Regulatory Uncertainty and FinTech Innovation[*]

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Abstract

Regulators often lack expertise and resources needed to assess the value of FinTech innovation, with instruments at their disposal being crude and underdeveloped. We advance a theory where FinTech innovators, incumbents, and regulators strategically respond to opportunities to innovate under uncertainty. In it, regulators acquire costly and imprecise information about the societal value of innovation while FinTech firms can not be certain about the regulatory response to this information. We show that the rate of innovation in FinTech depends on the budget and skills of the regulator in assessing the gains and risks to innovation, the private rents that accrue to innovators, and the number of FinTech firms with access to new technology. Multiple equilibria arise from the complementarity between regulatory preparedness/competence and investments into innovation, adding extrinsic risks to the regulation–innovation game. Among several policy implications, our theory shows that skilled regulators with ample budgets prompt FinTechs to innovate more.

Keywords: Equilibrium Multiplicity, FinTech, Imperfect Information, Regulatory Uncertainty.

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1 Introduction

The regulatory framework governing financial activities generally relies on rules enforced by an authoritative body upon providers and users of services. That framework has been challenged by developments in the digital domain. In it, payments generate data with unspecified ownership that can substitute collateral in lending decisions, financial assets can be traded by autonomous protocols at a high frequency across international borders, while contracts and markets can be maintained by an open pool of pseudonymous agents rather than a unique, identifiable legal entity. This FinTech ecosystem is complex. It consists of the simultaneous integration of forces that rarely emerge together: (1) breakthrough technologies, (2) new assets, markets, and services, and (3) new ways of designing financial infrastructure and executing contracts.

There is demand to rethink the regulatory architecture of financial services in light of FinTech. To date, relatively few — sometimes conflicting — directions have been offered. Regulatory actions have generally taken the form of crude interventions, rather than fine-tuned measures. Critically, they have left open for speculation what makes certain FinTech activities acceptable in the eye of regulators.[1] In other heavily regulated industries, such as pharmaceuticals, applicable criteria to be met are well defined and compliance is verifiable. In banking, the industry has been directly involved in setting regulatory standards. In those industries, regulatory stringency — rather than uncertainty — is the most prominent concern. Uncertainty about the regulatory perimeter and enforcement allows for the implementation of only a limited subset of new technologies at the frontier in FinTech. It has been argued that innovation has been stifled as a result.[2]

This paper presents a framework to study the impact of regulatory uncertainty on FinTech innovation stemming from regulators' ability and resources. Under a new US administration, the Department of Government Efficiency (DOGE), has been aggressively downsizing federal agencies, arguing that cutting regulatory oversight fosters economic growth (Reuters, 2025). However, our analysis shows that increasing regulatory capacity — by improving expertise and resources — may ultimately facilitate innovation, as seen in initiatives like the UK's Regulatory Innovation Office, which accelerates the approval of new technologies. Our framework is malleable and has a number of features that speak to this emerging industry. In it, FinTech firms and regula-

[1]For example, some crypto tokens have been classified as securities, while others as either commodities or derivatives. Of the former, a subset has been banned by the SEC on grounds of not complying with existing regulations.

[2]Similarly, although the stringent FDA approval process was implemented to ensure drug safety, it is widely perceived to have slowed pharmaceutical innovation by imposing high compliance costs and lengthy approval times.

tors strategically respond to opportunities to innovate. In the regulation–innovation game that ensues, FinTechs do not know how regulators will respond to the emergence of a new technology. This uncertainty arises because not every profitable application of a new digital technology is known at the time of its development. Ex post, some of the applications turn out to be socially less valuable than others, even hazardous. Take distributed ledgers, in particular blockchains, as an example. It has been the technological core of cryptocurrencies such as Bitcoin. They are a central feature of the crypto hype that unfolded over the last few years but has led to crashes (e.g., trading platforms such as FTX and stablecoin Terra) and even facilitated a short-lived banking crisis (Signature Bank and Silvergate Capital). On the flip side, blockchain is also the key technology behind smart contracts, which have the potential to improve economic relations (e.g., financial inclusion, trade, and credit) in countries with less developed institutions.

For regulators, information acquisition about the potential social value of new technologies is costly and imperfect. Depending on their structure, their ability to learn, and even their budgets, regulators may ban new technologies with some probability even if they are valuable — both privately and socially — or let new technologies play out even if they are socially costly. Notably, unlike in banking, the potential market failures that may arise from FinTech innovation have not yet been identified nor are they well understood. In addition, other concerns enter the regulators' valuation of innovation in the FinTech domain: it may make it harder for regulators to ensure financial stability, market integrity, and consumer protection; as well as prevent tax evasion, fraud, discrimination, and funding of illicit activities. As we demonstrate, in a world with potentially significant social costs associated with FinTech innovation, regulatory *laissez-faire* is not an equilibrium as a positive or a normative conclusion.[3] In turn, we show that the very existence of a regulatory framework and regulatory body shapes FinTech innovation. Moreover, their ability to regulate is key: that ability will depend on the budget given to the regulatory authority and its skills.

It is important that we define regulatory uncertainty in the context of our model. In it, the regulated cannot be certain about future limits on their business activities arising from a regulatory authority that faces a number of challenges: (1) it has an imperfect understanding of the activities of the regulated, (2) the instruments at its disposal are crude and its budget limited, and (3) it cannot commit to a certain course of action. A regulatory body imposes limits on the activities of the regulated in a less than perfectly predictable manner, and this lack of predictability does not just result

[3]The case for *laissez-faire* often builds on the argument that regulation is expensive and can be futile. Worse, it may lend legitimacy to an industry that may not deserve public support.

from randomness in the state of the world, but from a lack of experience, resources, skills, and technology of the regulator in assessing the societal value of innovation. Important aspects of regulatory uncertainty include the lack of clarity about the specific market failure that regulators want to mitigate; the effects of regulatory instruments on social welfare; why regulators seem unable to commit to guidelines; why seemingly identical assets, markets, or market participants are made subject to different rules; and why thresholds that trigger regulatory intervention seem arbitrary. As our theory shows, regulatory uncertainty and observed FinTech innovation are intrinsically endogenous.

Our model considers a class of games with three groups of players. One group comprises innovative FinTech firms that have an idea of how to develop and adapt a new technology, thereby potentially creating new markets. Firms without such an idea form a second group of players which we call incumbents. Firms in both groups can operate in an established ecosystem where they compete in a well-organized, oligopolistic-type market (e.g., the market for stablecoins). The third player is a regulator who has a limited budget that can be spent on learning about the societal effects of new technologies developed by FinTechs. At the time when FinTechs make their decision about developing a new technology, no one knows the potential societal value of FinTech innovation. At that time, regulators' instruments are "crude" as they can only either ban or approve a technology. They may later reassess what to do after spending resources learning about the new technology, but their knowledge remains imperfect and depends on their skills and resources.[4]

The *rate of innovation* is a key equilibrium outcome of our model. It arises from a number of forces that are endogenously at play: (1) the number of FinTech firms that choose to innovate, (2) their success probability, as determined by the effort and resources they spend on the innovation, and (3) the probability that they reap the benefits of their innovation, as modulated by the regulator's market interventions. This outcome depends on the rents that potential innovators can realize elsewhere, as well as on the limitations of the regulator, both in terms of its budget and skills.

Our analysis yields three novel insights, each carrying policy implications. First, multiple equilibria can exist. Specifically, while equilibria where the regulator always bans FinTech innovation regardless of the observed signal exist, there are also equilibria where the regulator will stop FinTech innovation only if signals are sufficiently poor. This multiplicity of equilibria, while arising from regulatory uncertainty, adds extrinsic risks as an additional layer of uncertainty to the FinTech regulation–innovation game. In practical terms, it matters that policymakers not only un-

[4]The crudeness of regulatory instruments currently used is showcased in the *Financial Times* article "Investors at risk in absence of adequate US crypto regulatory regime."

derstand how a lack of regulatory preparedness stifles socially valuable FinTech innovation, but are also aware of additional, endogenous uncertainty created by such unpreparedness.[5]

The second insight concerns the importance of regulator's skills and budget. If the regulator's skills in generating informative signals are poor, outright bans of new technologies are the only equilibrium outcome. If skills are sufficiently high, the equilibrium outcome depends also on the regulator's budget. If the budget is too low, there will be again only outright bans. With a sufficiently larger budget, the FinTech's chosen probability of success and the regulator's chosen signal precision are strategic complements. Accordingly, both efforts reinforce each other, potentially increasing the number of equilibria. Critically, our theory shows that ample regulatory budgets prompt FinTechs to *innovate more* provided the regulator's skills in generating informative signals are neither too poor nor too good. In practical terms, it matters that policymakers provide regulators with adequate budgets and secure the hiring of skilled personnel.

Third, we compare cases with a single and with multiple innovative FinTechs. Chief among the insights from this comparison is that the latter is not a simple extension of the former since innovative FinTechs may compete for the attention of an under-resourced regulator. As a result, regulatory uncertainty manifests itself along another dimension of multiplicity of equilibria as there can be also extrinsic risk with respect to the identity of the FinTech firm that innovates and develops its idea into a new technology. In practical terms, it matters how wide the domain (or mandate) of a regulatory body is defined.

A number of countries have experimented with the idea of using regulatory sandboxes. These comprise legally delimited spaces where FinTechs are allowed to test the waters of their innovation in an environment without immediate regulatory interference. Under this arrangement, regulators closely watch market activities and outcomes. In the language of our model, sandboxes translate into a way for regulators to learn about new technologies first and to decide later on whether to let FinTechs continue with new their activities. Without sandboxes, learning about new technologies is costlier and associated with greater risk. Accordingly, regulatory dismissal rates are higher, compounded by a lower effort by FinTechs, leading to lower innovation success probability.

The literature on the impact of regulatory uncertainty on FinTech innovation is rather limited. Grennan (2022) recounts the history of regulating FinTech in the US. Ran et al. (2023) report a positive impact of regulatory clarity on debt crowdfunding. Empirical findings in Cornelli et al.

[5]Lack of regulatory preparedness can be manifested in giving guidance that introduces legal risks. See, e.g., the *Financial Times* article "HSBC and Standard Chartered pressed by Hong Kong regulator to take on crypto clients."

(2023) indicate that overall risk of FinTechs operating in sandboxes is lower, thereby improving their access to capital, survival rates, and innovation activity. Auer and Claessens (2018) show how valuations and transaction volumes of cryptocurrencies respond to various news about regulatory actions. In related work, Charoenwong et al. (2024) look at investments in RegTech — compliance-driven investments in IT — by established financial firms and show how regulation can affect not only technology adoption but also market structure, an implication we theoretically characterize.[6]

On the theoretical front, Biais et al. (2023) argue that equilibrium BitCoin prices are prone to reflect sunspots, implying multiple equilibria and extrinsic volatility that can be detrimental for society. Gehrig and Ritzberger (2022) present a model where FinTech investments in ultra-fast trading technologies can lead to appropriation of market power, excess price volatility, and equilibrium multiplicity in markets with intermediated trading. Chiu et al. (2022) argue that problems with decentralized finance can be alleviated by building an infrastructure supported by a third party. More broadly, studies such as Boot and Thakor (1993) and Morrison and White (2013) examine the regulator's reputation and its interaction with regulatory transparency (Chen et al., 2024) or information structure (Goldstein and Huang, 2016; Cong et al., 2020). None of these papers study the effect of regulatory uncertainty on FinTech innovation.[7]

Our paper also contributes to a larger branch in the literature that studies general underinvestment problems associated with R&D investments (Besanko et al., 2018). Along these lines, Gehrig and Stenbacka (2023) study how the ability of firms and policymakers to assess the viability of projects affects investment and optimal subsidy rates. In their analysis, R&D investments always carry positive externalities and policymakers' ability to assess projects is exogenous. This literature shares with our model that key decisions are based on the imperfect assessments of projects and that threshold decision rules are optimal. With our focus on FinTech innovation adoption, however, we introduce regulatory uncertainty — ex ante uncertainty about whether projects impose positive or negative externalities on society — and let the regulator's precision of knowledge about projects be endogenous.

Regulatory uncertainty of the type considered here is a recent phenomenon and theoretical inquiries into its nature and effects on FinTech innovation adoption are still scarce. Academic interest in regulatory uncertainty has, however, some history in the context of pharmaceuticals (e. g.,

[6]Not specific to FinTech, an emerging empirical literature has documented how policy uncertainty affects firm innovation (see, e.g., Cong and Howell, 2021; Campello et al., 2022).

[7]Easley and O'Hara (2009) show that regulation of unlikely events can moderate the effects of ambiguity, thereby increasing participation and generating welfare gains.

Carpenter and Ting, 2007) and medical technology (e. g., Stern, 2017). There, it is the innovator who provides verifiable but costly information (e. g., by providing results of experiments or experimental test runs) to the regulator, upon which the latter decides whether or not to approve an application. As we argue, however, such costly signaling game does not capture the reality of FinTech. In turn, we present a framework in which it is the regulator who generates costly information about the potential societal effects of innovation. The regulator's budget is limited, and potential innovators compete among themselves, either for market shares within the boundaries of a given technology or for the regulator's limited resources when they aim to expand the current frontier.

Finally, concerning regulation and competition, Callander and Li (2024) build a cheap talk model, and focus on how competition created by the innovation impacts regulatory decision making. Our study differs by endogenizing innovation and focusing on risks under symmetric learning rather than informational asymmetry and lobbying; in particular, we do not need to assume firms know their innovations' social value better than the regulators. We highlight a novel firm competition through the regulatory budget channel, where monopolies enjoying the entire regulatory attention innovate more — contrary to the Arrow Replacement Effect in Callander and Li (2024).

We note that the model we propose applies to innovation in the FinTech industry today, as opposed to innovation in general. First, the ultimate effects of FinTech innovation are virtually impossible to gauge and they carry potentially large negative economic and societal effects. For comparison, an unregulated pharmaceutical drug generally only affects those individuals who undergo the drug treatment. FinTech innovation, instead, can affect all economic agents by facilitating discrimination, tax evasion, and even terrorism. Second, note that innovation in pharmaceuticals is typically introduced by existing leading firms (e. g., Bayer and Pfizer). Likewise, in the tech industry, leading companies either develop innovation themselves or acquire innovative firms they see as competitors (e. g., Meta and Google). In other words, other sectors preemptively innovate in-house or acquire disruptive innovations in the market. The end-result is the creation of entrenched incumbents "protected" by regulation (via licenses and patents). This is different from what happens in FinTech, where leading innovators are generally born out of new start-ups and remain independent. Their closer competitors in the financial industry — banks — have only reluctantly adopted innovation in FinTech be it for fear of regulation or inability to understand and integrate innovation into their business models. Finally, our model is timely to FinTech in particular as most countries are actively debating over different regulatory frameworks for the industry.

The remainder of our paper is organized as follows. Section 2 presents the setup of the game. Section 3 studies the equilibrium outcomes with a single innovative FinTech. Section 4 extends the analysis to the case with multiple FinTechs. Section 5 introduces a disruptor FinTech who has a first-mover advantage over other players. Section 6 is a brief discussion of further model extensions and their policy implications. Section 7 concludes.

2 Setup

We first present a general overview of the model, before delving into the details of our setting. We use FinTech innovations as concrete examples of disruptive innovation, though the framework applies more generally to other technological innovations such as nuclear power and generative AI.

2.1 Overview

There are $N \in \mathbb{Z}_{\geq 2}$ risk-neutral firms potentially providing financial products and services in a four-period economy. Of those, $m \in \{1, \ldots, N\}$ firms are hit with an "idea" (innovation) leading to a new, applicable financial technology.[8] They are thus called FinTechs and form a set $\mathbb{M}:=\{1, \ldots, m\}$. The $N - m$ non-FinTechs compete in a well-established conventional market, each to realize a safe profit there. A FinTech can enter the conventional market or try to create a differentiated market with the innovative technology.[9] We allow the possibility that one FinTech is the lead disruptor/innovator who has a first-mover advantage over all other players.

Given its untested nature, a new technology is risky as it leads to the creation of a new market only with some probability. A FinTech influences this probability by exerting a costly effort in stage $t = 1$. A perfect and publicly observable signal ("market price") on whether the FinTech's technology can successfully mature is then generated in stage $t = 2$. If the technology matures, the FinTech becomes the monopolist for that new market and can generate positive private returns. Consistent with the notion that innovative efforts take time to pay off, these returns are only realized in the realization stage $t = 3$.

[8]We use "technology" here to refer generically to the emergence of a new product, service, or market. Our model applies to disruptive innovations beyond FinTech too.

[9]Examples of FinTechs developing new technologies and tapping into new markets include banks leaving branch competition to enter digital payment and credit (Jiang et al., 2024) as well as firms migrating from centralized exchanges (CEX) into the decentralized space (DEX) such as Binance, AppoloX, and ShapeShift.

A regulator typically does not know the new technology or fully understands right away the idea behind it.[10] The regulator pursues the interests of its stakeholders instead of the private returns of such technology. Such stakeholders may be consumers, special interest groups, or society as a whole. The key is that the regulator's and the FinTech's interests are not fully aligned, and that the regulator has only imperfect knowledge about how the new technology will affect its stakeholders at the time of policy making.

In what follows, the regulator is interested in the new technology's societal consequences, which include consumer welfare and other potential externalities. Positive externalities arise if the new technology can later be adapted in ways that are beneficial to society; examples include easing access to credit, democratization of banking services, and fraud prevention. Negative externalities arise if, for example, the new technology can be later abused for illegal activities such as money laundering and tax evasion, or turns out to have adverse implications for consumer protection or financial stability.

While a priori uncertain about its actual societal effects, the regulator can work on improving its understanding of a new technology. Specifically, in addition to the public perfect signal on the future private success of a new technology there is also a public imperfect signal about its future societal value, and the regulator can improve the precision of the latter signal by spending resources on its information content in $t = 1$, either right after the lead disruptor has made its effort choice or jointly with the other innovating FinTechs. The signal is publicly observed in stage $t = 2$. For example, a regulator (such as the SEC) can task a working group of experts with identifying the legal status of a newly developed token as a financial asset. The regulator can also elicit from stress-testing traditional banks the likely extent to which the new financial product or service may disrupt the stability of the financial system. Similarly, a regulator (such as the BIS) may hire Ph.D. graduates from data science to study the implications of generative AI on the financial industry. Spending resources on signal precision may also include finding an appropriate regulatory framework.[11]

After observing the signals, the regulator may decide to ban the financial product or service associated with the new technology in stage $t = 2$, leaving the FinTech without long-term pri-

[10] Here lies the challenge of regulating disruptive innovations: Designing and implementing policies in the face of such uncertainty is particularly relevant in an age when the technical mastery of new technologies is beyond the policymakers' skills in general.

[11] Note that reducing regulatory uncertainty does not mean advocating for any particular innovation. See, e.g., the *Financial Times* article "SEC approves first spot bitcoin ETFs in boost to crypto advocates".

	1 Implementation	2 Intervention	3 Realization
Firms:	• Innovative firms decide whether to become FinTechs through developing new technology and exert costly effort to improve success probability *while* • Non-FinTechs as incumbents in established market offer conventional products & services		Private returns realized
Signals:		• Perfect signal on future private returns (if technology implemented and effort exerted) *and* • Imperfect signal on future social value (if returns positive)	
Regulator:	Spend resources to improve precision of future signals about technology's social value	Observe signals, then • Ban technology *or* • Let FinTech proceed	Social value realized

Figure 1: Model Overview.

vate returns. Alternatively, the regulator may decide to leave the FinTech unregulated and let it reap its long-term profits. Immediately following disruptive innovations, regulators are often confined to such crude, binary interventions as fine-tuned instruments require regulatory bodies to gain further experience with how the new technology unfolds, where its weaknesses lie, and how to correct them.[12] In a way, our framework is best suited for studying regulatory preparedness, competence, and immediate regulatory reactions to innovation.

[12]Research by Ran et al. (2023) on the regulation of crowdfunding platforms shows that dozens of countries around the world choose to either completely ban on leave the activity unregulated.

We detail the various stages of the regulation–innovation game in Figure 1. In our baseline case, we do not consider any first-moving, lead disruptor. We note that our key insights that (i) regulatory capacity matters for innovation, (ii) innovators compete for regulatory capacity, and (iii) regulator's budget constraint becomes binding endogenously depending on innovators' effort are not crucially dependent whether the innovators move before the regulators.

2.2 The Established Market

In the conventional market with homogenous service quality, each of the N firms can supply the service at a constant marginal cost, which we normalize to zero. Demand in this market is deterministic and linear; i. e., $p = \eta - q$, with p as price, q as quantity demanded, and η as the size of the market (the quantity bought and sold if the market were fully competitive). The regulator's rules (if there are any) are pre-determined, their impact is deterministic and normalized to zero. The potential social value of this market is known and equals the maximum consumer rent $\eta^2/2$.

2.3 New FinTech Markets

Each new technology developed from the innovative idea (if pursued by a FinTech) has three stages: an implementation stage $t = 1$ (for the case with a lead disruptor this happens at the beginning of stage $t = 1$ before everyone else makes a choice), an intervention stage $t = 2$, and a realization stage $t = 3$ (cf. Figure 1).

