - \hat{q}_H$. It is equivalent to show that $\hat{\rho}_j^{Aug.} - \hat{q}_j = \rho + (1-\rho) f\left((1-\rho)\mathcal{J}\right) - f(\mathcal{J})$ decreases in $\mathcal{J}$ since $\mathcal{J}\left(\hat{u}_B,\psi^B\right) > \mathcal{J}\left(\hat{u}_H,\psi^B\right)$. Take the first-order derivative of $\hat{\rho}_j^{Aug.} - \hat{q}_j$ w.r.t. $\mathcal{J}$, we obtain $(1-\rho)^2 z'\left((1-\rho)\mathcal{J}\right) - z'\left(\mathcal{J}\right)$, which is non-positive if $z'\left((1-\rho)\mathcal{J}\right) \leq z'\left(\mathcal{J}\right)/(1-\rho)^2$. Since z' is non-increasing, both LHS and RHS are increasing in ρ. When $\rho = 1$, $LHS = 0 < z'(\mathcal{J}) = RHS$ holds. It is sufficient to show $LHS \leq RHS$ when $\rho = 1-\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_B,\psi^B)}$. That is, $z'\left(\frac{\mathcal{J}}{\mathcal{J}(\hat{u}_B,\psi^B)}\mathcal{J}^*\right) \leq z'(\mathcal{J})/(1-\rho)^2$ holds for $\mathcal{J} \in [\mathcal{J}^*, \mathcal{J}(\hat{u}_B,\psi^B)]$. Since both LHS and RHS increase in $\mathcal{J}$, it is sufficient to check the two extremes. When $\mathcal{J} = \mathcal{J}(\hat{u}_B,\psi^B)$, $\mathcal{J}^{*2} z'(\mathcal{J}^*) < \mathcal{J}(\hat{u}_B,\psi^B)^2 z'(\mathcal{J}(\hat{u}_B,\psi^B))$, which holds because $\mathcal{J}^2 z'(\mathcal{J})$ increases in $\mathcal{J}$ as $2z'(\mathcal{J}) + \mathcal{J}z''(\mathcal{J}) > z'(\mathcal{J}) + \mathcal{J}z''(\mathcal{J}) \geq 0$. When $\mathcal{J} = \mathcal{J}^*$, $\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_B,\psi^B)}\mathcal{J}^* \cdot z'\left(\frac{\mathcal{J}}{\mathcal{J}(\hat{u}_B,\psi^B)}\mathcal{J}^*\right) < \mathcal{J}(\hat{u}_B,\psi^B) z'(\mathcal{J}^*) \Leftarrow \mathcal{J}^* \cdot z'\left(\mathcal{J}^*\right) < \mathcal{J}(\hat{u}_B,\psi^B) z'(\mathcal{J}^*)$ holds. This is because $\mathcal{J}z'(\mathcal{J})$ increases in $\mathcal{J}$ as $z'(\mathcal{J}) + \mathcal{J}z''(\mathcal{J}) \geq 0$. Hence, we show $\hat{\rho}_B^{Aug.} - \hat{\rho}_H^{Aug.} < \hat{q}_B - \hat{q}_H$, which indicates $\frac{\hat{\rho}_B^{Aug.}}{\hat{\rho}_H^{Aug.}} < \frac{\hat{q}_B}{\hat{q}_H}$.