Private returns and private cost. Each new technology's private returns are risky as of $t = 1$, known in $t = 2$, and realized in $t = 3$.[13] The stochastic private return $\tilde{R}_i$ of FinTech $i \in \mathbb{M}$ follows

$$\tilde{R}_i = \begin{cases} R & \text{with probability } \alpha_i \\ 0 & \text{with probability } 1 - \alpha_i \end{cases} \tag{1}$$

where $R \in \mathbb{R}_{++}$. The success probability α_i is set by the respective FinTech i. Control of the success probability comes at a private cost $c(\alpha_i)$ to this FinTech, with $c'(\alpha_i) > 0$ and $c''(\alpha_i) > 0$ for all $\alpha_i \in (0, 1)$, as well as $c(0) = 0$, $c'(0) = 0$, and $\lim_{\alpha_i \to 1} c'(\alpha_i) = \infty$.[14] Some insights are eas-

[13]That private returns accrue only at $t = 3$ is made solely for the sake of clarity. There are no qualitative changes if there were some private returns already at $t = 2$. The key is that there are private returns that can only be realized after the regulator has had a chance to intervene.

[14]Throughout the paper, for functions whose values grow without bound we allow for limits with infinite values.

ier to interpret on the basis of closed-form solutions by focusing on marginal costs given by $c'(\alpha_i) = \alpha_i/(1-\alpha_i)$, which are zero for $\alpha_i = 0$ and grow with no bounds when α_i converges to unity.[15] If more than one innovative FinTech exists ($m > 1$), their cost functions c are identical and their private returns R_i are *i. i. d.* random variables.

Social value. Innovating firms have limited liabilities and are in general not aligned with their social value. Let the new technology's gross value to society be a measurable, real-valued, stochastic variable $\tilde{V}_i$. It is known only at the realization stage $t = 3$ and conditional on the realized private return. If $\tilde{R}_i = 0$, the gross social value can take any value; as the FinTech stops operation of the new technology anyway, it does not matter for the FinTech's or the regulator's decision problem what the social value precisely is, and without loss of generality let it be $\tilde{V}_i = 0$. If $\tilde{R}_i = R$, the gross social value follows a standard normal distribution with mean $\mu_V = 0$ and standard deviation $\sigma_V = 1$. If more than one innovative FinTech exists ($m > 1$), their technologies' gross values to society $\tilde{V}_i$ are *i. i. d.* random variables and are additive.

Signals and the regulator's cost of their precision. The social value of the technology is unknown prior to $t = 3$. However, there is a publicly observable signal $\tilde{S}_i$ about this value at $t = 2$, provided the innovation has become privately successful; i. e., $\tilde{R}_i = R$. Such signal is a measurable, real-valued, stochastic variable with mean $\mu_S = 0$ and standard deviation $\sigma_S = 1$. To make the regulatory task practically relevant, we allow it to be correlated with the gross social value $\tilde{V}_i$. In technical terms, signal and gross social value follow a bivariate standard normal distribution with correlation $\rho_i \geq 0$.[16]

The regulator exerts some control over the information content of signals. Specifically, spending resources at $t = 1$ improves the precision of signals at $t = 2$. Such signal precision with regards to FinTech i is measured by the correlation ρ_i. If the signal is uncorrelated with the social value, the signal is most imprecise and thus not informative at all. If the signal is perfectly correlated with the social value, the signal precision is perfect and the signal thus fully informative. In between, the larger the correlation ρ_i between signal and social value, the better is the signal

[15] Together with $c(0) = 0$, this gives us $c(\alpha_i) = -\big(\alpha_i + \ln(1-\alpha_i)\big)$ as the specific functional form.

[16] Limiting attention to $\rho_i \geq 0$ is without loss of generality. If $\rho_i < 0$, the information content of some signal S_i when $\rho_i \geq 0$ would be the same as the information content of some signal $-S_i$ when $\rho_i < 0$.

precision.[17] The signal precision with regards to some FinTech i has no bearing for the information content of signals about any other FinTech $j \neq i$ for all $i, j \in \mathbb{M}$.

Let $G \in \mathbb{R}_{++}$ denote the total (social value of the) resources available to the regulator, and $f : [0,1] \to \mathbb{R}_+$ the function mapping the correlation of signals with the (gross) social value onto the costs of a regulator. Function f is the same for all innovative FinTechs. It satisfies $f'(\rho_i), f''(\rho_i) > 0$ for all $\rho_i \in (0,1)$, $f(0) = f'(0) = 0$, and $\lim_{\rho_i \to 1} f'(\rho_i) = \infty$. These properties reflect that generating non-informative signals does not cost anything, that informative signals are costly, that costs are increasingly higher the better is the precision of signals, and that perfect signals are prohibitively costly. We also let the costs depend on the regulator's skills and capability to improve the precision of signals. As with the FinTech's cost function c, the interpretation of results simplifies by focusing on marginal costs given by $f'(\rho_i) = \theta\rho_i/(1-\rho_i)$ with $\theta \in \mathbb{R}_{++}$ reflecting the regulator's skills; i. e., the regulator can utilize a given increase of the budget for a high θ not as effective as for a low θ.[18]

Required minimum social value. As in Callander and Li (2024), we assume that regulators require a minimum social value. This could be a safety margin; i. e., an imposed second layer of insurance of society against harm from any new, untested technology. Regulators may also require the social value to cover the cost to design and enforce a regulatory framework that will deter a FinTech from taking socially costly actions (e.g., those harming national security) after approval of its technology. Moreover, it could be very costly for the regulator privately when welfare is below the threshold due to career concerns, political promotion, etc. Accordingly, a necessary condition for any new technology to be acceptable to the regulator is that its expected social value is larger than some minimum level $v > 0$, bearing two immediate implications. First, if the regulator does not spend any resources on the precision of signals, the conditional expected social value $\mathrm{E}(\tilde{V}_i|S_i)$ always falls short of the required threshold regardless which signal S_i is observed. Second, by spending resources on the information content of signals, the conditional mean $\mathrm{E}(\tilde{V}_i|S_i)$ exceeds the required threshold for at least some signals S_i.[19]

Regulatory instruments. Even though the regulator can increase its preparedness, the immediate regulatory toolbox is limited due to the innovative nature of FinTech. The regulator can

[17]Spending resources on signal precision may also include identifying a regulatory framework that prevents socially costly outcomes for a specific FinTech innovation.

[18]Together with $f(0) = 0$, this gives us $f(\rho) = -\theta\big(\rho + \ln(1-\rho)\big)$.

[19]Our results hold equivalently if $\tilde{V}_i \sim \mathrm{N}(-v, 1)$ and regulators approve technologies provided $\mathrm{E}(\tilde{V}_i|S_i) > 0$.

either ban a technology right away or leave its application unregulated. In principle, the regulator can apply these instruments with or without regard for the signal $\tilde{S}_i$. If the regulator applies them conditional on its signal, it is said to pursue a policy of *informed intervention*. If the regulator bans the technology without regard for the signal, it is said to impose an *outright ban*. Leaving the new technology unregulated regardless of the signal (*laissez-faire*) is not an option; given the information available, it would mean condoning the technology despite an insufficient expected social value.[20]

Lead innovator. Oftentimes a lead innovator or disruptor would explore a technology before other innovators or regulators have put in the effort or resources to innovate or prepare for regulation. We model in Section 5 the possibility of an FinTech implementing a disruptive innovation at the very beginning of stage $t = 1$ before anyone else makes any decision. In the baseline, we leave out this possibility.

3 Baseline Game Between a Disruptive Innovator and the Regulator

In the baseline analysis, we shut down lead innovator and study the innovation game when $m = 1$. Without loss of generality, let this firm be FinTech 1, and for the sake of saving on notational clutter, we drop subscript i when referring to the only innovative FinTech in this section. We derive the best response functions for the regulator and for all firms, with a focus on the innovative FinTech, and properties of equilibria. Where appropriate, numerical examples further illustrate key insights and findings.

3.1 The Regulator's Decision Problem

The following preliminary considerations are helpful to understand the regulator's problem. If FinTech 1 decides in stage $t = 1$ to not develop its idea into a new technology, and instead to operate in the established market, the regulator will not want to waste resources on signals about the technology associated with FinTech 1's idea. If, however, FinTech 1 decides to develop its idea into a new technology, the regulator's problem becomes subtle. The regulator would let the

[20] In Section 6 we discuss *laissez-faire* as a viable policy option when $v < 0$.

FinTech proceed in stage $t = 2$ if and only if the new technology's conditional expected social value $\mathrm{E}(\tilde{V}|S)$ is larger than the required minimum social value $v > 0$. This is the case if and only if the technology is deemed to be privately successful and, additionally, the regulator has spent resources to improve the precision of signals ($\rho > 0$), with the observed signal being deemed sufficiently good. The latter holds provided $S > s$ where s is implicitly defined by $\mathrm{E}(\tilde{V}|S = s) = v$. Given the distributions of $\tilde{V}$ and $\tilde{S}$ (bivariate standard normal), the expected social value conditional on s is $\mathrm{E}(\tilde{V}|S = s) = \rho s$, implying that the critical signal value is $s = v/\rho$. Accordingly, if $S > v/\rho$, the signal is sufficiently good as it indicates that the technology is, on expectation, socially beneficial, and the regulator leaves the FinTech unregulated. By contrast, if $S \leq v/\rho$, the signal is not sufficiently good as it indicates that the technology is socially costly, and the regulator stops the FinTech by banning its technology.

Let φ be the probability density of the standard normal distribution and Φ the associated cumulative distribution function. Also, define the *expected net social value* of the new technology as of stage $t = 1$ as the expected social value in excess of the required minimum social value. As the properties of the bivariate standard normal distribution include $\mathrm{E}(\tilde{V}|S > s) = \rho\varphi(s)/\big(1 - \Phi(s)\big)$, this expected net social value is:

$$\alpha\big(1 - \Phi(s)\big)\big(\mathrm{E}(\tilde{V}|S > s) - v\big) = \alpha\Big(\rho\varphi(s) - \big(1 - \Phi(s)\big)v\Big). \tag{2}$$

The regulator's objective is to maximize expected welfare subject to its budget constraint, *taking as given* the probability of success α (set by FinTech 1). The budget constraint requires that expenditures on improving the signal precision $f(\rho)$ shall not exceed the regulator's budget G. The regulator can also spend part of its budget G on other socially valuable activities whose value to society equals the resources the regulator directs to them. Expected welfare thus comprises the new technology's expected net social value, the resources G available to the regulator net of what has been spent to improve the precision of signals, $f(\rho)$, and the welfare loss associated with imperfect competition in the established market.[21] Accordingly, the regulator's problem reads:

$$\max_{\rho \in [0,1[} \quad \alpha\Big(\rho\varphi(s) - \big(1-\Phi(s)\big)v\Big) + G - f(\rho) - \frac{\eta^2}{2\big(N + \mathbb{I}_{\{0\}}(\alpha)\big)^2} \tag{3}$$

$$\text{s.t.} \quad G \geq f(\rho),$$

with $\mathbf{1}_0 : [0,1] \mapsto \{0,1\}$ as an indicator function defined by:

$$\mathbf{1}_0(\alpha) := \begin{cases} 1 & \text{if } \alpha = 0, \\ 0 & \text{otherwise.} \end{cases}$$

We make the following assumption for tractability.

Assumption 1 (Stationary points) For any $\alpha > 0$, the expected welfare is a function of signal precision ρ that has at most three stationary points.

The regulator's problem (3) has the following solution.

Lemma 1 (Regulator's best response to a single innovative FinTech) *Let* $r : \mathbb{R}_{++} \times [0,1] \mapsto [0,1]$ *be the correspondence:*

$$r(\theta, \alpha) = \Big\{\rho \in]0,1[\,\Big|\, \alpha\varphi(\tfrac{v}{\rho}) - f'(\rho) = 0 \text{ and } \alpha\varphi(\tfrac{v}{\rho})\tfrac{v^2}{\rho^3} - f''(\rho) < 0\Big\}. \tag{4}$$

There are unique $(H, \bar{\theta}, \underline{G}) \in \mathbb{R}^3_{++}$ *and* $\overline{G} \geq \underline{G}$ *such that the solution* ρ^* *to the regulator's problem* (3) *satisfies* $\rho^* = \mathcal{P}(\alpha, \theta, G)$ *where* $\mathcal{P} : [0,1] \times \mathbb{R}^2_{++} \mapsto [0,1]$ *is a function defined by*

$$\mathcal{P}(\alpha, \theta, G) = \begin{cases} r(\theta, \alpha) & \text{if } (\alpha, \theta, G) \in]0,1] \times]0, \bar{\theta}] \times [\overline{G}, \infty[, \\ f^{-1}(G) & \text{if } (\alpha, \theta, G) \in]0,1] \times]0, \bar{\theta}] \times [\underline{G}, \overline{G}], \\ 0 & \text{otherwise,} \end{cases} \tag{5}$$

with $\bar{\theta} = H\alpha$; $\underline{G} = \overline{G}$ *if* $\theta = H\alpha$; $\partial\underline{G}/\partial\alpha < 0$ *and* $\partial\overline{G}/\partial\alpha > 0$ *if* $\theta < H\alpha$; $r_\theta(\theta, \alpha) < 0$ *and* $r_\alpha(\theta, \alpha) > 0$ *if* $(\theta, G) \in]0, H\alpha] \times [\overline{G}, \infty[$.

Proof. See Appendix A. ■

[21] Adding the FinTech's effort to the expected net social value is without consequence as long as the regulator considers this effort as given.

Lemma 1 specifies the conditions under which the regulator opts for informed interventions rather than for imposing an *outright ban* on the new financial technology. Recall, an outright ban means that the regulator does not generate any information on FinTech 1's idea (i. e., $\rho^* = 0$), and denies the FinTech the approval of its new technology regardless of which signal S of its social value is observed. A policy of *informed interventions* means that the regulator invests in the signal's precision at stage $t = 1$ and leaves the FinTech unregulated in stage $t = 2$ provided the observed signal S is higher than $s = v/\rho^*$. If the observed signal S is not higher than $s = v/\rho^*$, the technology is banned at stage $= 2$. A informed intervention policy is *unconstrained* if the regulator's budget constraint is not binding at ρ^*, and *constrained* otherwise. In either case, if banned then FinTech 1 will have spent in vain its efforts at stage $t = 1$ to make the technology a private success.

An outright ban is in the regulator's best interest if any of the following holds true: the regulator has only a rather small budget (i. e., G is smaller than some $\underline{G}$); the regulator's skills and capability to improve the precision of signals are rather poor (i. e., θ is larger than some $\bar{\theta}$); and, trivially, the FinTech has not developed its idea into a new technology ($\alpha = 0$). By contrast, it is in the best interest of the regulator to pursue a policy of informed interventions (i. e., $\rho^* > 0$), provided neither of those conditions holds (i.e., $G > \underline{G}$, $\theta < \bar{\theta}$, and $\alpha > 0$).

Provided it opts for informed interventions, the regulator can set its most desired signal precision $\rho^* = r(\theta, \alpha)$ (for which the respective first-order and second-order conditions for a local maximum are satisfied) only if its budget constraint is not binding; i. e., the budget G is not smaller than some critical value, $\overline{G}$. Should the regulator not have sufficient resources to improve the signal's precision as much as it would like, it can still be enough to make such constrained informed interventions a better way forward than an outright ban. In that case, the regulator uses its entire budget on the signal's precision; i. e., $\rho^* = f^{-1}(G)$). A binding budget constraint for the regulator has important repercussions for FinTech 1. Since $\Phi\big(v/f^{-1}(G)\big) > \Phi\big(v/r(\theta, \alpha)\big)$ for $f^{-1}(G) < r(\theta, \alpha)$, the probability of rejecting FinTech 1's new technology at stage $t = 2$ is larger when the budget constraint is binding than if the budget constraint is not binding.

The thresholds $\bar{\theta}$, $\underline{G}$, and $\overline{G}$ have some important properties. Those are driven by the fact that the regulator's objective function may, in general, be not concave in ρ everywhere.[22] There can thus be multiple local maxima. One local maximum always exists at $\rho = 0$, since $\rho = 0$ satisfies

[22] If it were concave everywhere, there could ever be only outright bans.

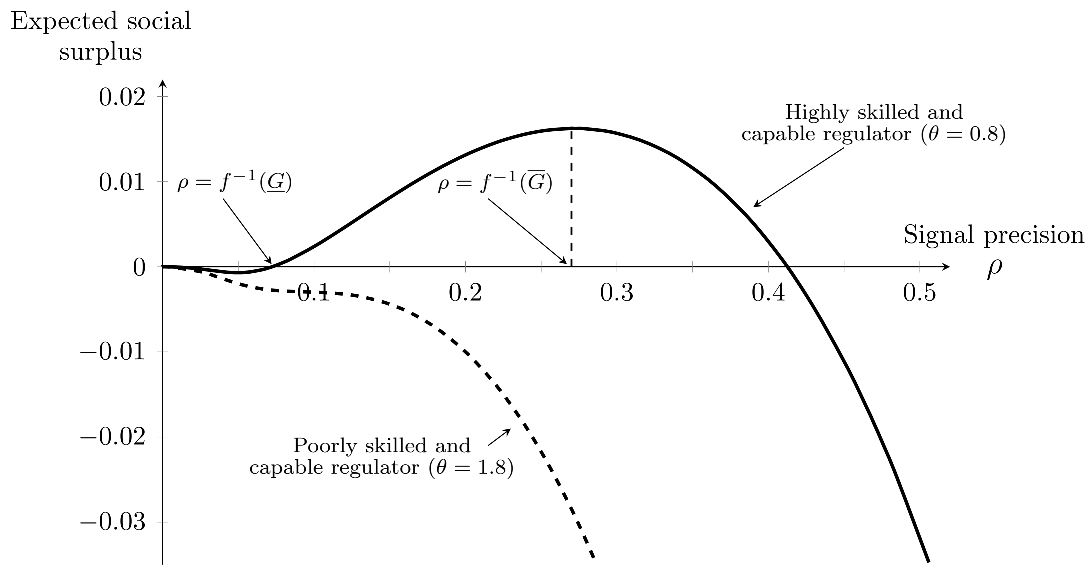


Figure 2: Signal precision and expected social surplus (for $v = 0.1$ and $\alpha = 0.8$).

the associated first-order and second-order conditions:

$$\begin{aligned} \alpha\varphi(\tfrac{v}{\rho}) - f'(\rho) &= 0, \\ \tfrac{\partial}{\partial\rho}\Big(\alpha\varphi(\tfrac{v}{\rho}) - f'(\rho)\Big) &< 0. \end{aligned} \tag{6}$$

If the objective function has at most three stationary points, however, there is at most one other local maximum and, provided it exists, is given by $r(\theta, \alpha)$. Figure 2 illustrates for two specifications the expected social surplus, defined as the difference between expected net social value and the cost of signal precision, for which the objective function has at most two local maxima. For $\theta = 0.8$, there are two local maxima and the global maximum is at $\rho \approx 0.27$; for $\theta = 1.8$, the global maximum is at $\rho = 0$. With $\theta = 1.8$, the regulator is thus so unskilled and incapable that spending resources on signal precision will cost always more than can be gained from more informative signals.

Threshold capability $\bar{\theta}$. This threshold is defined as the θ such that the expected net social value is strictly positive for some $\rho > 0$ provided $\theta < \bar{\theta}$, and negative for every $\rho > 0$ provided $\theta \geq \bar{\theta}$. Threshold $\bar{\theta}$ is directly proportional to the success probability α; i.e., there is a real number $H \in \mathbb{R}_{++}$ such that $\bar{\theta} = H\alpha$. If the success probability α increases, it becomes more likely that the social value of the new technology will be different from zero and thus less likely that the regulator will spend its resources in vain. Accordingly, improving the signal's precision is still profitable, even if their (marginal) costs would be somewhat larger.

Budget thresholds $\overline{G}$ and $\underline{G}$. As f^{-1} is the inverse of the regulator's cost function, $f^{-1}(G)$ is the maximum correlation between signal and social value affordable with a budget G.[23] Given the properties of the cost function f, its inverse f^{-1} is a monotone, increasing, and concave function of the regulator's budget G with $\lim_{G\to 0} f^{-1}(G)=0$ and $\lim_{G\to\infty} f^{-1}(G)=1$. Therefore, provided the regulator's skills and capability are such that $\theta<\bar{\theta}$, there is a threshold $\overline{G}>0$ implicitly defined by $f^{-1}(\overline{G})-r(\theta,\alpha)=0$ such that:

$$f^{-1}(G) - r(\theta,\alpha) \in \begin{cases} \mathbb{R}_{++} & \text{if} \quad G > \overline{G}, \\ \mathbb{R}_{-} & \text{if} \quad G < \overline{G}. \end{cases} \tag{7}$$

Accordingly, only if the regulator's budget is larger than threshold $\overline{G}$, the regulator has the resources to fund its most desired signal precision $r(\theta,\alpha)$; otherwise it's budget constraint is binding. By the implicit function theorem, $\partial\overline{G}/\partial\alpha>0$. Intuitively, a higher effort by FinTech 1 increases the success probability α, which in turn makes it more profitable for the regulator to improve the signal precision. As such, the regulator is induced to spend more resources on identifying the value of the new technology to society. However, for a given budget G, it also becomes more likely that this budget falls short of what the regulator needs to generate the desired signal precision $r(\theta,\alpha)$.