Lastly, we check case (2) when $\mathcal{J}(\hat{u}_H,\psi^B) < \mathcal{J}^*$. Suppose $\mathcal{J}(\hat{u}_B,\psi^B) < \mathcal{J}^*$. Following the above analysis, $z'\left((1-\rho)\mathcal{J}\right) \leq z'\left(\mathcal{J}\right)/(1-\rho)^2$ also holds for $\rho = 0$. Since both LHS and RHS are increasing in ρ, this inequality holds for all ρ, which indicates $\hat{\rho}_j^{Aug.} - \hat{q}_j = \rho + (1-\rho) z\left((1-\rho)\mathcal{J}\right) - z(\mathcal{J})$ decreases in $\mathcal{J}$. Therefore, once again, we show $\hat{\rho}_B^{Aug.} - \hat{\rho}_H^{Aug.} < \hat{q}_B - \hat{q}_H$, which indicates $\frac{\hat{\rho}_B^{Aug.}}{\hat{\rho}_H^{Aug.}} < \frac{\hat{q}_B}{\hat{q}_H}$. Suppose $\mathcal{J}(\hat{u}_B,\psi^B) \geq \mathcal{J}^*$ holds. For $\rho < 1-\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_B,\psi^B)}$, $\hat{\rho}_B^{Aug.} < \hat{q}_B$ according to Lemma 3. Then, again, $\frac{\hat{\rho}_B^{Aug.}}{\max\left\{\hat{\rho}_H^{Aug.},\hat{q}_H\right\}} < \frac{\hat{q}_B}{\hat{q}_H} = \frac{\mathcal{J}(\hat{U}_H,\psi^B)}{\mathcal{J}(\hat{U}_B,\psi^B)}$. For $\rho \geq 1-\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_B,\psi^B)}$, we apply the reasoning in case (1) and show $z'\left(\frac{\mathcal{J}}{\mathcal{J}(\hat{u}_B,\psi^B)}\mathcal{J}^*\right) \leq z'(\mathcal{J})/(1-\rho)^2$ holds for $\mathcal{J} \in [\mathcal{J}(\hat{u}_H,\psi^B), \mathcal{J}(\hat{u}_B,\psi^B)]$, which is suffcient to check the two extremes. We have checked the $\mathcal{J} = \mathcal{J}(\hat{u}_B,\psi^B)$. When $\mathcal{J} = \mathcal{J}(\hat{u}_H,\psi^B)$, $\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_B,\psi^B)}\mathcal{J}(\hat{u}_H,\psi^B) \cdot z'\left(\frac{\mathcal{J}^*}{\mathcal{J}(\hat{u}_B,\psi^B)}\mathcal{J}(\hat{u}_H,\psi^B)\right) \leq \mathcal{J}(\hat{u}_H,\psi^B) z'(\mathcal{J}(\hat{u}_H,\psi^B))\frac{\mathcal{J}(\hat{u}_B,\psi^B)}{\mathcal{J}^*} \Leftarrow \mathcal{J}(\hat{u}_H,\psi^B) \cdot z'\left(\mathcal{J}(\hat{u}_H,\psi^B)\right) \leq \mathcal{J}(\hat{u}_H,\psi^B) z'(\mathcal{J}(\hat{u}_H,\psi^B))\frac{\mathcal{J}(\hat{u}_B,\psi^B)}{\mathcal{J}^*}$ holds because $\mathcal{J}z'(\mathcal{J})$ increases in $\mathcal{J}$ and $\frac{\mathcal{J}(\hat{u}_B,\psi^B)}{\mathcal{J}^*} > 1$.

We turn to the second bullet point. Notice that when $\rho = 1$, $\hat{\rho}_B^{Aug} = \hat{\rho}_H^{Aug} = 1$, then $\frac{\hat{\rho}_B^{Aug}}{\hat{\rho}_H^{Aug}} = 1 < \frac{\mathcal{J}(\hat{U}_H,\psi^B)}{\mathcal{J}(\hat{U}_B,\psi^B)}$, which indicates that headquarters is better off holding the decision authority. Next, we show $\frac{\hat{\rho}_B^{Aug}}{\hat{\rho}_H^{Aug}}$ decreases in ρ, which is equivalent to $\frac{\hat{\rho}_H^{Aug}}{\hat{\rho}_B^{Aug}} < \frac{\partial\hat{\rho}_H^{Aug}/\partial\rho}{\partial\hat{\rho}_B^{Aug}/\partial\rho}$. Since $\frac{\hat{\rho}_H^{Aug}}{\hat{\rho}_B^{Aug}} < 1$, it is sufficient to show $\frac{\partial\hat{\rho}_H^{Aug}}{\partial\rho} > \frac{\partial\hat{\rho}_B^{Aug}}{\partial\rho}$. $\frac{\partial\hat{\rho}_j^{Aug}}{\partial\rho} = 1 - z\left((1-\rho)\mathcal{J}\right) - (1-\rho)\mathcal{J}z'\left((1-\rho)\mathcal{J}\right)$. Because both $z(x)$ and $x \cdot z'(x)$ are increasing functions, $\frac{\partial\hat{\rho}_H^{Aug}}{\partial\rho} - \frac{\partial\hat{\rho}_B^{Aug}}{\partial\rho} = \left(z\left((1-\rho)\mathcal{J}(\hat{u}_B,\psi^B)\right) - z\left((1-\rho)\mathcal{J}(\hat{u}_H,\psi^B)\right)\right) +$
$\left((1-\rho)\mathcal{J}(\hat{u}_B,\psi^B) \cdot z'\left((1-\rho)\mathcal{J}(\hat{u}_B,\psi^B)\right) - (1-\rho)\mathcal{J}(\hat{u}_H,\psi^B) \cdot z'\left((1-\rho)\mathcal{J}(\hat{u}_H,\psi^B)\right)\right) > 0$ holds. Therefore, we can find a cutoff ρ^* above which $\frac{\hat{\rho}_B^{Aug}}{\hat{\rho}_H^{Aug}} < \frac{\mathcal{J}(\hat{U}_H,\psi^B)}{\mathcal{J}(\hat{U}_B,\psi^B)}$ always holds.

Proof of Proposition 5. For notational simplicity, we drop ψ_l^B in the following analysis. As shown in the Proposition 3, $\hat{\Gamma}\left(\hat{E}_H,\hat{e}_H\right) < \Gamma^*$ and $\Gamma(w,0) < \Gamma^*$. A comparison of equation (15) and (16) leads to

$$\mathbb{E}\left|\hat{\Gamma}^{Rep.} - \Gamma^*\right| - \mathbb{E}\left|\hat{\Gamma}_H^{Aug.} - \Gamma^*\right| < 0$$

$$
\begin{aligned}
&\Leftrightarrow \left(\rho - \max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\}\right)\left(\Gamma^* - \Gamma(w,0)\right) + \max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\}\left(\Gamma^* - \Gamma\left(\hat{E}_H, \hat{e}_H\right)\right) > 0 \\
&\Leftrightarrow \frac{\rho - \max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\}}{\max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\}} + \frac{\Gamma^* - \Gamma\left(\hat{E}_H, \hat{e}_H\right)}{\Gamma^* - \Gamma(w,0)} > 0 \\
&\Leftrightarrow \frac{\rho}{\max\left\{\hat{\rho}_H^{Aug.}, \hat{q}_H\right\}} + \frac{\Gamma^* - \Gamma\left(\hat{E}_H, \hat{e}_H\right)}{\Gamma^* - \Gamma(w,0)} > 1
\end{aligned}
$$

Similarly, as shown in the Proposition 3, $\hat{\Gamma}\left(\hat{E}_B, \hat{e}_B\right) \geq \Gamma^*$. A comparison of equation (15) and (16) leads to

$$
\begin{aligned}
&\mathbb{E}\left|\hat{\Gamma}^{Rep.} - \Gamma^*\right| - \mathbb{E}\left|\hat{\Gamma}_B^{Aug.} - \Gamma^*\right| < 0 \\
\Leftrightarrow &\left(\rho - \hat{\rho}_B^{Aug.}\right)\left(\Gamma^* - \Gamma(w,0)\right) + \rho_B^{Aug.}\left(\Gamma\left(\hat{E}_B, \hat{e}_B\right) - \Gamma^*\right) > 0 \\
\Leftrightarrow &\frac{\rho - \hat{\rho}_B^{Aug.}}{\hat{\rho}_B^{Aug.}} + \frac{\Gamma\left(\hat{E}_B, \hat{e}_B\right) - \Gamma^*}{\Gamma^* - \Gamma(w,0)} > 0 \\
\Leftrightarrow &\frac{\rho}{\hat{\rho}_B^{Aug.}} + \frac{\Gamma\left(\hat{E}_B, \hat{e}_B\right) - \Gamma^*}{\Gamma^* - \Gamma(w,0)} > 1
\end{aligned}
$$

The Effectiveness of No AI vs. Replacement AI for the case $\psi_l \leq \underline{\tilde{\psi}}_H$ According to Observation 3, information has no value to headquarters because headquarters allocates all funds to their clients in all states. Knowing this, the branch incurs no effort to acquire information. Then headquarters will not use augmentation AI. The equilibrium loan composition $(w,0)$ leads to the expected distance $\left|\tilde{\Gamma}\left(w,0;\psi^B\right) - \tilde{\Gamma}^*(\psi^B)\right|$, for $\psi^B \in \{\psi_l^B, \psi_h^B\}$. On the other hand, replacement AI leads to the first-best allocation whenever it is informative. However, if replacement AI fails to generate an informative signal, the equilibrium loan composition is determined by the prior belief ψ_0^B, causing the expected distance $\left|\Gamma\left(\tilde{E}^*(\psi_0^B), \tilde{e}^*(\psi_0^B); \psi^B\right) - \tilde{\Gamma}^*(\psi^B)\right|$ for $\psi^B \in \{\psi_l^B, \psi_h^B\}$. Since the first-best allocation will always allocate (weakly) more resources to the branch's clients, we reach the following result.

Proposition 1A. If $\psi_l \leq \underline{\tilde{\psi}}_H$, the effectiveness of replacement AI (weakly) dominates no AI, irrespective of AI performance.

In this situation, even with the presence of augmentation AI, headquarters will not use it and allocates all resources to its clients. No information is generated. Replacement AI resolves the issue of disproportion of resource allocation and generate information for better decision making.

Proof of Lemma 4.