Provided the regulator's skills are such that $\theta<\bar{\theta}$, there is another budget threshold $\underline{G} > 0$ implicitly defined by $\alpha\Big(f^{-1}(\underline{G})\varphi\big(\frac{v}{f^{-1}(\underline{G})}\big) - \big(1-\Phi\big(\frac{v}{f^{-1}(\underline{G})}\big)\big)v\Big)-\underline{G}=0$ such that

$$\alpha\left(f^{-1}(G)\varphi\left(\frac{v}{f^{-1}(G)}\right) - \left(1-\Phi\left(\frac{v}{f^{-1}(G)}\right)\right)v\right) - G \in \begin{cases} \mathbb{R}_{++} & \text{if} \quad G > \underline{G}, \\ \mathbb{R}_{-} & \text{if} \quad G < \underline{G}. \end{cases} \tag{8}$$

Only if the regulator's budget exceeds this threshold $\underline{G}$, spending it on signal precision is better than imposing an outright ban (spending only parts of budget G is not an option as the budget constraint is binding). By the implicit function theorem, $\partial\underline{G}/\partial\alpha<0$. Accordingly, the higher the effort α by FinTech 1, the less likely it is that the regulator's budget G falls short of what is required to generate any signal precision that generates a positive net social value. Since $\underline{G}=\overline{G}$ for $\theta=\bar{\theta}$ and $\partial\underline{G}/\partial\alpha<0$ and $\partial\overline{G}/\partial\alpha>0$, one obtains $\underline{G}<\overline{G}$ for all $\alpha>\theta/H$. The following example, along with the accompanying Figure 3, illustrates the policy regimes as implied by Lemma 1.

Example: Let $v=0.1$ and $\alpha=0.8$ such that $\bar{\theta}\approx 1.449$.

[23]More specifically, $f^{-1}(G)=1+W\big(-e^{-1-\frac{G}{\theta}}\big)$ where W is the product log (or Lambert) function.

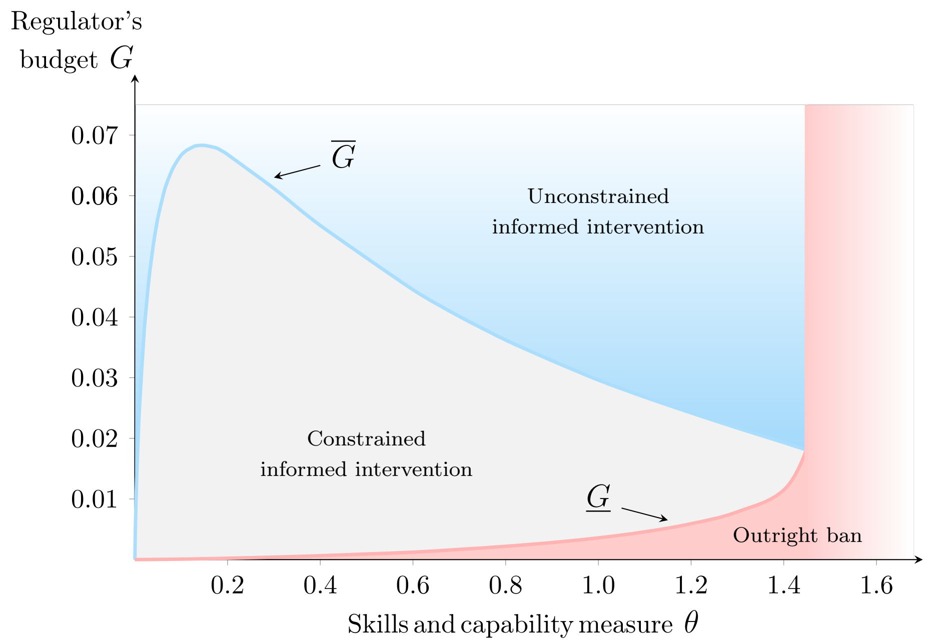


Figure 3: Regulator's characteristics and policy regimes (for $v = 0.1$ and $\alpha = 0.8$).

1. Suppose the regulator's skills and capability are poor such that $\theta > \bar{\theta}$ (i. e., right of the vertical red line in Figure 3). The regulator's best response to $\alpha = 0.8$ is to place an outright ban. Regardless of how large the budget is, generating any informative signal is simply too costly.

2. Suppose the regulator's skills and capability are sufficiently good such that $\theta \leq \bar{\theta}$. For combinations of θ and G for which

   (a) $G < \underline{G}$ (i. e., below the red line in Figure 3), the regulator's best response to $\alpha = 0.8$ is to place an outright ban. The budget is too small to allow for any feasible signal precision to be effective enough.

   (b) $\underline{G} \leq G < \overline{G}$ (i. e., between the red and the blue lines in Figure 3), the regulator's best response to $\alpha = 0.8$ is to pursue a policy of informed interventions. The regulator's budget constraint is binding, though. Hence, the regulator sets $\rho^* = f^{-1}(G)$.

   (c) $G \geq \overline{G}$ (i. e., above the blue line in Figure 3), the regulator's best response to $\alpha = 0.8$ is to pursue a policy of informed interventions. Since the regulator's budget constraint is not binding, the regulator sets $\rho^* = r(\theta, 0.8)$.

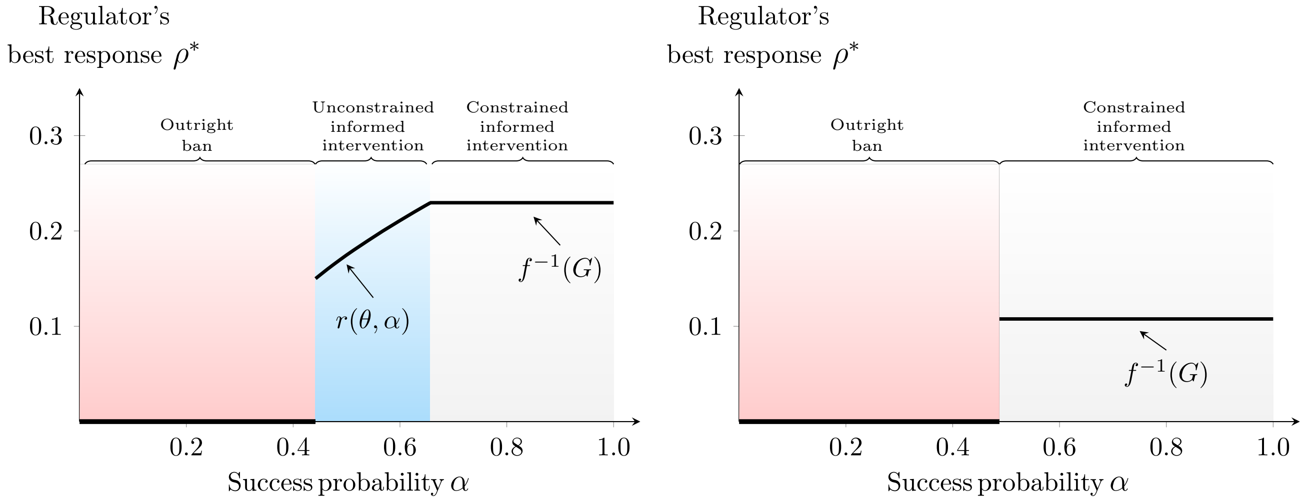
Note, the blue line ($\overline{G}$) is non-monotone in θ. If the regulator is highly skilled and capable (θ close to zero), only few resources are required to fund even a very high signal precision. If the regulator's skills and capability are rather poor (θ close to $\bar{\theta}$), the regulator does not find it optimal to generate a high precision of signals, such that only relatively few resources will be spent on it. *End of example*

The role of success probability α. The strategic interaction among players is of particular interest to us. According to Lemma 1, FinTech 1's (perceived or actual) choice of its own probability of success α affects the regulator's choice of signal precision ρ. First, regardless its budget G, the regulator sets $\rho = 0$, and hence places an outright ban on the new technology, if $\alpha < \theta/H$. This is because improving the precision of signals would be rather costly and at the same time quite likely in vain. Second, provided $\alpha \geq \theta/H$, the regulator would ideally want a precision of signals given by a correlation of $\rho = r(\theta, \alpha)$. This correlation is increasing in the success probability α. It simply becomes more profitable to spend resources on signal precision when it is less likely that those expenses will be made in vain (i. e., that the FinTech cannot turn its idea into a successful new technology and regulatory intervention becomes thus pointless). This also implies that an increasing probability of success α makes it more likely that the regulator possesses too few resources to generate the desired correlation $r(\theta, \alpha)$, in which case signal precision is restricted to what the regulator can just afford (i. e., $\partial\overline{G}/\partial\alpha > 0$). Finally, the regulator may have too low a budget to ever have sufficient resources for a correlation $r(\theta, \alpha)$, regardless of α. Nevertheless, for sufficiently high success probability α it can still be profitable to spend even such low a budget on signal precision if the probability of spending it in vain becomes very small (i. e., $\partial\underline{G}/\partial\alpha < 0$).

The following example, along with Figure 4, illustrates the role of α on the regulator's choice ρ^*.

Example: Let $v = 0.1$ and $\theta = 0.8$ such that $H \approx 1.811$. A necessary condition for the regulator to not place an outright ban is that the FinTech 1's success probability is at least $\alpha = \theta/H \approx 0.442$, for only then $\theta \leq \bar{\theta}$ obtains. The ex ante-probability of the innovation's gross social value falling short of $v = 0.1$ is $\Phi(v) \approx 0.540$.

1. Suppose the regulator's budget is $G = 0.025$ (see Figure 4a). *Outright bans* are the regulator's best response for small success probabilities, $\alpha \lessapprox 0.442$. *Unconstrained informed interventions* with $\rho^* = r(\theta, \alpha) \geq r(\theta, \theta/H) \approx 0.150$ are the



(a) Budget $G = 0.025$

(b) Budget $G = 0.005$

Figure 4: Regulator's best responses to FinTech's choice of success probability (for $v = 0.1$, $\theta = 0.8$).

best response if $\alpha \gtrapprox 0.442$ and $f\big(r(\theta, \alpha)\big) \leq G = 0.025$; the latter holds provided $\alpha \lessapprox 0.657$. *Constrained informed interventions* are optimal for even larger α, in which case $\rho^* = f^{-1}(G) \approx 0.223$. Accordingly, with informed interventions, the probability that the regulator will stop the FinTech after observing the signal is at least $\Phi\Big(v/f^{-1}(G)\Big) \approx 0.668$ and at most $\Phi\Big(v/r(\theta, \theta/H)\Big) \approx 0.748$.

2. Suppose the regulator's budget is $G = 0.005$ (Figure 4b). Such budget renders a correlation of $r(\theta, \theta/H)$ infeasible as $G < \underline{G}$ at $\alpha = \theta/H$. Hence, even if α is above $\theta/H \approx 0.442$, the regulator may still place an *outright ban* on the technology. Only if α is as large as $\alpha \approx 0.487$, the regulator pursues a policy of *constrained informed interventions* because only then spending its small budget is worthwhile (probability of spending it in vain is only then sufficiently small). The regulator's tight budget only allows for a correlation of $\rho = f^{-1}(G) \approx 0.108$, though. A lower correlation is not efficient, a higher correlation is not feasible. The probability that the regulator will stop the FinTech after observing the signal is $\Phi\Big(v/f^{-1}(G)\Big) \approx 0.823$.

End of example

3.2 Equilibria

We consider a simultaneous game in which all firms and the regulator make their own decisions by taking as given the others' decisions. Here, we focus on *Nash* equilibria in pure strategies.

The firms' decision problems. The number n of firms operating in the established ecosystem is either N (if FinTech 1 does not develop a new technology) or $N-1$ (otherwise). This oligopolistic market is characterized by a *Cournot-Nash* equilibrium with either $n = N$ or $n = N-1$ operating firms, respectively. In such equilibrium, each firm $l \in \{1, \dots, n\}$, which operates in the established market, produces $q_l = \eta/(n+1)$ and makes a profit of $\pi_l = \eta^2/(n+1)^2$. The total quantity sold is $q = \eta n/(n+1)$ such that the welfare loss due to imperfect competition in that market amounts to $0.5\eta^2/(n+1)^2$.

The conventional, established market serves one purpose here: to define the outside option for the innovator. If the innovator remains in that market, what it gets depends on how many others compete there. If the innovator leaves the market, then it does not care what the others (not innovating incumbents) get. Accordingly, FinTech 1 chooses between operating in the established market and developing its idea into the new technology. In the former case, it generates $\pi_1 = \eta^2/(N+1)^2$ in profits. In the latter, it generates $\alpha\big(1-\Phi(v/\rho)\big)R - c(\alpha)$ in expected profits, which depends on the chosen probability of success α and the signal precision ρ set by the regulator. FinTech 1 *takes as given* the regulator's choice of the signal precision, ρ. Hence the probability $\Phi(v/\rho)$ that the regulator will dismiss the technology after observing the signal at the intervention stage $t = 2$ is also given to FinTech 1. This probability is one if and only if the regulator sets $\rho = 0$. It is strictly decreasing in ρ and always positive. Therefore, FinTech 1 solves at stage $t = 1$:

$$\max_{\alpha \in [0,1]} \quad \alpha\Big(1 - \Phi\big(\tfrac{v}{\rho}\big)\Big)R - c(\alpha) + \mathbf{1}_0(\alpha)\frac{\eta^2}{(N+1)^2}. \tag{9}$$

Lemma 2 (Innovative FinTech's best response to regulator) *Let $a : \mathbb{R}_{++} \times [0,1] \mapsto [0,1]$ be a function defined by*

$$a(R,\rho) = \frac{\big(1-\Phi(v/\rho)\big)R}{\big(1-\Phi(v/\rho)\big)R + 1}, \tag{10}$$

and let $\mathcal{N} : \mathbb{R}_{++} \times]0,1[\mapsto \mathbb{Z}_{\geq 2}$ be a function defined by

$$\mathcal{N}(R,\rho) = \min\Big\{N \in \mathbb{Z}_{\geq 2} \,\Big|\, \big(1-\Phi(v/\rho)\big)R - \ln\Big(\big(1-\Phi(v/\rho)\big)R + 1\Big) \geq \eta^2/(N+1)^2\Big\}. \tag{11}$$

The solution α^* to FinTech 1's problem (9) *satisfies* $\alpha^* = \mathcal{A}(\rho, N, R)$ *where* $\mathcal{A} : [0,1] \times \mathbb{Z}_{\geq 2} \times \mathbb{R}_{++} \mapsto [0,1]$ *is a function defined by*

$$\mathcal{A}(\rho, N, R) = \begin{cases} a(R,\rho) & \textit{if } N \geq \mathcal{N}(R,\rho), \\ 0 & \textit{otherwise}, \end{cases} \tag{12}$$

with the following properties:

1. $a_R(R,\rho) > 0$, $a(0,\rho) = 0$, *and* $\lim_{R\to\infty} a(R,\rho) = 1$;
2. $a_\rho(R,\rho) > 0$, $a(R,0) = 0$, *and* $a(R,1) < 1$;
3. $\mathcal{N}(R,\rho) \leq \mathcal{N}(R,\rho')$ *for* $1 \geq \rho' > \rho > 0$ *and* $\mathcal{N}(R,\rho) \leq \mathcal{N}(R',\rho)$ *for* $R' > R > 0$.

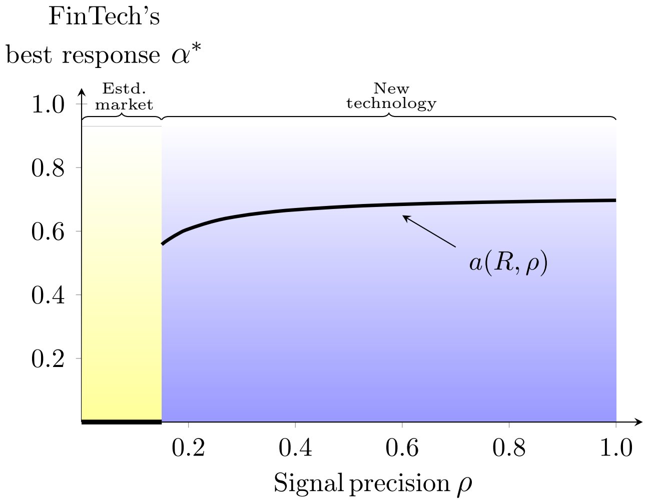
Proof. See Appendix B ■

The Lemma states that FinTech 1's optimal effort, and hence its optimal success probability α^*, responds to the signal precision ρ set by the regulator. Provided $\alpha^* > 0$, the first-order condition to FinTech 1's problem (9), which after rearranging terms yields Eq. (10), defines α^* as an implicit function of the signal precision ρ.

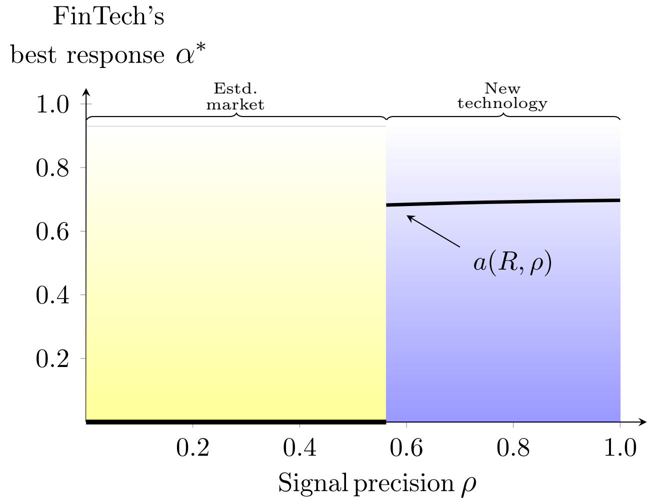
If signals are left perfectly uninformative by the regulator ($\rho = 0$), and the probability of being dismissed thus equals one (i. e., $\Phi(v/\rho) = 1$), FinTech 1's expected profit from developing its idea is zero at best. It is thus best for FinTech 1 not to waste any effort on developing its idea into a new technology, regardless how much profits it can make in the established ecosystem.

If, however, the regulator pursues a policy of informed interventions ($\rho > 0$), FinTech 1's expected profit from developing its idea is strictly positive. Yet, FinTech 1 will embark on developing its idea into a new technology only if the profits it can make in the established market are sufficiently low. The latter is true if that market is rather competitive; i. e., the number N of firms that can service this market is larger than some threshold $\mathcal{N}(R,\rho)$. For lower potential private returns R, and worse signal precision ρ, expected profits associated with the new technology are smaller. FinTech 1 will thus opt for the established market even if that market is more competitive; i. e., the threshold $\mathcal{N}(R,\rho)$ is larger, such that the number N of firms can be even larger and FinTech 1 will yet opt for the established market.

Finally, provided FinTech 1 goes ahead with the new technology and hence $\alpha^* > 0$, a higher private return, R, and a better signal precision, ρ, increase FinTech 1's expected marginal benefits



(a) Number of Firms $N = 14$



(b) Number of Firms $N = 9$

Figure 5: FinTech's best response to regulator's choice of signal precision (for $v = 0.1$, $R = 5$, $\eta = 10$).

from developing the new technology. This induces FinTech 1 to put in more effort; i. e., the chosen success probability α^* increases.

The following example illustrates the role of ρ for FinTech 1's choice of α^* (see Figure 5).

Example: Let $v = 0.1$, $R = 5$, and $\eta = 10$.

1. Suppose the number of firms is $N = 14$ (see Figure 5a). Provided ρ is such that $14 \geq \mathcal{N}(R, \rho)$ (i. e., if $\rho \gtrapprox 0.15$), FinTech 1 will go ahead with the development of the new technology with a success probability of at least $\alpha^* \approx 0.558$; this probability is increasing in ρ and reaches its maximum for $\rho = 1$ at $\alpha^* \approx 0.697$.
2. Suppose the number of firms is $N = 9$ (Figure 5b). Provided ρ is such that $9 \geq \mathcal{N}(R, \rho)$ (i. e., if $\rho \gtrapprox 0.562$), FinTech 1 will go ahead with the development of the new technology with a success probability of at least $\alpha^* \approx 0.682$; this probability is increasing in ρ and reaches its maximum for $\rho = 1$ at $\alpha^* \approx 0.697$.

End of example

***Nash* equilibria in pure strategies.** We focus on equilibria that entail the least possible uncertainty about equilibrium strategies, and hence minimizes in a way the scope for regulatory uncertainty.[24] Let α^{e} and ρ^{e} denote equilibrium choices by FinTech 1 and the regulator, respectively, thus satisfying:

$$\begin{aligned} \alpha^{\mathrm{e}} &= \mathcal{A}(\rho^{\mathrm{e}}, N, R), \\ \rho^{\mathrm{e}} &= \mathcal{P}(\alpha^{\mathrm{e}}, \theta, G), \end{aligned} \tag{13}$$

and let $n^{\mathrm{e}}{:=}N{-}1{+}\mathbf{1}_0(\alpha^{\mathrm{e}})$ denote the equilibrium number of firms operating in the established market.