F irst, $\hat{\mathcal{D}}_j\left(\psi^B\right) \leq \hat{\mathcal{D}}_j^{\emptyset}\left(\psi^B\right)$ and $\tilde{\mathcal{D}}_H\left(\psi^B\right) \leq \tilde{\mathcal{D}}_H^{\emptyset}\left(\psi^B\right)$. Given $\psi^B = \psi_h^B$, $\hat{\mathcal{D}}_j\left(\psi^B\right) = \hat{\mathcal{D}}_j^{\emptyset}\left(\psi^B\right)$ as the resulting allocation is $(w,0)$ regardless of whether a signal is generated. Given $\psi^B = \psi_l^B$, it is enough to show $\hat{\Gamma}(\hat{E}_H, \hat{e}_H) > \hat{\Gamma}(w,0) \Leftrightarrow \frac{\psi^H f'(\hat{E}_H) + \psi^H(H+\beta B) - 2(1-\psi^H)}{\psi_l^B f'(\hat{e}_H) + \psi_l^B(B+\alpha H) - 2(1-\psi_l^B)} > \frac{\psi^H f'(w) + \psi^H(H+\beta B) - 2(1-\psi^H)}{\psi_l^B f'(0) + \psi_l^B(B+\alpha H) - 2(1-\psi_l^B)}$, which is always true for a decreasing function f'. The same reasoning applies to crisis time.

Next, $\hat{\mathcal{D}}_j^{\emptyset}\left(\psi^B\right) \leq \tilde{\mathcal{D}}_H^{\emptyset}\left(\psi^B\right)$. Given $\psi^B = \psi_h^B$, $\hat{\mathcal{D}}_j^{\emptyset}\left(\psi^B\right) = 0$. So $\tilde{\mathcal{D}}_H^{\emptyset}\left(\psi^B\right) \geq 0$ always holds. Given $\psi^B = \psi_l^B$, $\hat{\mathcal{D}}_j^{\emptyset}\left(\psi_l^B\right) \leq \tilde{\mathcal{D}}_H^{\emptyset}\left(\psi_l^B\right) \Leftrightarrow \frac{\psi^H f'(w) + \psi^H(H+\beta B) - 2(1-\psi^H)}{\psi_l^B f'(0) + \psi_l^B(B+\alpha H) - 2(1-\psi_l^B)} \geq \frac{f'(w) + \psi^H(H+\beta B)}{f'(0) + \psi_l^B(B+\alpha H)}$. It is sufficient to check $\psi^H f'(w) - 2(1-$

$\psi^H) - \psi_l^B f'(0) + 2(1-\psi_l^B) \geq f'(w) - f'(0) \Leftrightarrow (1-\psi_l^B)(f'(0)+2) \geq (1-\psi^H)(f'(w)+2)$, which holds under Assumption 2. Together we have $\hat{\mathcal{D}}_j(\psi^B) \leq \hat{\mathcal{D}}_j^{\emptyset}(\psi^B) \leq \tilde{\mathcal{D}}_H^{\emptyset}(\psi^B)$.

Moreover, according to Proposition 3, $\hat{\mathcal{D}}_j(\psi^B) \leq \tilde{\mathcal{D}}_H(\psi^B)$.

Hence, for any $\tilde{\gamma} \in (0,1)$ and $\hat{\gamma} \in (0,1)$, $\tilde{\gamma}\tilde{\mathcal{D}}_H + (1-\tilde{\gamma})\tilde{\mathcal{D}}_H^{\emptyset} \geq \hat{\gamma}\hat{\mathcal{D}}_j + (1-\hat{\gamma})\hat{\mathcal{D}}_j^{\emptyset} \Leftrightarrow \tilde{\gamma}(\tilde{\mathcal{D}}_H - \tilde{\mathcal{D}}_H^{\emptyset}) + \tilde{\mathcal{D}}_H^{\emptyset} \geq \hat{\gamma}(\hat{\mathcal{D}}_j - \hat{\mathcal{D}}_j^{\emptyset}) + \hat{\mathcal{D}}_j^{\emptyset} \Leftrightarrow \max\{\tilde{\gamma},\hat{\gamma}\} \cdot (\tilde{\mathcal{D}}_H - \hat{\mathcal{D}}_j) - |\tilde{\gamma}-\hat{\gamma}| \cdot (\hat{\mathcal{D}}_j - \hat{\mathcal{D}}_j^{\emptyset}) \geq (1-\max\{\tilde{\gamma},\hat{\gamma}\}) \cdot (\hat{\mathcal{D}}_j^{\emptyset} - \tilde{\mathcal{D}}_H^{\emptyset})$. Since $\tilde{\mathcal{D}}_H - \hat{\mathcal{D}}_j \geq 0$, $\hat{\mathcal{D}}_j - \hat{\mathcal{D}}_j^{\emptyset} \leq 0$, and $\hat{\mathcal{D}}_j^{\emptyset} - \tilde{\mathcal{D}}_H^{\emptyset} \leq 0$, the last inequality always holds.