Proposition 1 (Equilibrium for single, non-disruptor FinTech)

1. Outright ban: *For all* $(\theta, G, N) \in \mathbb{R}^2_{++} \times \mathbb{Z}_{\geq 2}$, *a* Nash *equilibrium in pure strategies with* $(\alpha^{\mathrm{e}}, \rho^{\mathrm{e}}, n^{\mathrm{e}}) = (0, 0, N)$ *always exists.*

2. Informed interventions: *For every* $G \in \mathbb{R}_{++}$ *there is* $\hat{\theta} \in]0, a(R,1)H[$ *with* $\partial\hat{\theta}/\partial G \geq 0$, *such that a* Nash *equilibrium in pure strategies with* $\alpha^{\mathrm{e}}\rho^{\mathrm{e}} > 0$, *and* $n^{\mathrm{e}} = N - 1$ *exists* provided $\theta \in]0, \hat{\theta}]$ and $N \geq \mathcal{N}(R, \rho^{\mathrm{e}})$. *There can be multiple such* Nash *equilibria in pure strategies, which may not be Pareto-ranked.*

3. Properties: *Let* $\alpha^{\mathrm{e}}_{\max}$ *and* $\rho^{\mathrm{e}}_{\max}$ *be defined by*

$$\alpha^{\mathrm{e}}_{\max} := \max \left\{ \alpha \in [0,1] \,\middle|\, \alpha = \mathcal{A}(\rho, N, R) \text{ and } \rho = \mathcal{P}(\alpha, \theta, G) \right\}$$

$$\rho^{\mathrm{e}}_{\max} := \max \left\{ \rho \in [0,1] \,\middle|\, \alpha = \mathcal{A}(\rho, N, R) \text{ and } \rho = \mathcal{P}(\alpha, \theta, G) \right\}$$

Provided $\alpha^{\mathrm{e}}_{\max} > 0$ *and* $\rho^{\mathrm{e}}_{\max} > 0$, *such equilibrium has the following properties*

- $\partial\alpha^{\mathrm{e}}_{\max}/\partial\theta < 0$ *and* $\partial\rho^{\mathrm{e}}_{\max}/\partial\theta < 0$;
- $\partial\alpha^{\mathrm{e}}_{\max}/\partial G \geq 0$ *and* $\partial\rho^{\mathrm{e}}_{\max}/\partial G \geq 0$;
- $\partial\alpha^{\mathrm{e}}_{\max}/\partial R > 0$ *and* $\partial\rho^{\mathrm{e}}_{\max}/\partial R \geq 0$;
- $\mathcal{N}(R, \rho^{\mathrm{e}}_{\max})$ *is (weakly) smaller for smaller* θ *and larger* G.

Proof. See Appendix C ■

Proposition 1 states that an outright ban always constitutes a *Nash* equilibrium. However, *Nash* equilibria with informed interventions co-exist provided the regulator's skills and capability are sufficiently good and the established market is sufficiently competitive.

[24] With mixed strategies, players randomize their equilibrium actions, creating more strategic uncertainty.

The proposition bears clear implications for regulation. The threshold value $\hat{\theta}$ for the regulator's skills and capability, below which equilibria with informed interventions can exist, is independent from the degree of competition in the established market, but may depend on the budget of the regulator: If the budget constraint is binding in equilibrium, the regulator has to be rather skilled and capable in generating informative signals about the new technology. Otherwise, the feasible signal precision either implies that the probability of regulatory approval is so small that it is better for the FinTech 1 to operate in the established market, or that the regulator is better off by not spending any resources at all and placing an outright ban instead. Note that a tighter budget permits equilibria with informed interventions only if the regulator's skills and capability are better.

The threshold $\mathcal{N}(R, \rho^{\mathrm{e}})$ for the competition in the established market depends, in principle, on the regulator's skills and capability to generate informative signals and on its budget. Specifically, the threshold is (weakly) larger for a less skilled and capable regulator or a regulator with only a modest budget. The reason is that FinTech 1 will in either case expect lower profits from developing its idea into a new technology because the probability that the regulator will stop FinTech 1 after observing the signal is rather high. For FinTech 1 to develop the idea despite lower expected profits, the competition in the established market needs to be stronger (hence the profits FinTech 1 can make there be lower).

With a better skilled and capable regulator, FinTech 1 also has better incentives to care about the success of the new technology (as the regulator will seek to generate more informative signals), thereby increasing expected private returns on the new technology. In the same vein, giving the regulator a larger budget not only permits equilibria with informed interventions when they were infeasible for lower budgets. If the budget constraint is binding, a larger budget may also facilitate an equilibrium in which the regulator sets a better signal precision and thus FinTech 1 a higher success probability, thereby making both, FinTech 1 and the regulator, better off. To be clear, the regulator's skills and budget matter for different reasons. Only its skills determine the regulator's first-order (marginal) condition, whereas skills and budget together determine whether a regulator's resource constraint is binding. Hence, if the regulator's budget constraint is binding in equilibrium, better skills can fully make up for a lower budget (and vice versa). If the constraint is not binding, however, a lower budget does not matter but better skills still do.

An example illustrates the possibility of multiple equilibria with informed interventions.

Example: Let $R = 0.0198$, $v = 0.01$, $\theta = 0.106$, $G = 0.1$, $\eta = 0.1$, and $N = 30$. Then, three equilibria exist

1. $\rho^* = 0$ and $\alpha^* = 0$
2. $\rho^* \approx 0.0163$ and $\alpha^* \approx 0.0053$
3. $\rho^* \approx 0.0185$ and $\alpha^* \approx 0.0058$

With this specification, comparing the values for the respective objective functions, the regulator strictly prefers the third equilibrium over the first equilibrium, and the first equilibrium over the second equilibrium. In contrast, FinTech 1 strictly prefers the third equilibrium over the second, and the second equilibrium over the first equilibrium. Therefore, equilibria cannot be Pareto-ranked here. *End of example*

We conclude by highlighting that regulatory uncertainty not only comes in the form of the risk that a privately successful FinTech may have to close operations after making their investment and before their full returns are realized. Regulatory uncertainty also manifests itself in form of multiple equilibria. Multiplicity of equilibria arises as FinTech 1's effort (which determines the success probability α) and the regulator's effort (which determines signal precision ρ) are strategic complements, provided the regulator's skills and capability to generate informative signals are sufficiently good and its budget sufficiently large.

4 Multiple Innovative FinTechs

In this section, we let multiple FinTechs have an idea to develop a new technology. To highlight key additional effects that come into play only with multiple innovative FinTechs, we can focus on the case with two innovative FinTechs; i. e. $\mathbb{M} = \{1, 2\}$. We do this for traceability since we can show that the additional implications we obtain from this case extend to the more general case where more than two FinTechs are capable to innovate. The key difference to the single FinTech case refers to the regulator's best response, which is what our focus will be on. Note, when referring to a specific innovative FinTech, we reintroduce subscripts in the remainder of this section. Accordingly, α_1 and α_2 are the success probabilities set by FinTech 1 and FinTech 2, respectively, and ρ_1 and ρ_2 the associated signal precision chosen by the regulator.

4.1 The Regulator's Decision Problem

For each of the innovative FinTechs, the regulator has to decide how precise a signal it wants to generate about their respective social value. Given the innovative FinTechs' choices of success probabilities $\{\alpha_i\}_{i\in\{1,2\}}$, the regulator aims to maximize expected welfare subject to its budget constraint. The latter requires that the total expenses on signal precision across all innovative FinTechs do not exceed the budget G. The regulator's problem is thus to find the pair (ρ_1, ρ_2) of correlation coefficients solving

$$\max_{(\rho_1,\rho_2)\in[0,1]^2} \quad \sum_{i=1}^{2}\left[\alpha_i\Big(\rho_i\varphi\big(\tfrac{v}{\rho_i}\big) - \Big(1-\Phi\big(\tfrac{v}{\rho_i}\big)\Big)v\Big) - f(\rho_i)\right] + G - \frac{\eta^2}{2\Big(N-1+\sum_{i=1}^{2}\mathbf{1}_0(\alpha_i)\Big)^2} \tag{3'}$$

$$\text{s.t.}$$

$$G \geq \sum_{i=1}^{2} f(\rho_i).$$

As regards its solution (ρ_1^*, ρ_2^*), the following insights are particularly interesting.

Lemma 3 (Regulator's best response to multiple innovative FinTechs)
Let $\alpha\in]0,1[$ and $\theta\in\mathbb{R}_{++}$ be such that $\alpha>\theta/H$, and let $\Gamma:[0,1]^2\mapsto\mathbb{R}_+$ be a function defined by $\Gamma(\rho_1,\rho_2) = f(\rho_1)+f(\rho_2)$. Then, $\Gamma(\rho_1,\rho_2)=G$ defines ρ_2 as implicit function $\gamma:[0,1]\times\mathbb{R}_+\mapsto[0,1]$ of ρ_1 and G, i. e. $\rho_2=\gamma(\rho_1,G)$, with fixed point $\bar{\rho}=\gamma(\bar{\rho},G)$.

Assume that for $\rho_2=\gamma(\rho_1,G)$, the expected net social value $\sum_{i=1}^{2}\Big[\alpha_i\Big(\rho_i\varphi\big(v/\rho_i\big)-\Big(1-\Phi\big(v/\rho_i\big)\Big)v\Big)\Big]$ has at most three *stationary points on the closed interval $\rho_1\in[0,\bar{\rho}]$.*

The solution (ρ_1^*,ρ_2^*) to the regulator's problem (3') satisfies $\rho_i^*=\mathcal{P}(\alpha_i,\alpha_j,\theta,G)$ for $i,j\in\mathbb{M}$ with $i\neq j$ where $\mathcal{P}:[0,1]^2\times\mathbb{R}^2_{++}\mapsto[0,1]$ is a function with the following select key properties:

1. *If $\alpha_1=\alpha_2=\alpha>0$, there are $G_{\text{crit},1}\in]2\underline{G},2\overline{G}[$ and $G_{\text{crit},2}\in]2\underline{G},G_{\text{crit},1}]$ such that*
   - *$\mathcal{P}(\alpha_i,\alpha_j,\theta,G)=r(\theta,\alpha)$ for $i,j\in\mathbb{M}$ with $i\neq j$ provided $G\geq 2\overline{G}$;*
   - *$\mathcal{P}(\alpha_i,\alpha_j,\theta,G)=f^{-1}(G/2)$ for $i,j\in\mathbb{M}$ with $i\neq j$ provided $G\in[G_{\text{crit},1},2\overline{G}]$;*
   - *$\mathcal{P}(\alpha_i,\alpha_j,\theta,G)=\min\{f^{-1}(G),r(\theta,\alpha)\}$ and $\mathcal{P}(\alpha_j,\alpha_i,\theta,G)=0$ for $i,j\in\mathbb{M}$ with $i\neq j$ provided $G\in[\underline{G},G_{\text{crit},2}[$;*
   - *$\mathcal{P}(\alpha_i,\alpha_j,\theta,G)=0$ for $i,j\in\mathbb{M}$ with $i\neq j$ provided $G<\underline{G}$.*

2. If $\alpha_1\alpha_2 = 0$, Lemma 1 applies accordingly, i. e. $\mathcal{P}(\alpha_i, \alpha_j, \theta, G) = \mathcal{P}(\alpha_i, \theta, G)$ for $i, j \in \mathbb{M}$ with $i \neq j$.

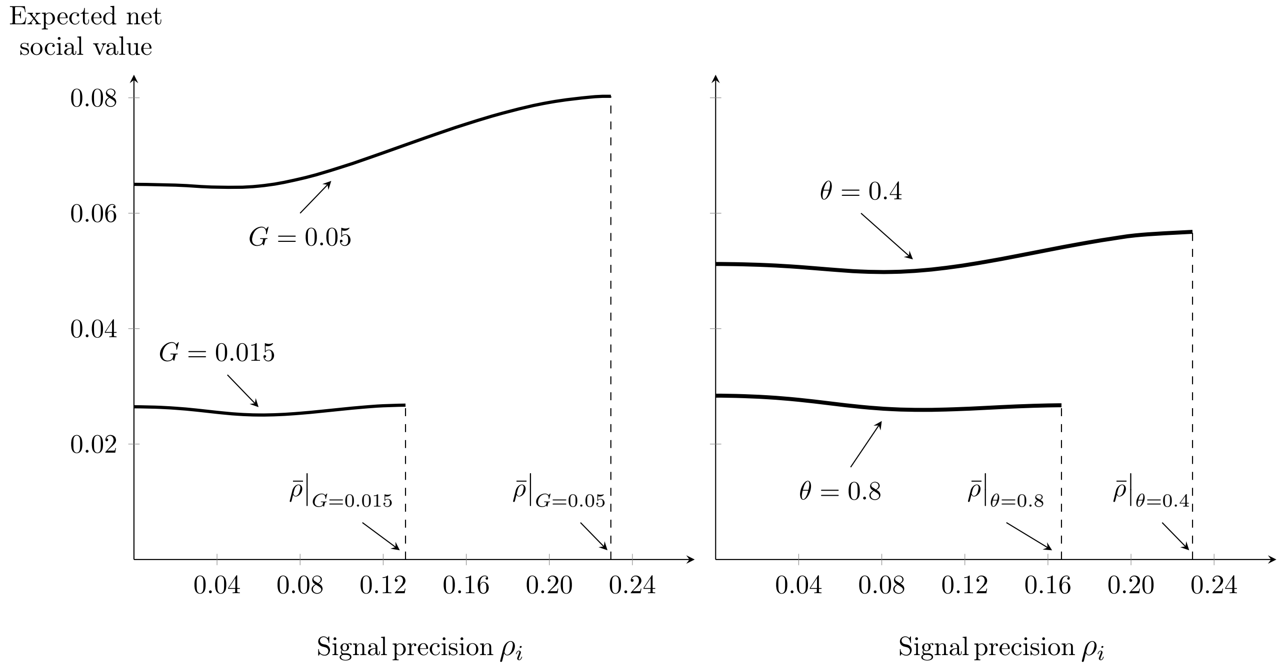
Proof. See Appendix D. ■

Lemma 3 is about a regulator facing two FinTechs that, provided they both develop their idea, will do so in the same way with the same success probability α. Additionally, if it was not for a lack of resources, the regulator is sufficiently skilled and capable to pursue a policy of informed interventions for both FinTechs given their success probability α.

When $\rho_2 = \gamma(\rho_1, G)$, the sum $\sum_{i=1}^{2}\left[\alpha_i\big(\rho_i\varphi(v/\rho_i) - \big(1 - \Phi(v/\rho_i)\big)v\big)\right]$ states the expected net social value provided the regulator's budget is fully spent on generating informative signals. This expected net social value is thus a function of ρ_1, for which we assume there are at most three stationary points on the closed interval $[0, \bar{\rho}]$. As shown in Appendix D, one stationary point is at $(\rho_1, \rho_2) = (0, \gamma(0, G))$, which always constitutes a local maximum. A marginal shift of resources towards signal precision about FinTech 1 does simply not generate sufficiently informative signals there that would justify spending those resources, whilst signals about FinTech 2 become less informative. Another stationary point is always at $(\rho_1, \rho_2) = (\bar{\rho}, \bar{\rho})$, which is either a local minimum or a local maximum. If by spending identical amounts on both innovative FinTechs, the budget G allows for signal precisions sufficiently close to the optimal signal precision $r(\theta, \alpha)$, doing so constitutes a local maximum. This is because for those high levels of expenses on each FinTech, balancing marginal costs across FinTechs is more important at the margin than exploiting any scale economies in generating a higher signal precision for one of them at the expense of the other.

If at most one further, third stationary point exist, it is necessarily a local minimum. This is because the two other stationary points are at the respective end of the domain for the function γ.[25] As argued above, $(\rho_1, \rho_2) = (0, \gamma(0, G))$ is a local maximum. If $(\rho_1, \rho_2) = (\bar{\rho}, \bar{\rho})$ is another local maximum, it implies that there has to be a third stationary point satisfying $\rho_1 > 0$ and $\rho_2 = \gamma(\rho_1, G) < \bar{\rho}$ and that this one is a local minimum. If $(\rho_1, \rho_2) = (\bar{\rho}, \bar{\rho})$ is a local minimum, however, there can not exist a third stationary point satisfying $\rho > 1$ and $\rho_2 = \gamma(\rho_1, G) < \bar{\rho}$ if their total number is limited to a maximum of three. A range of parametrizations meet the condition stated in Lemma 3 (see Figure 6).

[25] By symmetry, swapping labels of FinTechs 1 and 2 obtains the exactly inverse results for $\rho_1 \in [\bar{\rho}, \gamma(0, G)]$.



(a) $\alpha = 0.8$, $\theta = 0.8$, and $v = 0.1$

(b) $\alpha = 0.8$, $G = 0.025$, $v = 0.15$

Figure 6: Expected net social value with two innovative FinTechs and binding budget constraint.

Against this background, the first part in Lemma 3 states that the regulator's best response to FinTechs that are identical from the regulator's perspective (same fundamentals and same success probabilities) depends on its budget G. If the budget is large enough to facilitate a policy of unconstrained informed interventions for both FinTechs, the regulator will pursue such policy. For a somewhat smaller budget, the regulator will pursue a policy of constrained informed interventions. The regulator will treat all FinTechs equally provided its budget is not too small ($G \geq G_{\text{crit},1}$) as it then facilitates still a good deal of signal precision for each FinTech, even with an equal split of resources.

If the budget is rather small ($G < G_{\text{crit},2}$), however, the regulator better withdraws all resources from one FinTech, and imposes an outright ban on this one, while concentrating all resources on gathering information about the other FinTech. In other words, two fundamentally identical FinTechs get an *unequal treatment* from the regulator. Moreover, precisely because both FinTechs are identical, the regulator is indifferent as to which FinTech will be banned and which FinTech will benefit from informed interventions. A new manifestation of regulatory uncertainty may thus arise: an unequal treatment of fundamentally identical FinTechs that appears arbitrary. Equally interestingly, banning one FinTech and gathering information about the other one can be the opti-

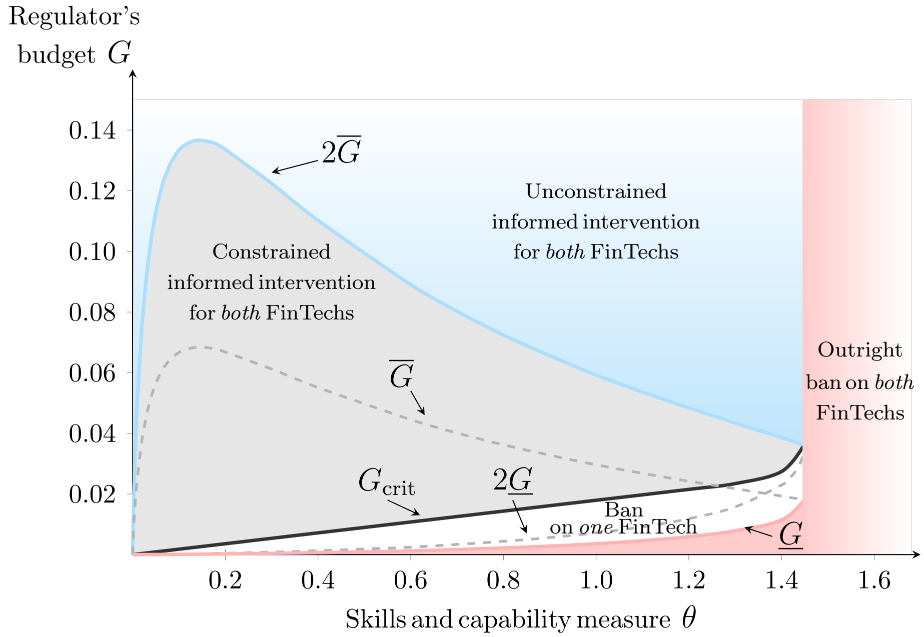


Figure 7: Regulator's characteristics and policy regimes with two innovative FinTechs (for $v = 0.1$ and $\alpha_1 = \alpha_2 = 0.8$).

mal response even if it implies that the regulator's budget is then not fully spent on that one FinTech. It thus looks as if the regulator's budget constraint is not binding and yet one FinTech faces an outright ban – even though it cannot be distinguished by any objective measure from its peer.

For the sake of completeness, two more results are stated in Lemma 3. First, if resources do not even suffice to effectively gather information about only one FinTech, then both FinTechs will be banned outright. Second, if one FinTech, although having an idea, does not develop this idea into a new technology (tantamount to setting its success probability to zero), the regulator's response simply resembles that of only one innovative FinTech.

Example: Recall the example on page 19, but suppose there are two innovative FinTechs, each with $v = 0.1$ and $\alpha = 0.8$ (such that $\bar{\theta} \approx 1.449$).

1. Suppose the regulator's skills and capability are poor such that $\theta > \bar{\theta}$ (i. e., right of the vertical red line in Figure 7). The regulator's best response to $\alpha = 0.8$ is to place an outright ban on both FinTechs. Regardless of how large the budget is, generating an informative signal for any innovative FinTech is simply not worth it.
2. Suppose the regulator's skills and capability are good such that $\theta \leq \bar{\theta}$. For combinations of θ and G for which

(a) $G \geq 2\overline{G}$ (i. e., above the blue line in Figure 7), the regulator's budget constraint is not binding and its best response to $\alpha = 0.8$ is to pursue a policy of informed interventions for both FinTechs; $\rho_1^* = \rho_2^* = r(\theta, 0.8)$.

(b) $G_{\text{crit}} \leq G < 2\overline{G}$ (i. e., between the solid black line and the blue line in Figure 7), the regulator's budget constraint is binding and its best response to $\alpha = 0.8$ is to pursue a policy of informed interventions for both FinTechs and treat them equally; $\rho_1^* = \rho_2^* = f^{-1}(G/2)$.

(c) $\underline{G} \leq G < G_{\text{crit}}$ (i. e., between the red line and the black line in Figure 7), the regulator's budget constraint is binding and its best response to $\alpha = 0.8$ is to pursue a policy of informed interventions for one FinTech and to impose a ban on the other FinTech; i. e., either $\left(\rho_1^*, \rho_2^*\right) = \left(f^{-1}(G), 0\right)$ or $\left(\rho_1^*, \rho_2^*\right) = \left(0, f^{-1}(G)\right)$.

(d) $G < \underline{G}$ (i. e., below the red line in Figure 7), the regulator's budget is too small to allow for any feasible signal precision to be effective enough, even if the budget is concentrated on only one innovative FinTech, and its best response to $\alpha = 0.8$ is to place an outright ban on both innovative FinTechs.