Proof of Lemma 5. Given $\psi^B = \psi_l^B$, the resource to headquarters is over-allocated in both crisis and non-crisis time. Then $\mathbb{E}\tilde{\mathcal{D}}^{Rep.}(\psi_l^B) < \mathbb{E}\hat{\mathcal{D}}^{Rep}(\psi_l^B) \Leftrightarrow \tilde{\mathcal{D}}^{\emptyset}(\psi_l^B) < \hat{\mathcal{D}}^{\emptyset}(\psi_l^B) = \hat{\mathcal{D}}_H^{\emptyset}(\psi_l^B) \Leftrightarrow \hat{\Gamma}(w,0;\psi_l^B) < \tilde{\Gamma}\left(\tilde{E}^*(\psi_0^B), \tilde{e}^*(\psi_0^B); \psi_l^B\right) \Leftrightarrow \frac{\psi_l^B f'(0) + \psi_l^B(B+\alpha H) - 2(1-\psi_l^B)}{\psi^H f'(w) + \psi^H(H+\beta B) - 2(1-\psi^H)} > \frac{f'(\tilde{e}^*(\psi_0^B)) + +\psi_l^B(B+\alpha H)}{f'(\tilde{E}^*(\psi_0^B)) + \psi^H(H+\beta B)}$. Since the denominator of the left-hand-side of the above inequality is smaller than that of the right-hand-side, it is enough to check $\psi_l^B f'(0) + 2\psi_l^B - (\psi^H f'(w) + 2\psi^H)) > f'(\tilde{e}^*(\psi_0^B) - f'(\tilde{E}^*(\psi_0^B) = \psi^H(H+\beta B) - \psi_0^B(B+\alpha H) \Leftrightarrow \psi_l^B f'(0) + \psi_0^B(B+\alpha H) + 2\psi_l^B > \psi^H f'(w) + \psi^H(H+\beta B) + 2\psi_H \Leftrightarrow \psi_l^B(f'(0)+2) - \psi^H(f'(w)+2) > \psi^H(H+\beta B) - \psi_0^B(B+\alpha H)$. If $\tilde{e}(\psi_0^B) = 0$, $f'(0) + \psi_0^B(B+\alpha H) < f'(w) + \psi^H(H+\beta B)$, then $\psi^H(H+\beta B) - \psi_0^B(B+\alpha H) > f'(0) - f'(w) > \psi_l^B f'(0) + \psi_0^B(B+\alpha H) + 2\psi_l^B$ as the last inequality holds under Assumption 2. Otherwise, if $\tilde{e}(\psi_0^B) > 0$, there exists parameter range such that the opposite holds. Given $\psi^B = \psi_h^B$, we have $\hat{E}^*(\psi_0^B) = \hat{E}^*(\psi_h^B) = w$, and thus $\mathbb{E}\hat{\mathcal{D}}^{Rep.}(\psi_h^B) = 0$. Then the result immediately follows.

Proof of Proposition 6. First, we show that $\tilde{\mathcal{D}}_H^{\emptyset}(\psi_l^B) \geq \tilde{\mathcal{D}}^{\emptyset}(\psi_l^B)$. Since $\tilde{e}^*(\psi_l^B) > \tilde{e}_H(\psi_0^B)$ and $\tilde{e}^*(\psi_l^B) > \tilde{e}^*(\psi_0^B)$, it is equivalent to show $\tilde{e}_H(\psi_0^B) \leq \tilde{e}^*(\psi_0^B)$, which is always true as $\tilde{e}_H(\psi_0^B) = w$.

Replacement AI is considered to be more effective than augmentation AI when

$$\begin{aligned}
&\lambda\left[\mathbb{E}\tilde{\mathcal{D}}_H^{Aug.}\left(\psi_l^B\right) - \mathbb{E}\tilde{\mathcal{D}}^{Rep.}\left(\psi_l^B\right)\right] + (1-\lambda)\left[\mathbb{E}\tilde{\mathcal{D}}_H^{Aug.}\left(\psi_h^B\right) - \mathbb{E}\tilde{\mathcal{D}}^{Rep.}\left(\psi_h^B\right)\right] > 0 \\
\Leftrightarrow\ &\tilde{\mathcal{D}}^{\emptyset}(\psi_l^B)\lambda \cdot \left[\tilde{\rho}_H^{'Aug.}\frac{\tilde{\mathcal{D}}_H(\psi_l^B)}{\tilde{\mathcal{D}}^{\emptyset}(\psi_l^B)} + (1-\tilde{\rho}_H^{'Aug.})\underbrace{\frac{\tilde{\mathcal{D}}_H^{\emptyset}(\psi_l^B)}{\tilde{\mathcal{D}}^{\emptyset}(\psi_l^B)}}_{>1} - 1 + \rho\right] + \tilde{\mathcal{D}}^{\emptyset}(\psi_h^B)(1-\lambda) \cdot \left[\frac{\tilde{\mathcal{D}}_H^{\emptyset}(\psi_h^B)}{\tilde{\mathcal{D}}^{\emptyset}(\psi_h^B)} - 1 + \rho\right] > 0 \\
\Leftarrow\ &\lambda \cdot \left[\tilde{\rho}_H^{'Aug.}\frac{\tilde{\mathcal{D}}_H(\psi_l^B)}{\tilde{\mathcal{D}}^{\emptyset}(\psi_l^B)} + 1 - \tilde{\rho}_H^{'Aug.} + \rho\right] + (1-\lambda) \cdot \left[\frac{\tilde{\mathcal{D}}_H^{\emptyset}(\psi_h^B)}{\tilde{\mathcal{D}}^{\emptyset}(\psi_h^B)} + \rho\right] > 1 \\
\Leftrightarrow\ &\lambda\tilde{\rho}_H^{'Aug.} \cdot \left[\frac{\rho}{\tilde{\rho}_H^{'Aug.}} + \frac{\tilde{\mathcal{D}}_H(\psi_l^B)}{\tilde{\mathcal{D}}^{\emptyset}(\psi_l^B)} + \frac{1-\tilde{\rho}_H^{'Aug.}}{\tilde{\rho}_H^{'Aug.}}\right] + (1-\lambda) \cdot \left[\frac{\tilde{\mathcal{D}}_H^{\emptyset}(\psi_h^B)}{\tilde{\mathcal{D}}^{\emptyset}(\psi_h^B)} + \rho\right] > 1
\end{aligned}$$

Proof of Corollary 2. The first-best solution satisfies $f'(\tilde{E}^*) + \psi^H(H+\beta B) = f'(\tilde{e}^*) + \psi^B(B+\alpha H)$. Differentiate both sides w.r.t. μ, we can obtain $\mu f''(\tilde{E}^*)\frac{\partial \tilde{E}^*}{\partial \mu} + \psi^H(H+\beta B) = \mu f''(\tilde{e}^*)\frac{\partial \tilde{e}^*}{\partial \mu} + \psi^B(B+\alpha H)$. Take the difference of the two equations, $f'(\tilde{E}^*) - \mu f''(\tilde{E}^*)\frac{\partial \tilde{E}^*}{\partial \mu} = f'(\tilde{e}^*) - \mu f''(\tilde{e}^*)\frac{\partial \tilde{e}^*}{\partial \mu} \Leftrightarrow \mu\left(f''(\tilde{E}^*) + f''(\tilde{e}^*)\right)\frac{\partial \tilde{e}^*}{\partial \mu} = f'(\tilde{e}^*) - f'(\tilde{E}^*)$. Since $f'' < 0$, $\frac{\partial \tilde{e}^*}{\partial \mu} < 0 \Leftrightarrow f'(\tilde{e}^*) - f'(\tilde{E}^*) > 0 \Leftrightarrow \tilde{e}^* < \tilde{E}^*$.

References

Acemoglu D, Restrepo P (2018)a. Modeling Automation. *AEA Papers and Proceedings*, vol. 108 48–53.

Acemoglu D, Restrepo P (2018)b. The Race Between Man and Machine: Implications of Technology for Growth, Factor Shares, and Employment. *American Economic Review* **108**(6) 1488–1542.

Acemoglu D, Restrepo P (2020). The Wrong Kind of AI? Artificial Intelligence and the Future of Labour Demand. *Cambridge Journal of Regions, Economy and Society* **13**(1) 25–35.

Acharya VV, Eisert T, Eufinger C, Hirsch C (2019). Whatever It Takes: The Real Effects of Unconventional Monetary Policy. *The Review of Financial Studies* **32**(9) 3366–3411. doi:10.1093/rfs/hhz005. https://doi.org/10.1093/rfs/hhz005.

Aghion P, Jones BF, Jones CI (2019). *Artificial Intelligence and Economic Growth*. University of Chicago Press, 237–282.

Aghion P, Tirole J (1997). Formal and Real Authority in Organizations. *Journal of political economy* **105**(1) 1–29.

Agrawal A, Gans J, Goldfarb A (2018). Prediction, Judgment, and Complexity: A Theory of Decision-Making and Artificial Intelligence. *The Economics of Artificial Intelligence: An Agenda* University of Chicago Press, 89–110.

Agrawal A, Gans JS, Goldfarb A (2019)a. Artificial Intelligence: the Ambiguous Labor Market Impact of Automating Prediction. *Journal of Economic Perspectives* **33**(2) 31–50.

Agrawal A, Gans JS, Goldfarb A (2019)b. Exploring the Impact of Artificial Intelligence: Prediction versus Judgment. *Information Economics and Policy* **47** 1–6.