Note, in this example the frontier between the symmetric and the asymmetric treatment of FinTechs is clear-cut (i. e. $G_{\text{crit},1} = G_{\text{crit},2} = G_{\text{crit}}$). The black line marks this frontier. As long as θ is sufficiently low and far away from $\bar{\theta}$, the critical budget G_{crit} is below the budget $\overline{G}$ that is necessary for an unconstrained informed intervention of a single innovative FinTech. For those parametrizations, G_{crit} is linear in θ as the regulator's choices depend only on the ratio G/θ if the budget constraint is binding. However, if θ is below but sufficiently close to $\bar{\theta}$, the critical budget G_{crit} is above the budget $\overline{G}$ that is necessary for an unconstrained informed intervention of a single innovative FinTech (as $G_{\text{crit}} > 2\underline{G}$ and $\partial G_{\text{crit}}/\partial\theta > 0$ whereas $\lim_{\theta\to\bar{\theta}} \overline{G} = \underline{G}$ and, for large θ, $\partial\overline{G}/\partial\theta < 0$). This means that while one FinTech gets an outright ban, the other FinTech benefits from unconstrained informed interventions. Accordingly, the regulator's choice is such that its budget constraint is slack under those circumstances. *End of example*

4.2 Equilibria

All firms and the regulator make their decisions simultaneously. The decision problem for FinTech $i \in \mathbb{M}$ at stage $t = 1$ is

$$\max_{\alpha_i \in [0,1]} \quad \alpha_i \Big(1 - \Phi\big(\tfrac{v}{\rho_i}\big)\Big) R - c(\alpha_i) + \mathbf{1}_0(\alpha_i) \frac{\eta^2}{(N + \mathbf{1}_0(\alpha_j))^2}. \tag{9'}$$

The solution to problem (9') defines the best response of FinTech i to the respective other FinTech's j choice of α_j and to the regulator's choice of ρ_i. The former matters to the extent that $\mathbf{1}_0(\alpha_j)$ determines the value to FinTech i of operating in the established market. In accordance with Lemma 2, FinTech i's best response is as follows.

Lemma 4 (FinTech i's best response to regulator and FinTech j) *The solution α_i^* to FinTech i's problem (9') satisfies $\alpha_i^* = \mathcal{A}(\alpha_j, \rho_i, N, R)$ where $\mathcal{A} : [0,1]^2 \times \mathbb{Z}_{\geq 2} \times \mathbb{R}_{++} \mapsto [0,1]$ is now a function defined by*

$$\mathcal{A}(\alpha_j, \rho_i, N, R) = \begin{cases} a(R, \rho_i) & \text{if } N \geq \mathcal{N}(R, \rho_i) + \big(1 - \mathbf{1}_0(\alpha_j)\big), \\ 0 & \text{otherwise}, \end{cases} \tag{14}$$

with functions a and $\mathcal{N}$ defined as in Lemma 2.

Proof. Follows the proof of Lemma 2. ■

Note that functions a and $\mathcal{N}$ still have the same properties as already described in Lemma 2. Let $(\alpha_1^{\mathrm{e}}, \alpha_2^{\mathrm{e}}, \rho_1^{\mathrm{e}}, \rho_2^{\mathrm{e}})$ denote equilibrium outcomes when $m = 2$, for which we present a select interesting insights.

Proposition 2 (Equilibrium for multiple innovative FinTechs)

1. Symmetric outright ban: *For all $(\theta, G, N) \in \mathbb{R}_{++}^2 \times \mathbb{Z}_{\geq 2}$, a* Nash *equilibrium in pure strategies with $(\alpha_1^{\mathrm{e}}, \alpha_2^{\mathrm{e}}, \rho_1^{\mathrm{e}}, \rho_2^{\mathrm{e}}) = (0,0,0,0)$ and thus $n^{\mathrm{e}} = N$ always exists.*

2. Asymmetric informed intervention: *For every $G \in \mathbb{R}_{++}$ there is $\hat{\theta} \in]0, a(R,1)H[$ with $\partial\hat{\theta}/\partial G \geq 0$, such that a* Nash *equilibrium in pure strategies with $(\alpha_i^{\mathrm{e}}, \rho_i^{\mathrm{e}}) \in]0,1[\times]0,1[$, $(\alpha_j^{\mathrm{e}}, \rho_j^{\mathrm{e}}) = (0,0)$, and $n^{\mathrm{e}} = N - 1$ exists* provided $\theta \in]0, \hat{\theta}]$ and $N \geq \mathcal{N}(R, \rho_i^{\mathrm{e}})$.

3. Symmetric informed intervention: *Let* $\widehat{G} := G/2$. *For every* $\widehat{G} \in \mathbb{R}_{++}$ *there is* $\widehat{\Theta} \in]0, \hat{\theta}[$ *such that a* Nash *equilibrium in pure strategies with* $(\alpha_i^{\mathrm{e}}, \rho_i^{\mathrm{e}}) \in]0,1[\times]0,1[$, $(\alpha_i^{\mathrm{e}}, \rho_i^{\mathrm{e}}) = (\alpha_j^{\mathrm{e}}, \rho_j^{\mathrm{e}})$, *and* $n^{\mathrm{e}} = N-2$ *exists* provided $\theta \in]0, \widehat{\Theta}]$ and $N \geq \mathcal{N}(R, \rho_i^{\mathrm{e}}) + 1$.

Proof. See Appendix E. ∎

The first two parts of the proposition reinforce already established insights from the case with a single non-disruptor FinTech (Proposition 1). First, there is always an equilibrium without any FinTech innovation (part 1). Second, an equilibrium with innovations by (at least) one FinTech exists under the identical conditions as it does exist if there is only a single non-disruptor FinTech. Combining these two insights, there is also an additional insight that cannot be obtained from the single non-disruptor FinTech case. To wit, under the conditions stated in part 2, regulatory uncertainty manifests itself along a second dimension of multiplicity of equilibria. Not only is there co-existence of equilibria without any FinTech innovation and of equilibria with FinTech innovation, there is also co-existence of equilibria that differ only with respect to the identity of the innovative FinTech that actually innovates and develops its idea into a new technology.

The most interesting implications, however, derive from the Proposition's part 3. According to this part, a regulator overseeing two FinTechs with a budget twice as large does not just replicates the insights from the single non-disruptor FinTech case. This is due to two effects. First, by Lemma 4, the regulator's best response is not always a symmetric treatment of fundamentally identical FinTechs that also behave identically. Second, the established market has different values to an innovative FinTech depending on whether or not its peer goes ahead with the development of their own idea.

Accordingly, if the budget of the regulator is at least twice as large as required to permit an equilibrium with unconstrained informed interventions in the single non-disruptor FinTech case, an equilibrium with unconstrained informed interventions exists for $m = 2$ innovative FinTechs provided the established market becomes not too profitable to operate in after one of the innovative FinTechs develops its idea into a new technology.

If the budget is less than twice as large, unconstrained informed interventions with $m = 2$ innovative FinTechs do not obtain in equilibrium. Provided the budget is not too small, however, both innovative FinTechs behaving identically and receiving the same attention by the regulator can again constitute an equilibrium provided the established market is sufficiently competitive even with both innovative FinTechs opting against operating there.

If the budget is too small, however, one of the following two things is going to happen. First, the regulator's constraint may imply that by splitting its resources equally across innovative FinTechs leaves them with a too low probability of regulatory approval such that expected profits are lower than by operating in the established market, even though that market would be sufficiently competitive if the regulator's budget and hence its chosen signal precision were larger. In that case, it is best for one FinTech to not develop their idea but to operate in the established market. The regulator thus generates signals of higher precision for the remaining, other FinTech, which accordingly develops its idea with a higher probability of regulatory approval (compared to a situation in which the regulator would have a somewhat larger budget). Second, the regulator's constraint may imply that it is in the best interest of the regulator to focus on one innovative FinTech (see Lemma 4). Accordingly, in anticipation of such response, one of the $m = 2$ innovative FinTechs will not even start developing their idea into a new technology and rather stay in the established market because making profits there is better than being dismissed by the regulator with certainty.

5 Lead Innovator with First Mover Advantage

5.1 Without Follower Innovator

If there is only the disruptor, the regulation game is one of a single FinTech, FinTech 1, that has a *first-mover advantage* over the regulator. The regulator's decision problem is again given by problem (3). Its solution yields the regulator's response function which FinTech 1 takes into account when solving its own problem at stage $t = 1$ given by

$$\max_{\alpha\in[0,1]} \quad \alpha\Big(1-\Phi\big(\tfrac{v}{\rho}\big)\Big)R - c(\alpha) + \mathbf{1}_0(\alpha)\frac{\eta^2}{(N+1)^2} \tag{15}$$

$$\text{s. t.}$$

$$\rho = \mathcal{P}(\alpha,\theta,G)$$

Let α^{d} denote the disruptor's choice of its success probability and $\rho^{\mathrm{d}} = \mathcal{P}(\alpha^{\mathrm{d}},\theta,G)$ the so determined outcome of the regulator's decision.

Proposition 3 (Equilibrium for single, disruptor FinTech)

1. *Equilibrium choices satisfy* $\alpha^{\mathrm{d}} \geq \alpha^{\mathrm{e}}_{\max}$*, and hence* $\rho^{\mathrm{d}} \geq \rho^{\mathrm{e}}_{\max}$*, with strict inequalities if and only if* $f^{-1}(G) > \rho^{\mathrm{e}}_{\max}$*.*

2. *For every* $G \in \mathbb{R}_{++}$ *there is* $\check{\theta} \in [\hat{\theta}, a(R,1)H[$ *such that* $\alpha^{\mathrm{d}} > 0$*, and thus* $\rho^{\mathrm{d}} > 0$*, for all* $\theta \in]0, \check{\theta}]$ *provided* $N \geq \mathcal{N}(R, \rho^{\mathrm{d}})$*.*

3. *Equilibria with informed interventions and equilibria with outright bans do not co-exist.*

Proof. See Appendix F ■

The solution to program (15) is somewhat subtle, and so are the insights stated in Proposition 3.[26] Suppose first that in a game with a single, non-disruptor FinTech, there is an equilibrium satisfying $\alpha^{\mathrm{e}}_{\max} > 0$ and $\rho^{\mathrm{e}}_{\max} > 0$ (i. e., informed interventions can occur in equilibrium). The least the disruptor can do in its game with the regulator is to pick its most preferred equilibrium from the set of equilibria that would obtain in a game with a single, non-disruptor FinTech, which by the Envelope theorem is $(\alpha^{\mathrm{e}}_{\max}, \rho^{\mathrm{e}}_{\max})$. If $\rho^{\mathrm{e}}_{\max} = f^{-1}(G)$, then $f^{-1}(G)$ is the highest possible signal precision not only in those games, but also in a sequential game. Therefore, $\mathcal{P}_\alpha(\alpha^{\mathrm{e}}_{\max}, \theta, G) = 0$, and the best a disruptor can do is to set $\alpha^{\mathrm{d}} = \alpha^{\mathrm{e}}_{\max}$. By contrast, if $\rho^{\mathrm{e}}_{\max} < f^{-1}(G)$, then $\alpha^{\mathrm{d}} > \alpha^{\mathrm{e}}_{\max}$ and $\rho^{\mathrm{d}} > \rho^{\mathrm{e}}_{\max}$. To see how, note that the solution to the FinTech's problem in a game with a single, non-disruptor FinTech (as stated in Lemma 2) implies that $\mathcal{P}_\alpha(\alpha^{\mathrm{e}}_{\max}, \theta, G) > 0$, i. e. there is capacity for further improvements in the precision of signals. Note also that, evaluated at $\rho^* = \mathcal{P}(\alpha^{\mathrm{e}}_{\max}, \theta, G)$,

$$\Big(1 - \Phi\big(\tfrac{v}{\rho^*}\big)\Big) R + \alpha R \varphi\big(\tfrac{v}{\rho^*}\big) \tfrac{v}{(\rho^*)^2} \mathcal{P}_\alpha(\alpha^{\mathrm{e}}_{\max}, \theta, G) - c'(\alpha) > 0 \tag{16}$$

for all $\alpha \leq \alpha^{\mathrm{e}}_{\max}$. Therefore, a disruptor is better off by choosing some $\alpha^{\mathrm{d}} > \alpha^{\mathrm{e}}_{\max}$ than with $\alpha = \alpha^{\mathrm{e}}_{\max}$.

Suppose next that in a game with a single, non-disruptor FinTech, there is no equilibrium satisfying $\alpha^{\mathrm{e}}_{\max} > 0$ and $\rho^{\mathrm{e}}_{\max} > 0$ (i. e., only outright bans occur in equilibrium). According to Lemma 2, the regulator would opt for informed interventions (i. e., $\rho^* > 0$) provided its skills and capabilities satisfy $\theta \leq H$ and if, additionally, the success probability α is such that $\alpha \geq \theta/H$ as well as $G \geq \underline{G}$. Let $\alpha_{\text{crit}} := \min\big\{\alpha \in]0,1[\,\big|\, \alpha \geq \theta/H \text{ and } G \geq \underline{G}\big\}$ denote the minimum success

[26] For details refer to Appendix F.

probability such that both conditions are satisfied for all $\alpha \in [\alpha_{\text{crit}}, 1]$. If such α_{crit} exists and satisfies

$$\alpha_{\text{crit}}\Big(1-\Phi\big(\tfrac{v}{\min\{f^{-1}(G),r(\theta,\alpha_{\text{crit}})\}}\big)\Big)R-c(\alpha_{\text{crit}})\geq \eta^2/(N+1)^2, \tag{17}$$

then a disruptor sets $\alpha^{\text{d}}=\alpha_{\text{crit}}>0$ rather than opting for the established market, even though the LHS in Eq. (16) is already negative when evaluated at α_{crit}. This is more likely the case the higher the private returns (i. e., R large), the more FinTechs potentially compete in the established market (i. e., N high), the less poor the regulator's skills and capability (i. e., θ not too high), or the less tight its budget (i. e., G not too small). By contrast, if α_{crit} does not exist, or if it exists but does not meet condition (17), a disruptor will also opt for the established market.

Proposition 3 has further important implications. First, there is less regulatory uncertainty if the FinTech is a disruptor. For one, equilibrium probabilities of implementing successfully an idea into a new technology are (weakly) higher than if all players make their choices at the same time. This implies that it is more likely that the idea develops into a privately profitable technology and also less likely that the regulator will dismiss such privately successful technology later. Less regulatory uncertainty also results because equilibria with outright bans and with informed interventions cannot co-exist; i. e. strategic uncertainty arising from multiplicity of equilibria is resolved.

Another important take-away from Proposition 3 is that for developments of new technologies to occur at all, the regulator can be less skilled and capable (for a given budget) or have a smaller budget (for given skills and capability) if the FinTech is a disruptor. Note, however, while the firm with a new idea is better off in equiliria of sequential games than in equilibria of games without a disruptor, the regulator may not. It is quite possible that the regulator prefers that all firms operate in the established market, keeping the welfare loss due to imperfect competition there low and saving the regulator's budget for its alternative uses. The regulator refrains from an outright ban of a technology that is already being developed only because doing so *after* the disruptor has already started working on its new technology will not get this FinTech back to service the established market.[27]

[27] Albeit not the topic of this paper, without a proper commitment mechanism in place, any such respective threat to do so is thus not subgame perfect.

5.2 With Follower Innovator

Consider next the case where in addition to the lead innovator FinTech 1 (i. e. disruptor), there is also another innovator. This FinTech 2 decides on its own innovation effort after observing the disruptor's own choice of effort but without knowledge of whether the disruptor's effort will actually translate into a new technology. Accordingly, FinTech 2 is henceforth called the follower innovator.

The regulator decides on signal precision about disruptor and follower innovator simultaneously, having observed the former's effort choice and making conjectures about the latter's effort choice. Formally the regulator's problem is thus again to solve program (3'). By Lemma 3, its solution is $\rho_i^* = \mathcal{P}(\alpha_i, \alpha_j, \theta, G)$ for $i, j \in \mathbb{M}$ with $i \neq j$. Therefore, $\mathcal{P}$ is the regulator's response functions which the disruptor takes into account when making its own choice of a success probability α_1.

The follower innovator (FinTech 2), having observed the lead innovator's choice and taking the regulator's choice as given, solves again program (9'). By Lemma 4, its solution is $\alpha_2^* = \mathcal{A}(\alpha_1, \rho_2, N, R)$; cf. Lemma 4. Therefore, $\mathcal{A}$ is the follower innovator's response functions the disruptor takes also into account.

The two response functions $\mathcal{P}$ and $\mathcal{A}$ may interact. This is because the disruptor's choice potentially influences how the regulator splits its scarce budget across the disruptor and the follower innovator, and thus the regulator's choice of the precision of signals about the follower innovator. The latter, in turn, determines the follower innovator's best effort choice.

Formally, the disruptor FinTech 1 solves

$$\max_{\alpha_1 \in [0,1]} \quad \alpha_1 \Big(1 - \Phi\big(\tfrac{v}{\rho_1}\big)\Big) R - c(\alpha_1) + \mathbf{1}_0(\alpha_1) \frac{\eta^2}{(N + \mathbf{1}_0(\alpha_2))^2} \tag{15'}$$

s. t.

$$\begin{pmatrix} \rho_1 \\ \rho_2 \\ \alpha_2 \end{pmatrix} = \begin{pmatrix} \mathcal{P}(\alpha_1, \alpha_2, \theta, G) \\ \mathcal{P}(\alpha_2, \alpha_1, \theta, G) \\ \mathcal{A}(\alpha_1, \rho_2, N, R) \end{pmatrix} \tag{RF}$$

Let $\alpha_1^{\mathrm{d,e}}$ denote the disruptor's choice of its success probability. Furthermore, let $\alpha_2^{\mathrm{d,e}}$, $\rho_1^{\mathrm{d,e}}$, and $\rho_2^{\mathrm{d,e}}$ denote the joint solution to equation (RF) given that $\alpha_1 = \alpha_1^{\mathrm{d,e}}$.

Proposition 4 (Equilibrium for single disruptor and single follower FinTech)
Equilibrium choices never satisfy simultaneously $\alpha_2^{\mathrm{d,e}} > 0$ *and* $\alpha_1^{\mathrm{d,e}} \leq \alpha_2^{\mathrm{d,e}}$.

Proof. See Appendix G ■

The proposition delivers two interesting additional results. First, should the follower FinTech innovate ($\alpha_2^{\mathrm{d,e}} > 0$), then only when the disruptor has actually decided to develop its own idea ($\alpha_1^{\mathrm{d,e}} > 0$). Accordingly, there is never an equilibrium without a disruptor paving the way for the innovation process. Second, the disruptor will always grab a larger share of the regulator's budget. As shown in Appendix G, if the disruptor and the follower FinTech innovate, then this is not confined to circumstances in which the regulator's has plenty of resources so that firms would not interact through the regulator's budget. Even with such interaction through the budget, both firms potentially innovate but the disruptor will put in more effort and gets a larger share in the regulator's budget. Even if the regulator's budget is so tight such that in a simultaneous game (Proposition 2) there would be only one FinTech actually innovating, a disruptor can strategically exert effort in order to hoover up so many resources from the regulator to crowd out a potential follower.

6 Discussion

We discuss further implications of our model, signposting potential avenues for future researchers to follow up.

Required social value. In our model, the unconditional expected social value is zero ($\mu_V = 0$) while the required social value v is strictly positive. The latter has a number of alternative, complementary justifications. Chief among them are a safety margin as required by the regulator and possible cost that the regulator incurs post-approval of a new technology. An immediate implication hereof is that *laissez-faire* is not a viable regulatory strategy.

Laissez-faire can form part of a viable regulatory strategy, nonetheless, if $v < 0$. This is tantamount to an unconditional expected social value that is not only positive but indeed outweighs any safety margin and future costs to the regulator. For example, without further informative signals about a new technology, its expected positive externalities exceed any expected negative externalities. Then, if no resources are spent on signal precision, the regulator will pursue a *laissez-faire* policy of letting the FinTech proceed unchallenged. However, since the expected net social value (2) is increasing and convex in signal precision ρ, an informed intervention strategy (where the regulator spends resources on signal precision and decides later on 'ban' versus 'proceed') may yet be the better choice. The reason is that it allows the regulator to reduce the probability of a false, unjustified approval of the technology which a *laissez-faire* policy necessarily entails.

Provided the regulator pursues a policy of informed interventions even when $v < 0$, it leaves the innovative FinTech at stage $t = 1$ as much in limbo as it is the case when $v > 0$. Moreover, the regulator's signal precision and the FinTech's effort choice remain strategical complements, and the effects of a binding budget constraint for the regulator also remain qualitatively.

Evolution of regulation along innovation cycles. Our analysis speaks to the key general stages in innovation cycles. Often, at the beginning of those cycles, there is no regulation— either because regulators do not exist, or are bribed, or do not see any potential for regulation. Examples here include not just the FinTech revolution considered in the present paper but also the emergence of the industrial tycoons in the 19*th* century US. Under those circumstances, an innovators' problem is simply to maximize expected private returns, which in our model obtains if the probability of regulatory dismissal is set to zero. At the following stage, a regulatory backlash may occur as a regulator may realize that innovations potentially harm their stakeholders while it remains too costly to generate sufficiently informative signals about what innovations will actually bring along. Hence, regulators may ban those innovative efforts outright. However, over time, the regulator may realize that by improving its technology of assessing innovations, a more efficient signal generation becomes feasible. The regulatory pendulum swings back and innovations take up again. That said, innovators are probably still one step ahead of the regulator, and the regulatory toolkit is still very coarse. This resembles very much a sequential game setting. Later, the regulator may catch up with innovators and act earlier. Then, our simultaneous game setting applies, thus leading to (more) strategic uncertainty including multiplicity of equilibria, though. Finally, the regulator may learn why and how to regulate. This is a well-studied stage with problems like regulatory capture and unintended consequences of regulation. Examples for this last stage range from contemporary banking to pharmaceuticals to car safety and to environmental protection, to name just a few. Our model speaks particularly to the second, third and fourth stages, albeit the transition from one stage to another is not modeled.