Athey SC, Bryan KA, Gans JS (2020). The Allocation of Decision Authority to Human and Artificial Intelligence. *AEA Papers and Proceedings* **110** 80–84. doi:10.1257/pandp.20201034. https://www.aeaweb.org/articles?id=10.1257/pandp.20201034.

Beck T, Degryse H, De Haas R, van Horen N (2018). When Arm's Length Is Too Far: Relationship Banking Over the Credit Cycle. *Journal of Financial Economics* **127**(1) 174 – 196. doi:https://doi.org/10.1016/j.jfineco.2017.11.007. http://www.sciencedirect.com/science/article/pii/S0304405X17302957.

Benmelech E, Bergman NK (2012). Credit Traps. *American Economic Review* **102**(6) 3004–32. doi:10.1257/aer.102.6.3004. https://www.aeaweb.org/articles?id=10.1257/aer.102.6.3004.

Bolton P, Freixas X, Gambacorta L, Mistrulli PE (2016). Relationship and Transaction Lending in a Crisis. *The Review of Financial Studies* **29**(10) 2643–2676. doi:10.1093/rfs/hhw041. https://doi.org/10.1093/rfs/hhw041.

Cetorelli N, Strahan PE (2006). Finance as a Barrier to Entry: Bank Competition and Industry Structure in Local U.S. Markets. *The Journal of Finance* **61**(1) 437–461. doi:10.1111/j.1540-6261.2006.00841.x. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1540-6261.2006.00841.x.

Chen MA, Wu Q, Yang B (2019). How Valuable Is FinTech Innovation? *The Review of Financial Studies* **32**(5) 2062–2106. doi:10.1093/rfs/hhy130. https://doi.org/10.1093/rfs/hhy130.

Coleman N, Feler L (2015). Bank Ownership, Lending, and Local Economic Performance During the 2008-2009 Financial Crisis. *Journal of Monetary Economics* **71** 50 – 66. doi:https://doi.org/10.1016/j.jmoneco.2014.11.001. http://www.sciencedirect.com/science/article/pii/S0304393214001585.

Cong LW, Gao H, Ponticelli J, Yang X (2019). Credit Allocation Under Economic Stimulus: Evidence from China. *The Review of Financial Studies* **32**(9) 3412–3460. doi:10.1093/rfs/hhz008. https://doi.org/10.1093/rfs/hhz008.

Deleersnyder B, Dekimpe MG, Steenkamp JBE, Leeflang PS (2009). The Role of National Culture in Advertising's Sensitivity to Business Cycles: An Investigation across Continents. *Journal of Marketing Research* **46**(5) 623–636. doi:10.1509/jmkr.46.5.623. https://doi.org/10.1509/jmkr.46.5.623.

Dogan M, Jacquillat A, Yildirim P (2018). Strategic Automation and Decision-Making Authority. *Available at SSRN 3226222* .

Dukes A, Zhu Y (2019). Why Customer Service Frustrates Consumers: Using a Tiered Organizational Structure to Exploit Hassle Costs. *Marketing Science* **38**(3) 500–515.

Dutt P, Padmanabhan V (2011). Crisis and Consumption Smoothing. *Marketing Science* **30**(3) 491–512. doi:10.1287/mksc.1100.0630. https://doi.org/10.1287/mksc.1100.0630.

Edeling A, Fischer M (2016). Marketing's Impact on Firm Value: Generalizations from a Meta-Analysis. *Journal of Marketing Research* **53**(4) 515–534.

Egan M (2020). Big Banks Accused of Favoring More Lucrative Small Business Loans in Coronavirus Program. *CNN Business* (April 21), https://www.cnn.com/2020/04/21/business/small-business-loans-ppp-lawsuit/index.html.

Frösén J, Jaakkola M, Churakova I, Tikkanen H (2016). Effective Forms of Market Orientation across the Business Cycle: A Longitudinal Analysis of Business-to-Business Firms. *Industrial Marketing Management* **52** 91–99.

Fuster A, Plosser M, Schnabl P, Vickery J (2019). The Role of Technology in Mortgage Lending. *The Review of financial studies* **32**(5) 1854–1899.

Giannetti M, Simonov A (2013). On the Real Effects of Bank Bailouts: Micro Evidence from Japan. *American economic journal. Macroeconomics* **5**(1) 135–167.

Gilje EP, Loutskina E, Strahan PE (2016). Exporting Liquidity: Branch Banking and Financial Integration. *The Journal of Finance* **71**(3) 1159–1184. doi:10.1111/jofi.12387. https://onlinelibrary.wiley.com/doi/abs/10.1111/jofi.12387.