Budget announcements as part of regulatory strategy. Our analysis has studied a set of regulatory games where the regulator has a (weak) strategic disadvantage, in that the regulator has no opportunity to move before any FinTech. This is a natural assumption since it is the very nature of (FinTech) innovations that nobody can foresee their consequences for society. Yet, one could still allow the regulator to have a first mover advantage in the sense that the regulator can announce before an innovative FinTech makes an effort choice to spend a certain budget on generating signals about such FinTech. There are two problems. First, any announced choice of signal precision is not part of a subgame-perfect equilibrium. Second, even if budgets could be pre-committed, doings so diminishes private incentives to innovate. For the sake of clarity and simplicity of argument, assume there is one potential disruptor. If the regulator does not commit a certain budget, the disruptor will set a success probability α^{d} inducing an unconstrained regulator to set signal precision to ρ^{d}. In setting α^{d}, the disruptor takes into account that by its own effort will determine how beneficial it is for the regulator to spend resources on signal precision. The higher the effort chosen by the disruptor, the more resources a regulator will use to improve signal precision about the disruptor. Consider next the case where the regulator pre-commits spending $f(\rho^{\mathrm{d}})$. Then, the disruptor knows that the signal precision will be also ρ^{d} but now regardless of its chosen success probability α. This effect lowers the incentive for the disruptor to exert own effort and thus the probability of a successful innovation.

Alternative use of regulator's budget. In the analysis conducted in the present paper, the regulator's budget could be spent either on generating informative signals about innovative FinTech's and their innovation's likely effects on society, or on the provision of other public goods or regulatory frameworks outside the realm of the FinTech industry. An alternative use of the regulator's resources could be to subsidize activities in the established markets. For example, in the sequential game with a single innovative FinTech, we have shown that it may be in the interest of the regulator to not let the FinTech develop its idea. However, due to its first-mover advantage, the FinTech still proceeds and develops a new technology in equilibrium. In those circumstances, it may seem a viable option to make the established market more attractive to the FinTech by granting a subsidy to those who operate there. Suppose the regulator is bound to a fair and equal treatment of all firms servicing the established market, such subsidy would have to be given to all firms, not just the innovative FinTech. Since the established market is of low value to the innovative FinTech especially if there are many firms servicing that market, this implies granting subsidies to a rather large number of firms. For a given budget, only little will thus actually benefit an individual FinTech. Moreover, if there are many firms potentially operating in the established market, the welfare loss associated with imperfect competition there would be limited, too. To sum up, such alternative use of the regulator's budget is probably adding only little economic value.

7 Concluding Remarks

We advance a framework studying the effects of regulatory uncertainty on FinTech innovation and adoption. We do so by proposing a game among FinTech entrants, incumbents, and a regulator. The game has key features that make it particularly suitable for the FinTech ecosystem. As opposed to other industries, the regulator generates costly information about the potential societal effects of innovation in FinTech. Moreover, the regulator's skills to acquire such information are imperfect and its budget limited. Lastly, innovators compete among themselves, either for market shares within the boundaries of a given technology frontier or for the regulator's limited resources when they aim to expand the current frontier. We focus on equilibria in pure strategies and show that regulatory uncertainty creates new, endogenous layers of risk — notably extrinsic risk as there are potentially multiple equilibria.

Our paper highlights the importance of additional research inquiries into FinTech innovation. For example, it is important for financiers to understand the risk of their borrowers. This is a general problem, not solely applicable to FinTechs. However, especially in FinTech, overall business risk is shaped by regulatory uncertainty. While this issue has been understudied in FinTech, our work incorporates its salient aspects and takes an initial step towards a better understanding of this source of risk.

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Appendix

A Proof of Lemma 1

The proof is in 8 steps:

Step 1 Preliminaries

(a) the properties of the standard normal distribution include $\varphi'(S) = -S\varphi(S)$;

(b) the objective function may not always be concave because $\frac{\partial}{\partial\rho}\Big(\alpha\big(\rho\varphi(s) - \big(1-\Phi(s)\big)v\big)\Big) = \alpha\varphi(s) \geq 0$ and $\frac{\partial^2}{\partial\rho^2}\Big(\alpha\big(\rho\varphi(s) - \big(1-\Phi(s)\big)v\big)\Big) = \alpha\varphi(s)s^2/\rho \geq 0$;

(c) there is a local maximum at $\rho = 0$ because $f'(0) = 0$ and $\lim\limits_{\rho\to 0}\big(\alpha\varphi(s)\big) = 0$, while $f''(0) > 0$ and $\lim\limits_{\rho\to 0}\big(\alpha\varphi(s)s^2/\rho\big) = 0$.

Step 2 Since $\lim\limits_{\rho\to 1}\frac{\partial}{\partial\rho}\Big(\alpha\varphi(\frac{v}{\rho}) - f'(\rho)\Big) < \lim\limits_{\rho\to 0}\frac{\partial}{\partial\rho}\Big(\alpha\varphi(\frac{v}{\rho}) - f'(\rho)\Big) = 0$, at most three stationary points implies that there is at most one $\rho > 0$ at which the objective function in program (3) has a (local) maximum. By the implicit function theorem, the ρ associated with such maximum is a continuous and differentiable function $r : \mathbb{R}_+ \times [0,1] \mapsto [0,1]$ defined by $r(\theta,\alpha) = \Big\{\rho \in]0,1[\,\Big|\, \alpha\varphi(\frac{v}{\rho}) - f'(\rho) = 0 \text{ and } \alpha\varphi(\frac{v}{\rho})\frac{v^2}{\rho^3} - f''(\rho) < 0\Big\}$ with

$$
\begin{aligned}
r_\alpha(\theta,\alpha) &= -\frac{\varphi(\frac{v}{\rho})}{\frac{\partial}{\partial\rho}\Big(\alpha\varphi(\frac{v}{\rho}) - f'(\rho)\Big)} > 0 \\
r_\theta(\theta,\alpha) &= \frac{\frac{\rho}{1-\rho}}{\frac{\partial}{\partial\rho}\Big(\alpha\varphi(\frac{v}{\rho}) - f'(\rho)\Big)} < 0
\end{aligned}
$$

since $\frac{\partial}{\partial\rho}\big(\alpha\varphi(\frac{v}{\rho}) - f'(\rho)\big) < 0$ when evaluated at a (local) maximum of the regulator's objective function.

Step 3 Since

$$
\begin{aligned}
\lim_{\theta\to 0}\alpha\Big(\rho\varphi\big(\tfrac{v}{\rho}\big) - \big(1-\Phi\big(\tfrac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) &> 0 \quad \text{for any } \rho \in]0,1[\\
\lim_{\theta\to\infty}\alpha\Big(\rho\varphi\big(\tfrac{v}{\rho}\big) - \big(1-\Phi\big(\tfrac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) &< 0 \quad \text{for any } \rho \in]0,1[\\
\alpha\Big(\rho\varphi\big(\tfrac{v}{\rho}\big) - \big(1-\Phi\big(\tfrac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) &= 0 \quad \text{for } \rho = 0
\end{aligned}
$$

and $r_\theta(\theta,\alpha) < 0$ provided $r(\theta,\alpha) \neq \emptyset$, the intermediate value theorem implies that there is $\bar\theta > 0$ such that

$$
\begin{aligned}
\alpha\Big(\rho\varphi\big(\tfrac{v}{\rho}\big) - \big(1-\Phi\big(\tfrac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) &= 0 \quad \text{for } \rho = r(\bar\theta,\alpha) \\
\max_\rho\Big\{\alpha\Big(\rho\varphi\big(\tfrac{v}{\rho}\big) - \big(1-\Phi\big(\tfrac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) \,\big|\, \rho \in [0,1]\Big\} &\leq 0 \quad \text{for any } \theta > \bar\theta \\
\max_\rho\Big\{\alpha\Big(\rho\varphi\big(\tfrac{v}{\rho}\big) - \big(1-\Phi\big(\tfrac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) \,\big|\, \rho \in [0,1]\Big\} &> 0 \quad \text{for any } \theta < \bar\theta
\end{aligned}
$$

$\bar{\theta}$ is unique because

$$\alpha\Big(\rho\varphi(\,v/\rho\,) - \big(1 - \Phi(\,v/\rho\,)\big)v\Big) > 0$$

for all $\rho\ \in]0,1[$, and (by the envelope theorem)

$$\frac{\mathrm{d}}{\mathrm{d}\theta}\left(\alpha\Big(\rho\varphi(\,v/\rho\,) - \big(1 - \Phi(\,v/\rho\,)\big)v\Big) - f(\rho)\right) < 0$$

for $\rho = r(\theta, \alpha)$, as well as $\lim_{\theta\to 0} f(\rho) = 0$ and $\lim_{\theta\to\infty} f(\rho) = \infty$, both for any ρ.

Step 4 For every $v > 0$, there is $H \in \mathbb{R}_{++}$ such that $\bar{\theta}$ is implicitly defined by $\bar{\theta} = \big\{\theta \,\big|\, H = \theta/\alpha\big\}$ with $\partial H/\partial\alpha = 0$ and $\partial H/\partial v < 0$. To show this, let

$$\begin{aligned} E_1 &= \alpha\Big(\rho\varphi\big(\tfrac{v}{\rho}\big) - \big(1 - \Phi\big(\tfrac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) \\ E_2 &= \alpha\varphi\big(\tfrac{v}{\rho}\big) - f'(\rho) \end{aligned}$$

Then, $E_1 = 0$ and $E_2 = 0$ for $\bar{\theta}$ and some $\rho^\dagger > 0$. According to the general implicit function theorem, $\bar{\theta}$ and $\rho^\dagger > 0$ thus satisfy

$$\frac{\partial\bar{\theta}}{\partial\alpha} = \frac{\frac{\partial E_1}{\partial\rho}\frac{\partial E_2}{\partial\alpha} - \frac{\partial E_2}{\partial\rho}\frac{\partial E_1}{\partial\alpha}}{\frac{\partial E_1}{\partial\theta}\frac{\partial E_2}{\partial\rho} - \frac{\partial E_1}{\partial\rho}\frac{\partial E_2}{\partial\theta}} = \frac{\bar{\theta}}{\alpha} \tag{18}$$

$$\frac{\partial\rho^\dagger}{\partial\alpha} = \frac{\frac{\partial E_2}{\partial\theta}\frac{\partial E_1}{\partial\alpha} - \frac{\partial E_1}{\partial\theta}\frac{\partial E_2}{\partial\alpha}}{\frac{\partial E_1}{\partial\theta}\frac{\partial E_2}{\partial\rho} - \frac{\partial E_1}{\partial\rho}\frac{\partial E_2}{\partial\theta}} = 0 \tag{19}$$

$$\frac{\partial\bar{\theta}}{\partial v} = \frac{\frac{\partial E_1}{\partial\rho}\frac{\partial E_2}{\partial v} - \frac{\partial E_2}{\partial\rho}\frac{\partial E_1}{\partial v}}{\frac{\partial E_1}{\partial\theta}\frac{\partial E_2}{\partial\rho} - \frac{\partial E_1}{\partial\rho}\frac{\partial E_2}{\partial\theta}} = -\alpha\bar{\theta}\frac{1 - \Phi\big(\frac{v}{\rho^\dagger}\big)}{f\left(\rho^\dagger\right)} \tag{20}$$

Eq. (18) implies $\partial\bar{\theta}/\partial\alpha = \bar{\theta}/\alpha = \varphi(\frac{v}{\rho^\dagger})(1-\rho^\dagger)/\rho^\dagger$ for all $\alpha\ \in]0,1[$, with the last equality following from the first-order condition (6). Eq. (19) implies $\mathrm{d}r\big(\bar{\theta},\alpha\big)/\mathrm{d}\alpha = 0$ for every $\rho^* = r(\bar{\theta},\alpha) > 0$ and $\bar{\theta}/\alpha = \varphi(\frac{v}{\rho^\dagger})(1-\rho^\dagger)/\rho^\dagger = H$ with $\partial H/\partial\alpha = 0$ as $\partial(\bar{\theta}/\alpha)/\partial\alpha = 0$. Finally, Eq. (20) implies $\partial H/\partial v < 0$.

Step 5 Suppose $\theta > \bar{\theta}$. By definition of $\bar{\theta}$, $\alpha\Big(\rho\varphi\big(\frac{v}{\rho}\big) - \big(1 - \Phi\big(\frac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) < 0$ for all $\rho > 0$. Since $\lim_{\rho\to 0}\alpha\Big(\rho\varphi\big(\frac{v}{\rho}\big) - \big(1 - \Phi\big(\frac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) = 0$, we obtain $\rho^* = 0$.

Step 6 Suppose $\theta \leq \bar{\theta}$. Since $\alpha\Big(\rho\varphi\big(\frac{v}{\rho}\big) - \big(1 - \Phi\big(\frac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) > 0$ for $\rho = r(\theta,\alpha)$, it follows from $\partial f^{-1}(G)/\partial G > 0$ that there is $\underline{G} > 0$ such that $\alpha\Big(f^{-1}(\underline{G})\varphi\big(\frac{v}{f^{-1}(\underline{G})}\big) - \big(1-\Phi\big(\frac{v}{f^{-1}(\underline{G})}\big)\big)v\Big) - \underline{G} = 0$ and $\alpha\Big(f^{-1}(G)\varphi\big(\frac{v}{f^{-1}(G)}\big) - \big(1-\Phi\big(\frac{v}{f^{-1}(G)}\big)\big)v\Big) - G < 0$ for all $G < \underline{G}$. Therefore, $\rho^* = 0$ if $G < \underline{G}$. By the implicit function theorem, $\partial\underline{G}/\partial\alpha = \big(\underline{G}/\alpha\big)\Big/\Big(1 -$

$\alpha\varphi(\frac{v}{f^{-1}(\underline{G})})/f'\big(f^{-1}(\underline{G})\big)\Big)$. As $f^{-1}(\underline{G}) < r(\theta, \alpha)$, we obtain $\alpha\varphi(\frac{v}{f^{-1}(\underline{G})})/f'\big(f^{-1}(\underline{G})\big) > 1$ and hence $\partial\underline{G}/\partial\alpha < 0$.

1. Suppose $\theta < \bar{\theta}$. Since $\partial f^{-1}(G)/\partial G > 0$ there is $\overline{G} > 0$ such that $f^{-1}(\overline{G}) - r(\theta, \alpha) = 0$ and $\rho^* = r(\theta, \alpha)$ if and only if $G \geq \overline{G}$. Note $\partial\overline{G}/\partial\alpha > 0$ as the implicit function theorem yields $\partial\overline{G}/\partial\alpha = r_\alpha(\theta, \alpha)\,\theta\frac{f^{-1}(\overline{G})}{1-f^{-1}(\overline{G})}$, with $r_\alpha(\theta, \alpha)$ evaluated at $r(\theta, \alpha) = f^{-1}(\overline{G})$.

Step 7 Suppose $\theta < \bar{\theta}$ and $G \in [\underline{G}, \overline{G}]$. Then $\alpha\Big(\rho\varphi\big(\frac{v}{\rho}\big) - \big(1 - \Phi\big(\frac{v}{\rho}\big)\big)v\Big) - f\big(\rho\big) > 0$ for $\rho = f^{-1}(G)$. Hence, $\rho^* = f^{-1}(G)$.

Step 8 Suppose $\alpha = \theta/H$. Then $\theta = \bar{\theta}$. Hence, $f^{-1}(\overline{G}) = r\big(\bar{\theta}, \bar{\theta}/H\big)$ by definition of $\overline{G}$. By definition of $\bar{\theta}$, $\alpha\Big(\rho\varphi\big(\frac{v}{\rho}\big) - \big(1 - \Phi\big(\frac{v}{\rho}\big)\big)v\Big) - G = 0$ for $\rho = r\big(\bar{\theta}, \bar{\theta}/H\big)$ and hence $f^{-1}(\underline{G}) = r\big(\bar{\theta}, \bar{\theta}/H\big)$. Therefore, $\overline{G} = \underline{G}$ if $\theta = \bar{\theta}$.

B Proof of Lemma 2

The Lemma follows from the first-order condition to program (9), rearranging terms and applying the implicit function theorem as well as the laws of limits. The critical value for the number N of FinTechs is the smallest natural number greater or equal 2 (i. e., $N \in \mathbb{Z}_{\geq 2}$), for which $a(\rho, R)\big(1 - \Phi(v/\rho)\big)R - c\big(a(\rho, R)\big) \geq \eta^2/(N+1)^2$ provided $\rho > 0$. Since $c(\alpha) = -(\alpha + \ln(1-\alpha))$ and $\alpha = a(\rho, R)$ according to Eq. (10), rearranging terms yields condition (11). By the Envelope theorem, indirect expected profits $a(\rho, R)\big(1 - \Phi(v/\rho)\big)R - c\big(a(\rho, R)\big)$ are increasing in ρ and R. Therefore, $\mathcal{N}(R, \rho)$ is (weakly) smaller for larger ρ and larger R.

C Proof of Proposition 1

1. Universal existence of an equilibrium with $\rho^{\mathrm{e}} = 0$ and $\alpha^{\mathrm{e}} = 0$:

   Existence follows directly from Lemmata 1 and 2.

2. Existence of equilibria with $\rho^{\mathrm{e}} > 0$ and $\alpha^{\mathrm{e}} > 0$: The proof is in 4 steps

Step 1 Preliminaries

a) Recall: according to Lemma 1, for $r(\theta, \alpha) \neq \emptyset$, r is a continuously differentiable function with
   - $r(\theta_1, \theta_1/H) = r(\theta_2, \theta_2/H) =: \kappa \in]0, 1[$ for all $(\theta_1, \theta_2) \in]0, H] \times]0, H]$,
   - $r_\alpha(\theta, \alpha) > 0$ for all $\alpha \in]\theta/H, 1[$ and $\theta \in]0, H[$,
   - $r(\theta, \alpha)$ strictly bounded away from unity for all $\alpha \in]\theta/H, 1]$ if $\theta \in]0, H[$.

b) Recall: according to Lemma 2, a is a continuously differentiable function with
   - $a_\rho(R, \rho) > 0$ for all $\rho \in [0, 1]$,
   - $a(R, 0) = 0$,

– $a(R,1) < 1$.

c) Define: let $a^{-1} : \mathbb{R}_+ \times [0,1] \mapsto [0,1]$ be a function defined by $a^{-1}(R,\alpha) = \rho$ if and only if $\alpha = a(R,\rho)$.

Step 2 Existence of $(\hat{\alpha},\hat{\rho}) \in]\theta/H, a(R,1)[\times]0,1[$ for which $\hat{\rho} = r(\theta,\hat{\alpha})$ and $\hat{\alpha} = a(R,\hat{\rho})$ provided θ sufficiently small.

– Suppose $\theta - \varepsilon = 0$ with $\varepsilon > 0$ small such that, for a given $G > 0$, the regulator's choice is $\rho^* = r(\theta,\alpha)$ with $r(\theta,\alpha)$ close to unity for all $\alpha \in]\theta/H, 1]$ except in some (arbitrarily small) neighborhood of $\alpha = \theta/H$.

– For $\alpha = \theta/H$, we have $a^{-1}(R,\alpha) < r(\theta,\alpha)$ because Lemma 1 implies that there is a constant $\kappa \in]0,1[$ such that $r(\theta,\alpha) = \kappa$ for any $\theta \in]0,H]$, and Lemma 2 implies $a^{-1}(R,\alpha)$ be close to zero.

– For $\alpha = a(R,1)$, we have $a^{-1}(R,\alpha) > r(\theta,\alpha)$ because $r(\theta, a(R,1)) < 1$ and $a^{-1}(R, a(R,1)) = 1$.

Therefore, by continuity of a and r there is a unique $(\hat{\alpha},\hat{\rho}) \in]\theta/H, a(R,1)[\times]0,1[$ such that $\hat{\rho} = r(\theta,\hat{\alpha})$ and $\hat{\alpha} = a(R,\hat{\rho})$.

Step 3 Non-existence of any $(\hat{\alpha},\hat{\rho}) \in]\theta/H, a(R,1)[\times]0,1[$ for which $\hat{\rho} = \min\{f^{-1}(G), r(\theta,\hat{\alpha})\}$ and $\hat{\alpha} = a(R,\hat{\rho})$ provided θ sufficiently large.

For every $G > 0$, Lemma 1 implies that there is $\tilde{\theta} \in]0, a(R,1)H[$ (that may depend on G) such that for $\theta \geq \tilde{\theta}$ we get $\rho^* \in]0,1[$ if $\alpha \geq a(R,1)$ and $\rho^* = 0$ if $\alpha < a(R,1)$. Since $a^{-1}(R,\alpha) > 0$ for all $\alpha \leq a(R,1)$, and $a(R,\rho) \leq a(R,1)$, no $(\hat{\alpha},\hat{\rho}) \in]\theta/H, a(R,1)[\times]0,1[$ exists for which $\hat{\rho} = \min\{f^{-1}(G), r(\theta,\hat{\alpha})\}$ and $\hat{\alpha} = a(R,\hat{\rho})$.

Step 4 Existence of a *Nash* equilibrium with $\rho^* > 0$ and $\alpha^* > 0$.

Since some $(\hat{\alpha},\hat{\rho}) \in]\theta/H, a(R,1)[\times]0,1[$ exists for which $\hat{\rho} = \min\{f^{-1}(G), r(\theta,\hat{\alpha})\}$ and $\hat{\alpha} = a(R,\hat{\rho})$ provided θ sufficiently small, and does not exist provided θ sufficiently large, continuity implies that there is $\hat{\theta} \in]0,\tilde{\theta}[$ such that for all $\theta \leq \hat{\theta}$ some $(\hat{\alpha},\hat{\rho}) \in]\theta/H, a(R,1)[\times]0,1[$ exists for which $\hat{\rho} = \min\{f^{-1}(G), r(\theta,\hat{\alpha})\}$ and $\hat{\alpha} = a(R,\hat{\rho})$.

– Then, for every $\theta \leq \hat{\theta}$, there is $\hat{N} \geq 2$ implicitly defined by

$$\hat{N} := \min\left\{x \in \mathbb{Z}_{\geq 2} \,\middle|\, \hat{\alpha}\big(1 - \Phi(v/\hat{\rho})\big)R - f(\hat{\alpha}) \geq \eta^2/(x+1)^2\right\}.$$

Therefore, at least one *Nash* equilibrium exists with $\rho^* > 0$ and $\alpha^* > 0$ for every $\theta \leq \hat{\theta}$ provided $N \geq \hat{N}$.

– Threshold $\hat{\theta}$ satisfies $\partial\hat{\theta}/\partial G \geq 0$. To see how, recall that in any equilibrium with informed interventions, the value of regulator's objective function (see program (3))is

$$\max_{\rho \in]0,1[} \left\{\alpha^{\mathrm{e}}\Big(\rho\varphi(s) - \big(1 - \Phi(s)\big)v\Big) - f(\rho) \,\middle|\, f(\rho) \leq G\right\} \geq 0 \tag{21}$$

and the value of FinTech 1's objective function (see program (9)) is

$$\max_{\alpha \in [0,1]} \left\{\alpha\Big(1 - \Phi\big(\tfrac{v}{\rho^{\mathrm{e}}}\big)\Big)R - c(\alpha)\right\} \geq \frac{\eta^2}{(N+1)^2}. \tag{22}$$

For $\theta \to \hat{\theta}$, at least one of the two conditions (21) and (22) holds with equality.

(a) Suppose in such equilibrium the budget constraint is binding; i. e., $\rho^{\mathrm{e}} = f^{-1}(G)$. Then, for any $\mathrm{d}G > 0$ there is $\mathrm{d}\theta > 0$ such that $\frac{\partial f^{-1}(G)}{\partial G}\mathrm{d}G + \frac{\partial f^{-1}(G)}{\partial \theta}\mathrm{d}\theta = 0$. Therefore, $\mathrm{d}\rho^{\mathrm{e}} = 0$ for those combined changes in G and θ, as long as $\mathrm{d}\alpha^{\mathrm{e}} = 0$, which would also leave condition (21) unchanged. In turn, as long as $\mathrm{d}\rho^{\mathrm{e}} = 0$, we also have $\mathrm{d}\alpha^{\mathrm{e}} = 0$ since the same α maximizes FinTech 1's objective function and condition (22) remains unchanged. Therefore, an equilibrium still just exists; i. e., $\partial\hat{\theta}/\partial G > 0$.

(b) Suppose in such equilibrium the budget constraint is not binding; i. e., $\rho^{\mathrm{e}} = r(\hat{\theta}, \alpha)$. Then, some $\mathrm{d}G > 0$ implies $\mathrm{d}\rho^{\mathrm{e}} = 0$ as long as $\mathrm{d}\alpha^{\mathrm{e}} = 0$, which would also leave the value of the regulator's objective function unchanged. In turn, as long as $\mathrm{d}\rho^{\mathrm{e}} = 0$, we also have $\mathrm{d}\alpha^{\mathrm{e}} = 0$ since the same α^{e} maximizes FinTech 1's objective function and thus condition (11) remains unchanged. Therefore, an equilibrium still just exists; i. e., $\partial\hat{\theta}/\partial G = 0$.

– Existence of multiple equilibria with $\rho^* > 0$ and $\alpha^* > 0$ is proven by means of an example in the main text. Since no equilibrium exists for $\theta > \hat{\theta}$, and if an equilibrium exist for $\theta \to 0$ it is unique, multiple equilibria can exist only for intermediate values of θ.

3. To prove the third statement, let E_3 and E_4 be defined by

$$\begin{aligned} E_3 &:= \rho - \min\{f^{-1}(G), r(\theta, \alpha)\} \\ E_4 &:= \alpha - a(R, \rho) \end{aligned} \tag{23}$$

and let $\alpha^{\mathrm{e}}_{\max}$ and $\rho^{\mathrm{e}}_{\max}$ be defined as in Proposition 1, no. 3. Provided $\alpha^{\mathrm{e}}_{\max} > 0$ and $\rho^{\mathrm{e}}_{\max} > 0$, such equilibrium satisfies $E_3 = 0$ and $E_4 = 0$ for $(\alpha, \rho) = (\alpha^{\mathrm{e}}_{\max}, \rho^{\mathrm{e}}_{\max})$, and by the implicit function theorem,

$$\begin{aligned}
\frac{\partial \rho^{\mathrm{e}}_{\max}}{\partial \theta} &= \frac{\frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial \theta}}{1 - \frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial \alpha} \frac{\partial a(R, \rho^{\mathrm{e}}_{\max})}{\partial \rho}} \\
\frac{\partial \alpha^{\mathrm{e}}_{\max}}{\partial \theta} &= \frac{\frac{\partial a(R, \rho^{\mathrm{e}}_{\max})}{\partial \rho} \frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial \theta}}{1 - \frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial \alpha} \frac{\partial a(R, \rho^{\mathrm{e}}_{\max})}{\partial \rho}} \\
\frac{\partial \rho^{\mathrm{e}}_{\max}}{\partial G} &= \frac{\frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial G}}{1 - \frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial \alpha} \frac{\partial a(R, \rho^{\mathrm{e}}_{\max})}{\partial \rho}} \\
\frac{\partial \alpha^{\mathrm{e}}_{\max}}{\partial \theta} &= \frac{\frac{\partial a(R, \rho^{\mathrm{e}}_{\max})}{\partial \rho} \frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial G}}{1 - \frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial \alpha} \frac{\partial a(R, \rho^{\mathrm{e}}_{\max})}{\partial \rho}} \\
\frac{\partial \rho^{\mathrm{e}}_{\max}}{\partial R} &= \frac{\frac{\partial a(R, \rho^{\mathrm{e}}_{\max})}{\partial R} \frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial \alpha}}{1 - \frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial \alpha} \frac{\partial a(R, \rho^{\mathrm{e}}_{\max})}{\partial \rho}} \\
\frac{\partial \alpha^{\mathrm{e}}_{\max}}{\partial R} &= \frac{\frac{\partial a(R, \rho^{\mathrm{e}}_{\max})}{\partial R}}{1 - \frac{\partial \min\{f^{-1}(G), r(\theta, \alpha^{\mathrm{e}}_{\max})\}}{\partial \alpha} \frac{\partial a(R, \rho^{\mathrm{e}}_{\max})}{\partial \rho}}
\end{aligned} \tag{24}$$

According to Lemma 1, $\partial r(\theta,\alpha)/\partial\theta = r_\theta(\theta,\alpha) < 0$, $\partial f^{-1}(G)/\partial\theta < 0$, and $\partial f^{-1}(G)/\partial G > 0$. According to Lemma 2, $\partial a(R,\rho)/\partial\rho = a_\rho(R,\rho) > 0$ and $\min\{f^{-1}(G), r(\theta,\alpha^{\mathrm{e}})\} < 1$ for all $\alpha \in [0,1]$ and $a(R,\rho) < 1$ for all $\rho \in [0,1]$. The latter implies that $\partial \min\{f^{-1}(G), r(\theta,\alpha^{\mathrm{e}})\}/\partial\alpha < \partial a^{-1}(R,\alpha^{\mathrm{e}})/\partial\alpha$ and thus $1 > \frac{\partial \min\{f^{-1}(G), r(\theta,\alpha^{\mathrm{e}})\}}{\partial\alpha}\frac{\partial a(R,\rho^{\mathrm{e}})}{\partial\rho}$ at an equilibrium $(\alpha^{\mathrm{e}}_{\max}, \rho^{\mathrm{e}}_{\max})$. Therefore, $\partial\alpha^{\mathrm{e}}_{\max}/\partial\theta < 0$ and $\partial\rho^{\mathrm{e}}_{\max}/\partial\theta < 0$, and $\partial\alpha^{\mathrm{e}}_{\max}/\partial G \geq 0$ and $\partial\rho^{\mathrm{e}}_{\max}/\partial G \geq 0$.

Finally, by the Envelope theorem, $\partial \max\Big(a(\rho^{\mathrm{e}},R)\big(1-\Phi(v/\rho^{\mathrm{e}})\big)R - c\big(a(\rho^{\mathrm{e}},R)\big)\Big)\Big/\partial\rho^{\mathrm{e}} > 0$, which together with $\partial\rho^{\mathrm{e}}_{\max}/\partial G \geq 0$ and $\partial\rho^{\mathrm{e}}_{\max}/\partial\theta < 0$ implies that $\hat{N}$ is (weakly) smaller for smaller θ and larger G.

D Proof of Lemma 3

We proof the first part of the Lemma in three steps below: first, there is a fixed point $\bar{\rho}$ as defined in the Lemma; second, the solution to the regulator's problem (3') is either $\rho_i^* = \rho_j^*$, or $\rho_i^* > 0$ and $\rho_j^* = 0$ for $i \neq j$; third, there are critical values $G_{\mathrm{crit},1}$ and $G_{\mathrm{crit},2}$ as defined in the Lemma.

The second part of the Lemma follows immediately by Lemma 1.

Step 1

Claim: $\Gamma(\rho_1,\rho_2) = G$ defines ρ_2 as implicit function $\gamma : [0,1]\times\mathbb{R}_+ \mapsto [0,1]$ of ρ_1 and G, i.e. $\rho_2 = \gamma(\rho_1, G)$, with fixed point $\bar{\rho} = \gamma(\bar{\rho}, G)$.

Proof: By the implicit function theorem,

$$\frac{\partial\gamma(\rho_1,G)}{\partial\rho_1} = -\frac{f'(\rho_1)}{f'(\rho_2)} < 0 \tag{25a}$$

$$\frac{\partial^2\gamma(\rho_1,G)}{\partial\,{\rho_1}^2} = -\frac{f''(\rho_1)\big(f'(\rho_2)\big)^2 + f''(\rho_2)\big(f'(\rho_1)\big)^2}{\big(f'(\rho_2)\big)^3} < 0 \tag{25b}$$

and, since $\lim_{\rho\to1} f(\rho) = \infty$ and $\lim_{\rho\to0} f(\rho) = 0$, also $\gamma(0,G) > 0$ and $\gamma(\rho,G) = 0$ for some $\rho = \hat{\rho} \in]0,1[$. Therefore, by Brouwer's fixed point theorem, there is a (unique) fixed point $\bar{\rho} = \gamma(\bar{\rho},G)$. For $f(\rho) = -\theta\big(\rho + \ln(1-\rho)\big)$, this fixed point satisfies

$$\bar{\rho} = 1 + W\big(-e^{-1-\frac{G}{2\theta}}\big)$$

Step 2 The *Lagrangian* for the regulator's problem (3') is

$$\begin{aligned}\mathscr{L} \;=\; & \sum_{i=1}^{2}\Big[\alpha_i\Big(\rho_i\varphi\big(\tfrac{v}{\rho_i}\big) - \Big(1-\Phi\big(\tfrac{v}{\rho_i}\big)\Big)v\Big) - f(\rho_i)\Big] \\ & + G - \frac{\eta^2}{2\big(N-1+\sum_{i=1}^{2}\mathbf{1}_0(\alpha_i)\big)^2} - \lambda\sum_{i=1}^{2}\big[f(\rho_i) - G\big]\end{aligned} \tag{26}$$

with

$$\frac{\partial \mathscr{L}}{\partial \rho_i} = \alpha\varphi\left(\tfrac{v}{\rho_i}\right) - f'(\rho_i) - \lambda f'(\rho_i) = 0 \tag{27a}$$

$$\lambda \sum_{i=1}^{2} \left[f(\rho_i) - G\right] = 0 \tag{27b}$$

$$\lambda \geq 0 \tag{27c}$$

and the bordered Hessian determinant

$$\begin{aligned} D(\rho_1,\rho_2) \;&=\; -\big(f'(\rho_1)\big)^2\Big(\alpha\varphi\big(\tfrac{v}{\rho_2}\big)\tfrac{v^2}{{\rho_2}^3} - f''(\rho_2) - \lambda f''(\rho_2)\Big) \\ &\quad -\big(f'(\rho_2)\big)^2\Big(\alpha\varphi\big(\tfrac{v}{\rho_1}\big)\tfrac{v^2}{{\rho_2}^3} - f''(\rho_1) - \lambda f''(\rho_1)\Big) \end{aligned} \tag{28}$$

Symmetric solutions The following claims establish that there is always some $\rho_1 = \rho_2 \geq \bar{\rho}$ constituting either a local maximum or a local minimum of the regulator's objective function.

Claim 2A: Suppose $r(\theta,\alpha) \leq G/2$, implying $\bar{\rho} \geq r(\theta,\alpha)$. Then $\rho_1^* = \rho_2^* = r(\theta,\alpha)$ is a local (and global) maximum.

Proof: By Lemma 1.

Suppose $r(\theta,\alpha) > G/2$, implying $\bar{\rho} < r(\theta,\alpha)$. Recall $f(\rho) = -\theta\big(\rho + \ln(1-\rho)\big)$.

Claim 2B: If $\alpha\varphi(v/\bar{\rho}) - f'(\bar{\rho}) > 0$ and $\alpha\varphi(v/\bar{\rho})\, v^2 / \bar{\rho}^3 - f''(\bar{\rho}) < 0$, then $\rho_1^* = \rho_2^* = \bar{\rho}$ is a local maximum.

Proof: Follows because $\lambda > 0$ and $D(\bar{\rho},\bar{\rho}) > 0$.

Claim 2C: If $\alpha\varphi(v/\bar{\rho}) - f'(\bar{\rho}) > 0$ and $\alpha\varphi(v/\bar{\rho})\, v^2 / \bar{\rho}^3 - f''(\bar{\rho}) > 0$, then $\rho_1^* = \rho_2^* = \bar{\rho}$ is a local maximum if and only if

$$v < \frac{\bar{\rho}}{(1-\bar{\rho})^{1/2}}, \tag{29}$$

and it is a local minimum otherwise.

Proof: Note first that $\lambda > 0$. Next, Eq. (27a) implies $1+\lambda = \alpha\varphi(v/\bar{\rho})\big/f'(\bar{\rho})$. Substituted into Eq. (28), $D(\bar{\rho},\bar{\rho}) > 0$ if and only if

$$\alpha\varphi\Big(\frac{v}{\bar{\rho}}\Big)\frac{v^2}{\bar{\rho}^3} - \alpha\varphi\Big(\frac{v}{\bar{\rho}}\Big)\frac{f''(\bar{\rho})}{f'(\bar{\rho})} < 0$$

which after rearranging terms and replacing f yields condition (29). If, instead, $v > \bar{\rho}\big/(1-\bar{\rho})^{1/2}$, then $\rho_1^* = \rho_2^* = \bar{\rho}$ is a local minimum since $D(\bar{\rho},\bar{\rho}) < 0$.

Claim 2D: If $\alpha\varphi(v/\bar{\rho}) - f'(\bar{\rho}) < 0$, then $\rho_1^* = \rho_2^* = \bar{\rho}$ is a local minimum.

Proof: Reducing ρ_1 as well as ρ_2 is both, feasible and increasing expected social welfare.

Asymmetric solutions The following claims establish that there is one (ρ_1, ρ_j) with $\rho_i > \rho_j \geq 0$ that constitutes a local maximum, and that this requires $\rho_i = \min\{r(\theta, \alpha, f^{-1}(G))\}$ and $\rho_j = 0$.

Claim 2E: There is some $\rho_i > 0$ and $\rho_j = 0$ for $i \neq j$ constituting a local maximum.

Proof: Note that that $\lim_{\rho \to +0} \left(\varphi(v/\rho_2)\, v^2 / {\rho_2}^3\right) = 0$. Therefore,

(a) $\lambda = 0$, $\rho_i = r(\theta, \alpha)$ and $\rho_j = 0$ simultaneously satisfy conditions(27a) and (27b) and $D(r(\theta, \alpha), 0) > 0$ such that $\rho_i^* = r(\theta, \alpha)$ and $\rho_j^* = 0$ is a local maximum provided $r(\theta, \alpha) \leq G$;

(b) $\lambda > 0$ and $\rho_i = f^{-1}(G)$ and $\rho_j = 0$ simultaneously satisfy conditions (27a) and (27b) and $D(f^{-1}(G), 0) > 0$ such that $\rho_i^* = f^{-1}(G)$ and $\rho_j^* = 0$ is a local maximum provided $r(\theta, \alpha) > G$.

Claim 2F: There is no $\rho_i > \rho_j > 0$ for $i \neq j$ constituting a local maximum if the expected net social value $\sum_{k=1}^{2} \Big[\alpha\Big(\rho_k \varphi\big(v/\rho_k\big) - \Big(1 - \Phi\big(v/\rho_k\big)\Big)v\Big)\Big]$ has *one* local minimum on the closed interval $\rho_i \in [0, \bar{\rho}]$ for $\rho_j = \gamma(\rho_i, G)$.

Proof: A necessary condition for $\rho_i > \rho_j > 0$ for $i \neq j$ is that $\lambda > 0$; i.e. the budget constraint is binding (for otherwise $\rho_i^* = \rho_j^* = r(\theta, \alpha)$, see Claim A). Hence, $\rho_j = \gamma(\rho_i, G)$. For this to be a local maximum, a necessary condition for $\rho_i > \rho_j > 0$ for $i \neq j$ is that they also satisfy Eq. (27a). As shown in Claim 2E, part (b), $(\rho_i, \rho_j) = (\gamma(0, G), 0)$ already constitutes a local maximum for $\sum_{k=1}^{2} \Big[\alpha_k\Big(\rho_k \varphi\big(v/\rho_k\big) - \Big(1 - \Phi\big(v/\rho_k\big)\Big)v\Big)\Big]$ for $\rho_j = \gamma(\rho_i, G)$. There are two possible cases to distinguish.

- $\rho_i = \rho_j = \bar{\rho}$ constitutes a local maximum. Then, above assumption of only one local minimum requires that there are at most two local maxima of the expected net social value on the interval $[\gamma(\rho_j, G)\,,\, \bar{\rho}]$ for $\rho_i = \gamma(\rho_j, G)$. Therefore, as there are already two local maxima, $\rho_i > \rho_j > 0$ for $i \neq j$ satisfying $\rho_i = \gamma(\rho_j, G)$ and, at the same time, condition (27a) cannot constitute another local maximum but necessarily a local minimum.
- $\rho_i = \rho_j = \bar{\rho}$ constitutes a local minimum. Then, above assumption of only one local minimum requires that the expected net social value in monotonously decreasing in ρ_j on the interval $\rho_j \in [0\,,\, \bar{\rho}]$ for $\rho_j = \gamma(\rho_i, G)$. Therefore, there is no $\rho_i > \rho_j > 0$ for $i \neq j$ satisfying conditions (27a) – (27c).

In sum, the solution to the regulator's problem (3') is either $\rho_i^* = \rho_j^*$, or $\rho_i^* > 0$ and $\rho_j^* = 0$ for $i \neq j$.

Step 3 For $G = 2\overline{G}$, the expected net social value after deducting the cost of generating signals is

$$\sum_{i=1}^{2} \left[\alpha\Big(\rho_i \varphi\big(\frac{v}{\rho_i}\big) - \Big(1 - \Phi\big(\frac{v}{\rho_i}\big)\Big)v\Big) - f(\rho_i)\right]$$

$$= \begin{cases} 2\Big[\alpha\Big(r(\theta,\alpha)\varphi\big(\frac{v}{r(\theta,\alpha)}\big) - \Big(1 - \Phi\big(\frac{v}{r(\theta,\alpha)}\big)\Big)v\Big) - f\big(r(\theta,\alpha)\big)\Big] & \text{if} \quad \rho_1^* = \rho_2^* = r(\theta,\alpha) \\ \alpha\Big(r(\theta,\alpha)\varphi\big(\frac{v}{r(\theta,\alpha)}\big) - \Big(1 - \Phi\big(\frac{v}{r(\theta,\alpha)}\big)\Big)v\Big) - f\big(r(\theta,\alpha)\big) & \text{if} \quad \rho_i^* = r(\theta,\alpha) \text{ and } \rho_j^* = 0 \end{cases}$$

where the first line is the respective value for a symmetric treatment of FinTechs and the second line the respective value for an asymmetric treatment. Both values are positive, but the former is twice as large as the latter.

For $G = 2\underline{G}$, the expected net social value after deducting the cost of generating signals is

$$\sum_{i=1}^{2} \left[\alpha\Big(\rho_i \varphi\big(\frac{v}{\rho_i}\big) - \Big(1 - \Phi\big(\frac{v}{\rho_i}\big)\Big)v\Big) - f(\rho_i)\right]$$

$$= \begin{cases} 2\Big[\alpha\Big(\bar\rho\varphi\big(\frac{v}{\bar\rho}\big) - \Big(1 - \Phi\big(\frac{v}{\bar\rho}\big)\Big)v\Big) - f\big(\bar\rho\big)\Big] & \text{if} \quad \rho_1^* = \rho_2^* = \bar\rho = f^{-1}(G/2) \\ \alpha\Big(\rho_i^*\varphi\big(\frac{v}{\rho_i^*}\big) - \Big(1 - \Phi\big(\frac{v}{\rho_i^*}\big)\Big)v\Big) - f\big(\rho_i^*\big) & \text{if} \quad \rho_i^* = \min\{r(\theta,\alpha), f^{-1}(G)\} \text{ and } \rho_j^* = 0 \end{cases}$$

where the value in the first line (symmetric treatment) is zero (by definition of $\underline{G}$) and the value in the second line (asymmetric treatment) is strictly positive (since $2\underline{G} > \underline{G}$).