Giné X, Kanz M (2017). The Economic Effects of a Borrower Bailout: Evidence from an Emerging Market. *The Review of Financial Studies* **31**(5) 1752–1783. doi:10.1093/rfs/hhx073. https://doi.org/10.1093/rfs/hhx073.

Granja J, Makridis C, Yannelis C, Zwick E (2020). Did the Paycheck Protection Program Hit the Target? Tech. rep., National Bureau of Economic Research.

Humphries JE, Neilson CA, Ulyssea G (2020). Information Frictions and Access to the Paycheck Protection Program. *Journal of Public Economics* **190** 104244.

Jakšič M, Marinč M (2019). Relationship Banking and Information Technology: The Role of Artificial Intelligence and FinTech. *Risk Management* **21**(1) 1–18.

Lamey L, Deleersnyder B, Steenkamp JBE, Dekimpe MG (2012). The Effect of Business-Cycle Fluctuations on Private-Label Share: What has Marketing Conduct Got to do with it? *Journal of Marketing* **76**(1) 1–19. doi:10.1509/jm.09.0320. https://doi.org/10.1509/jm.09.0320.

Lim N, Ham SH (2014). Relationship Organization and Price Delegation: An Experimental Study. *Management Science* **60**(3) 586–605.

Luo X, Tong S, Fang Z, Qu Z (2019). Frontiers: Machines vs. Humans: The Impact of Artificial Intelligence Chatbot Disclosure on Customer Purchases. *Marketing Science* **38**(6) 937–947.

Netzer O, Lemaire A, Herzenstein M (2019). When Words Sweat: Identifying Signals for Loan Default in the Text of Loan Applications. *Journal of Marketing Research* **56**(6) 960–980.

O'Connell J, Van Dam A, Gregg A, Fowers A (2020). More than half of emergency small-business funds went to larger businesses, new data shows. *The Washington Post* (December 2), https://www.washingtonpost.com/business/2020/12/01/ppp-sba-data/.

Peers Y, Van Heerde HJ, Dekimpe MG (2017). Marketing Budget Allocation across Countries: the Role of International Business Cycles. *Marketing Science* **36**(5) 792–809.

Sawers P (2020). How Chase is using AI to update banking. *VentureBeat* (July 15), https://venturebeat.com/2020/07/15/how-chase-is-using-ai-to-update-banking/.

Sherman E (2020). Many public companies that got ppp loans had lots in the bank. *Forbes* (April 24), https://www.forbes.com/sites/eriksherman/2020/04/24/public-companies-ppp-loans-money/#998224f40d23.

Simester D, Zhang J (2010). Why Are Bad Products So Hard to Kill? *Management Science* **56**(7) 1161–1179.

Simester D, Zhang J (2014). Why Do Salespeople Spend So Much Time Lobbying for Low Prices? *Marketing Science* **33**(6) 796–808.

Srinivasan R, Lilien GL, Sridhar S (2011). Should Firms Spend More on Research and Development and Advertising during Recessions? *Journal of Marketing* **75**(3) 49–65. doi:10.1509/jmkg.75.3.49. https://doi.org/10.1509/jmkg.75.3.49.

Steenkamp JBEM, Fang EE (2011). The Impact of Economic Contractions on the Effectiveness of R&D and Advertising: Evidence from U.S. Companies Spanning Three Decades. *Marketing Science* **30**(4) 628–645. doi:10.1287/mksc.1110.0641. https://doi.org/10.1287/mksc.1110.0641.

U.S. Small Business Administration (2020). PPP loan forgiveness. Accessed: 2020-09-29, https://www.sba.gov/funding-programs/loans/coronavirus-relief-options/paycheck-protection-program#section-header-2.

Van Heerde HJ, Gijsenberg MJ, Dekimpe MG, Steenkamp JBE (2013). Price and Advertising Effectiveness over the Business Cycle. *Journal of Marketing Research* **50**(2) 177–193.

Walsh M (2020). AI Should Change What You Do â Not Just How You Do It. *Harvard Business Review* (September 21), https://hbr.org/2020/09/ai-should-change-what-you-do-not-just-how-you-do-it.

Wieczner J, Morris DZ (2020). Meet the one-branch bank that did more ppp lending than citi. *Fortune* (July 15), https://fortune.com/2020/07/15/ppp-loans-bank-fintech-cross-river-citi/.

Wiggers K (2020). Google releases AI tool for processing Paycheck Protection Program loans. *VentureBeat* (May 1), https://venturebeat.com/2020/05/01/google-releases-ai-solution-to-help-lenders-process-paycheck-protection-program-loans/.

Zhang Y (2018). Assessing Fair Lending Risks Using Race/Ethnicity Proxies. *Management Science* **64**(1) 178–197. doi:10.1287/mnsc.2016.2579. https://doi.org/10.1287/mnsc.2016.2579.