Therefore, by the intermediate value theorem, there are $G_{\text{crit},1} \in]2\underline{G}, 2\overline{G}[$ and $G_{\text{crit},2} \in]2\underline{G}, G_{\text{crit},1}]$ as defined in the Lemma.

E Proof of Proposition 2

1. The proofs of the Proposition's parts 1) and 2) are identical to the proof of their respective counterparts 1) and 2) in Proposition 1 (see Appendix C).

2. To prove part 3) of the Proposition, recall Proposition 1, part 2), and Lemma 4.

   Suppose a regulator overseeing potentially two innovative FinTechs, i. e. $m = 2$, is given a budget G that is exactly twice as large as if it were overseeing only one innovative FinTech, i. e. $m = 1$. Suppose also $\hat\theta - \theta < \varepsilon$ for some arbitrarily small ε. Then, $G/2$ is greater but arbitrarily close to $\underline{G}$ provided $\alpha_i = \alpha_j = a\big(R, f^{-1}(G/2)\big)$.

   While $\rho_i = \rho_j = f^{-1}(G/2)$ (just about) generates a positive net social value, it does not maximize welfare because according to Lemma 4, $G_{\text{crit}} > \underline{G}$ for every $\alpha_i = \alpha_j = \alpha$ including $\alpha_i = \alpha_j = a\big(R, f^{-1}(G/2)\big)$. Instead, $\rho_i^* > f^{-1}(G/2)$ and $\rho_j^* = 0$ if $\alpha_i = \alpha_j = a\big(R, f^{-1}(G/2)\big)$.

Therefore, $\alpha_i = \alpha_j = a\big(R, f^{-1}(G/2)\big)$ and $\rho_i = \rho_j = f^{-1}(G/2)$ does not constitute a Nash equilibrium under those circumstance.

Accordingly, by the intermediate value theorem, there is $\Theta < \hat{\theta}$ such that $\rho_i\rho_j = 0$ for all $\theta > \Theta$. Conversely, for every $\widehat{G} \in \mathbb{R}_{++}$ there is $\widehat{\Theta} \in]0, \Theta]$ such that $\rho_i^{\mathrm{e}} > \rho^{\mathrm{e}}$, $\alpha_i^{\mathrm{e}} > \alpha^{\mathrm{e}}$ and $\rho_j^{\mathrm{e}} = \alpha_j^{\mathrm{e}} = 0$.

Suppose $\theta < \widehat{\Theta}$. An additional condition for a symmetric *Nash* equilibrium with informed interventions is $N \geq \min\Big\{N \in \mathbb{Z}_{\geq 2} \,\Big|\, \big(1 - \Phi(v/\rho)\big)R - \ln\Big(\big(1 - \Phi(v/\rho)\big)R + 1\Big) \geq \eta^2/N^2\Big\}$, which is equivalent to $N \geq \mathcal{N}(R, \rho_i^{\mathrm{e}}) + 1$.

F Proof of Proposition 3

Proof.

1. Equilibrium choices satisfy $\alpha^{\mathrm{d}} \geq \alpha^{\mathrm{e}}_{\max}$, $\rho^{\mathrm{d}} \geq \rho^{\mathrm{e}}_{\max}$, and hence also $\mathcal{N}(R, \rho^{\mathrm{d}}) \leq \mathcal{N}(R, \rho^{\mathrm{e}}_{\max})$.

Step 1 Preliminaries

(a) Note that $\alpha^{\mathrm{e}}_{\max}\big(1 - \Phi(v/\rho^{\mathrm{e}}_{\max})\big)R - c\big(\alpha^{\mathrm{e}}_{\max}\big) \geq \alpha^{\mathrm{e}}\big(1 - \Phi(v/\rho^{\mathrm{e}})\big)R - c\big(\alpha^{\mathrm{e}}\big)$ for all $(\alpha^{\mathrm{e}}, \rho^{\mathrm{e}})$ by the Envelope theorem (applied for $\alpha^* = \mathcal{A}(\rho, N, R)$, considering changes in ρ).

(b) If $\alpha^{\mathrm{e}}_{\max} > 0$, there is $\bar{\alpha} \in]0, 1[$ defined by $\mathcal{P}(\alpha, \theta, G) = 0$ for all $\alpha < \bar{\alpha}$ and $\mathcal{P}(\alpha, \theta, G) > 0$ for all $\alpha \geq \bar{\alpha}$.

Step 2 Suppose there is only one *Nash* equilibrium in simultaneous games satisfying $\alpha^{\mathrm{e}} \geq \bar{\alpha}$ and $\rho^{\mathrm{e}} > 0$ and that (contrary to the claim above) $\alpha^{\mathrm{d}} < \alpha^{\mathrm{e}}_{\max}$, implying $\rho^{\mathrm{d}} = \mathcal{P}(\alpha^{\mathrm{d}}, \theta, G) \leq \rho^{\mathrm{e}}_{\max} = \mathcal{P}(\alpha^{\mathrm{e}}_{\max}, \theta, G)$. Since $\mathcal{P}(\alpha, \theta, G) > a^{-1}(R, \alpha)$ for all $\alpha < \alpha^{\mathrm{e}}_{\max}$ satisfying $\mathcal{P}(\alpha, \theta, G) > 0$, FinTech 1 can further increase its expected profits by setting $\alpha = a(R, \rho^{\mathrm{d}}) > \alpha^{\mathrm{d}}$, contradicting the initial claim that some $\alpha^{\mathrm{d}} < \alpha^{\mathrm{e}}_{\max}$ was maximizing expected profits for FinTech 1. Therefore, $\alpha^{\mathrm{d}} \geq \alpha^{\mathrm{e}}_{\max}$. Indeed, the first-order condition for FinTech 1's problem (15) evaluated at $\alpha = \alpha^{\mathrm{e}}_{\max}$ (and thus $\rho^* = \mathcal{P}(\alpha^{\mathrm{e}}_{\max}, \theta, G)$) implies (16). Therefore, $\alpha^{\mathrm{d}} = \alpha^{\mathrm{e}}_{\max}$ if and only if $\partial\rho^*/\partial\alpha = 0$ (i. e., if $\rho^{\mathrm{e}} = f^{-1}(G)$) and $\alpha^{\mathrm{d}} > \alpha^{\mathrm{e}}_{\max}$ otherwise; see LHS in

Step 3 Suppose there are two *Nash* equilibria in simultaneous games satisfying $\alpha^{\mathrm{e}} > 0$ and $\rho^{\mathrm{e}} > 0$. Let

$$\alpha^{\mathrm{e}}_{\min} := \min\Big\{\alpha \in]0, 1] \,\Big|\, \alpha = \mathcal{A}(\rho, N, R) \text{ and } \rho = \mathcal{P}(\alpha, \theta, G)\Big\}$$

$$\rho^{\mathrm{e}}_{\min} := \min\Big\{\rho \in]0, 1] \,\Big|\, \alpha = \mathcal{A}(\rho, N, R) \text{ and } \rho = \mathcal{P}(\alpha, \theta, G)\Big\}$$

By the arguments made in Step 2, a necessary condition for $\alpha^{\mathrm{d}} < \alpha^{\mathrm{e}}_{\max}$ is that $\alpha^{\mathrm{d}} < \alpha^{\mathrm{e}}_{\min}$. If that were true, it also had to be true that $\alpha^{\mathrm{d}} > a(R, \rho^{\mathrm{d}})$. However, by construction of $a(R, \rho)$,

$$a(R, \rho^{\mathrm{d}})\big(1 - \Phi(v/\rho^{\mathrm{d}})\big)R - c\big(a(R, \rho^{\mathrm{d}})\big) > \alpha^{\mathrm{d}}\big(1 - \Phi(v/\rho^{\mathrm{d}})\big)R - c\big(\alpha^{\mathrm{d}}\big)$$

and

$$\alpha^{\mathrm{e}}_{\min}\big(1-\Phi(v/\rho^{\mathrm{e}}_{\min})\big)R - c\big(\alpha^{\mathrm{e}}_{\min}\big) > a(R,\rho^{\mathrm{d}})\big(1-\Phi(v/\rho^{\mathrm{d}})\big)R - c\big(a(R,\rho^{\mathrm{d}}\big)$$

and

$$\alpha^{\mathrm{e}}_{\max}\big(1-\Phi(v/\rho^{\mathrm{e}}_{\max})\big)R - c\big(\alpha^{\mathrm{e}}_{\max}\big) > \alpha^{\mathrm{e}}_{\min}\big(1-\Phi(v/\rho^{\mathrm{e}}_{\min})\big)R - c\big(\alpha^{\mathrm{e}}_{\min}\big)$$

(the last inequality holds by the Envelope theorem). Accordingly, $(\alpha^{\mathrm{e}}_{\max}, \rho^{\mathrm{e}}_{\max}) \succ (\alpha^{\mathrm{d}}, \alpha^{\mathrm{d}})$ for FinTech 1. Therefore, the initial claim that $\alpha^{\mathrm{d}} < \alpha^{\mathrm{e}}_{\min}$ is false.

Step 4 In cases with more than two equilibria in simultaneous games satisfying $\alpha^{\mathrm{e}} > 0$ and $\rho^{\mathrm{e}} > 0$, the arguments put forward in Step 2 and Step 3 apply equivalently (i. e. Step 2 to all odd and Step 3 to even numbered equilibria, accordingly).

Step 5 Finally, suppose that $(\alpha^{\mathrm{e}}_{\max}, \rho^{\mathrm{e}}_{\max}) = (0,0)$. Since both, α and ρ are bounded to the closed interval $[0,1]$, it must be true that $\alpha^{\mathrm{d}} \geq \alpha^{\mathrm{e}}_{\max}$, $\rho^{\mathrm{d}} \geq \rho^{\mathrm{e}}_{\max}$.

All things considered, this proves that equilibrium choices satisfy $\alpha^{\mathrm{d}} \geq \alpha^{\mathrm{e}}_{\max}$, $\rho^{\mathrm{d}} \geq \rho^{\mathrm{e}}_{\max}$, and hence also $\mathcal{N}(R,\rho^{\mathrm{d}}) \leq \mathcal{N}(R,\rho^{\mathrm{e}}_{\max})$.

2. For every $G \in \mathbb{R}_{++}$ there is $\check{\theta} \in [\hat{\theta}, a(R,1)H[$ such that $\alpha^{\mathrm{d}} > 0$, $\rho^{\mathrm{d}} > 0$, and $n^{\mathrm{d}} = N-1$ for all $\theta \in]0, \check{\theta}[$ and $N \geq \mathcal{N}(R,\rho^{\mathrm{d}})$.
To prove this, let $\theta = \hat{\theta}$.

Step 1 Suppose $\rho^{\mathrm{e}}_{\max} = f^{-1}(G)$ such that $\big(\alpha^{\mathrm{e}}_{\max}, \rho^{\mathrm{e}}_{\max}\big) = \big(a(R, f^{-1}(G)), f^{-1}(G)\big)$ according to Proposition 1. Hence, $\big(\alpha^{\mathrm{d}}, \rho^{\mathrm{d}}\big) = \big(a(R, f^{-1}(G)), f^{-1}(G)\big)$ according to first-order condition (16). By the properties of f, $\partial f^{-1}(G)/\partial\theta < 0$ and, according to Lemma 2, $\partial a\big(R, f^{-1}(G)\big)/\partial\theta = a_\rho\big(R, f^{-1}(G)\big)\big(\partial f^{-1}(G)/\partial\theta\big) < 0$. Accordingly, by definition of $\hat{\theta}$ at least one of the following conditions is violated if $\theta - \hat{\theta} > 0$,

$$a\big(R, f^{-1}(G)\big)\Big(f^{-1}(G)\varphi(v/f^{-1}(G)) - \big(1-\Phi(v/f^{-1}(G))\big)v\Big) - G \geq 0 \tag{30}$$

or

$$a\big(R, f^{-1}(G)\big)\Big(1-\Phi\big(\tfrac{v}{f^{-1}(G)}\big)\Big)R - c\Big(a\big(R, f^{-1}(G)\big)\Big) \geq \frac{\eta^2}{(N+1)^2} \tag{31}$$

such that an equilibrium with informed interventions does not exist in simultaneous games.

As regards sequential games, however, note first that (by Lemma 2), $\rho^* > 0$ provided $\theta \leq H$ and if, additionally, α is such that $\alpha \geq \theta/H$ and $G \geq \underline{G}$. Let $\alpha_{\text{crit}} := \min\big\{\alpha \in]0,1[\,\big|\, \alpha \geq \theta/H \text{ and } G \geq \underline{G}\big\}$. If $\alpha_{\text{crit}} \neq \emptyset$ and

$$\alpha_{\text{crit}}\Big(1-\Phi\big(\tfrac{v}{\min\{f^{-1}(G), r(\theta,\alpha_{\text{crit}})\}}\big)\Big)R - c(\alpha_{\text{crit}}) \geq \eta^2/(N+1)^2, \tag{32}$$

then $\alpha^{\mathrm{d}} = \alpha_{\text{crit}} > 0$ even though $\alpha^{\mathrm{e}}_{\max} = 0$. Therefore, $\hat{\theta} \leq \check{\theta}$.

Step 2 Suppose $\rho^{\mathrm{e}}_{\max} < f^{-1}(G)$. According to part (1b), step 2, of this proof, $\alpha^{\mathrm{d}} > \alpha^{\mathrm{e}}_{\max}$ and $\rho^{\mathrm{d}} > \rho^{\mathrm{e}}_{\max}$. Accordingly, while

$$\alpha\Big(\rho\varphi(v/\rho) - \big(1 - \Phi(v/\rho)\big)v\Big) - f(\rho) \geq 0 \tag{33}$$

or

$$\alpha\Big(1 - \Phi\big(\tfrac{v}{\rho}\big)\Big)R - c(\alpha) \geq \frac{\eta^2}{(N+1)^2} \tag{34}$$

are binding at $\theta = \hat{\theta}$ for $(\alpha, \rho) = (\alpha^{\mathrm{e}}_{\max}, \rho^{\mathrm{e}}_{\max})$, neither condition (33) nor condition (34) is binding for $(\alpha, \rho) = (\alpha^{\mathrm{d}}, \rho^{\mathrm{d}})$. Therefore, in simultaneous games, either condition (33) or condition (34) or both are violated for any $\theta - \hat{\theta} > 0$, such that an equilibrium with informed interventions does not exist. However, in sequential games, condition (33) as well as condition (34) remain slack if $\theta - \hat{\theta} = \varepsilon$ for sufficiently small $\varepsilon > 0$, such that an equilibrium with informed interventions exists then.

3. Equilibria with informed interventions and equilibria with outright bans do not co-exist. Provided an equilibrium with $\alpha^{\mathrm{d}} > 0$ (and hence $\rho^{\mathrm{d}} > 0$) exist, it satisfies

$$\alpha^{\mathrm{d}}\Big(1 - \Phi\big(\tfrac{v}{\alpha^{\mathrm{d}}}\big)\Big)R - c(\alpha^{\mathrm{d}}) \geq \frac{\eta^2}{(N+1)^2} \tag{35}$$

Therefore, FinTech 1 is (weakly) better off than with $\alpha = 0$ (and hence $\rho = 0$). As FinTechs move before the regulator, FinTech 1 will opt for $\alpha^{\mathrm{d}} > 0$ and the regulator follows suit by setting $\rho^{\mathrm{d}} > 0$.

■

G Proof of Proposition 4

Proof. The proof is in two steps

Claim 1 Suppose $\alpha_1^{\mathrm{d,e}} > 0$ and $\alpha_2^{\mathrm{d,e}} > 0$ holds in equilibrium. Then, $\alpha_1^{\mathrm{d,e}} > \alpha_2^{\mathrm{d,e}} > 0$.

To show this suppose that $\alpha_2^{\mathrm{d,e}} = \alpha_1^{\mathrm{d,e}} > 0$. By Lemma 3, $\rho_2^{\mathrm{d,e}} = \rho_1^{\mathrm{d,e}} > 0$.

- If $f(\rho_1^{\mathrm{d,e}}) + f(\rho_2^{\mathrm{d,e}}) < G$, then $\alpha_2^{\mathrm{d,e}}$ satisfies the first-order condition

$$\Big(1 - \Phi\big(\tfrac{v}{\rho_2^{\mathrm{d,e}}}\big)\Big)R - c'(\alpha_2^{\mathrm{d,e}}) = 0, \tag{36}$$

that is, $\alpha_2^{\mathrm{d,e}} \leq \alpha^{\mathrm{e}}_{\max}$. With regards to $\alpha_1^{\mathrm{d,e}}$, given the regulator's budget is supposed to be slack, Proposition 3 applies accordingly. Hence, inequality (16) holds accordingly thus contradicting the initial claim $\alpha_2^{\mathrm{d,e}} = \alpha_1^{\mathrm{d,e}} > 0$.

- If $2f(\rho_1^{\mathrm{d,e}}) = G$, then $\rho_1^{\mathrm{d,e}} = \rho_2^{\mathrm{d,e}} = f^{-1}(G/2)$ according to Lemma 3. Hence, $\alpha_2^{\mathrm{d,e}}$ again satisfies the first-order condition (36). However, the disruptor's choice, $\alpha_1^{\mathrm{d,e}}$, satisfies

$$\Big(1 - \Phi\big(\tfrac{v}{f^{-1}(G/2)}\big)\Big)R + \alpha_1 R\varphi\big(\tfrac{v}{f^{-1}(G/2)}\big)\tfrac{v}{(f^{-1}(G/2))^2}\tfrac{\partial \rho_1^*}{\partial \alpha_1} - c'(\alpha_1)$$
$$> \Big(1 - \Phi\big(\tfrac{v}{f^{-1}(G/2)}\big)\Big)R - c'(\alpha_1) = 0$$

because provided the regulator spends equal amounts on signal precision for each FinTech, and if FinTech 2 would not respond further to any changes in α_1, we obtain $\partial\rho_i^*/\partial\alpha_i = -(\rho^*)^3/\big(2\alpha(v^2 - (\rho^*)^2/(1-\rho^*))\big) > 0$.[28] This effect will be further amplified by a lower α_2 in response to FinTech 2's reduced share in the regulator's budget, thus further increasing FinTech 1's share in the budget. Therefore, $\alpha_2^{\mathrm{d,e}} = \alpha_1^{\mathrm{d,e}}$ is not true.

Claim 2 Suppose $\alpha_1^{\mathrm{d,e}}\alpha_2^{\mathrm{d,e}} = 0$ holds in equilibrium. Then, $\alpha_2^{\mathrm{d,e}} = 0$.

The proof is by contradiction. Suppose $\alpha_2^{\mathrm{d,e}} > 0$. Then, $\alpha_1^{\mathrm{d,e}}\alpha_2^{\mathrm{d,e}} = 0$ requires $\alpha_1^{\mathrm{d,e}} = 0$. This implies that (N, θ, G) are such that it is profitable for a single FinTech to leave the established market and be observed by the regulator. If that is so, however, then $\alpha_1^{\mathrm{d,e}} = 0$ is not optimal:

- Suppose (N, θ, G) is such that besides symmetric outright bans symmetric informed interventions are possible equilibria in games with multiple innovative FinTechs moving simultaneously with the regulator (see Proposition 2, No. 3). Then, the *least* improvement a disruptor can do over not pursuing the innovation is setting $\alpha_1 = \alpha_1^{\mathrm{e}}$ and thus inducing regulator and follower FinTech 2 to set $(\rho_1, \rho_2) = (\rho_1^{\mathrm{e}}, \rho_2^{\mathrm{e}})$ and $\alpha_2 = \alpha_1^{\mathrm{e}}$.
- Suppose (N, θ, G) is such that besides symmetric outright bans only asymmetric informed interventions are the only possible equilibria in games with multiple innovative FinTechs moving simultaneously with the regulator (see Proposition 2, No. 2 except those characterized in No. 3). Then, the *least* improvement a disruptor can do over not pursuing the innovation is setting $\alpha_1 = \alpha_{\max}^{\mathrm{e}} > 0$ and thus inducing regulator and follower FinTech 2 to set $\rho_1 = \rho_{\max}^{\mathrm{e}}$, $\rho_2 = 0$ and $\alpha_2 = 0$.
- Suppose (N, θ, G) is such that only symmetric outright bans are equilibria in games with multiple innovative FinTechs moving simultaneously with the regulator (see Proposition 2, No. 1) but such that informed interventions are still an equilibrium in games with a single, disruptor FinTech moving before the regulator (see Proposition 3, No. 2). Then, the *least* improvement a disruptor can do over not pursuing the innovation is setting $\alpha_1 = \alpha^{\mathrm{d}} > 0$ and thus inducing regulator and follower FinTech 2 to set $\rho_1 = \rho^{\mathrm{d}}$, $\rho_2 = 0$ and $\alpha_2 = 0$.

■

[28] This expression is strictly positive as $(v^2 - (\rho^*)^2/(1-\rho^*)) < 0$ provided $\rho_i^* = \rho_j^* = f^{-1}(G/2)$ constitutes a maximum of the regulator's objective function, see Proof of Lemma 3.