THE EFFECTS OF PRUDENTIAL SUPERVISION ON BANK RESILIENCY AND PROFITS IN A MULTI-AGENT SETTING

Documents de travail GREDEG
GREDEG Working Papers Series

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GREDEG WP No. 2015-24
http://www.gredeg.cnrs.fr/working-papers.html

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THE EFFECTS OF PRUDENTIAL SUPERVISION ON BANK RESILIENCY AND PROFITS IN A MULTI-AGENT SETTING

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GREDEG Working Paper No. 2015-24

Abstract

This article studies the effects of prudential supervision on bank resiliency and profitability within an agent-based framework that allows us to simulate persistent crisis conditions. It focuses on the stabilizing effect of prudential supervision introduced alongside three "traditional" regulatory instruments: a norm, a market-based CDS insurance mechanism and a tax in the form of a bail-in instrument. The results show that: (i) supervision enhances the regulatory instruments’ efficiency, (ii) the regulatory norm can postpone the bank’s default, but not avoid it, (iii) the CDS mechanism only produces positive results on resiliency and profitability if the regulator supervises, and (iv) the tax bail-in instrument is the most powerful tool in the regulator’s arsenal as it potentiates profitable bank operation under long-lasting crisis conditions.

Keywords: Prudential supervision; Banking system supervision; Financial institution regulation; Agent Based Modeling; Multi-Agent Simulation;

JEL classification: C63; E65; G28
1. Introduction

The 2008 financial crisis highlighted the weakness of the deregulated financial system within an environment of growing risk and convoluted market instruments that failed to achieve their objective of risk diversification. Concurrently, the crisis revealed that traditional theoretical and empirical models were ill adapted to crisis conditions and produced flawed results especially at turning points in the economic cycle.

As a consequence of the severe economic recession that followed the 2008 crisis, regulators in western economies and the United States concentrated their focus on the re-regulation of the financial sector. The theoretical and empirical literature largely followed suit. Whereas some researchers focused their attention on traditional prudent abol tools such as capital requirements and how they may be improved in order to produce a less pronounced restrictive effect on credit and growth, others began to investigate whether alternative instruments and transmission channels could be used to ensure the same objective of risk reduction, but with lesser negative consequences. In this context, increasingly growing attention has been given to the role of prudential supervision both in directly ensuring the regulatory objective of risk reduction, as well as in complementing and increasing the efficiency of other instruments implemented by the regulatory authority.

Indeed, recent papers such as Delis and Staikouras (2011) begin to question the effectiveness of traditional tools such as capital requirements in reducing risk. As an alternative, they focus on the efficiency of prudential supervision in terms of bank audits and sanctions. They find that the usage of such “alternative” tools contributes significantly towards ensuring the stability of the financial system where more “traditional” instruments such as capital requirements falter. Hardy and Nieto (2008) suggest that increased supervisory stringency contributes positively towards risk reduction and therefore improves the stability of the financial system. The prudential effect of supervision is confirmed by Bassett et al. (2012) who conclude that increased supervisory stringency increases the quality of loans by incentivizing banks to lend to relatively risk-free clients. Aside from the direct effect of supervision on risk reduction, the role of prudential supervision in complementing other instruments is also documented in the literature. Ratnovski (2013) finds that it is possible, by means of using “alternative” regulatory methods geared towards increasing transparency in the banking sector, to improve the resiliency of the sector to shocks, as well as to enhance the efficiency of prudential instruments such as the liquidity ratio. Furthermore, Maddaloni and Peydro (2013) argue that reducing supervisory stringency diminishes the risk of a credit crunch appearing under tighter lending conditions resulting from higher capital requirements or liquidity ratio constraints. Their conclusions are of particular interest since they are indicative of supervisory measures and traditional macro-prudential tools coexisting and producing better results when coordinated and utilized together.

The objective of this paper is to look in more detail at the effects of prudential supervision introduced alongside regulatory instruments in an environment of persistent crisis conditions. We do so within a multi-agent framework that allows us to better integrate the persistent crisis conditions into the model and to study the behavior of the financial sector. Persistent crisis conditions in the model are defined as a situation in which the proportion of high risk clients in the economy remains elevated even after an initial

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1 See Agenor and da Silva (2011), Gertler and Kiyotaki (2010), Benigno et al. (2012) for examples of prudential instruments such as Loan-to-Value (LTV) ratios, liquidity and reserve requirements.
shock, thereby placing a strain on the bank’s ability to cope with its clients’ defaults. We focus on the effects of different prudential supervision configurations on bank profitability and default rates. The study is conducted in an environment of costly monitoring and informational asymmetry where the bank is unable to gauge the exact risk level of its clients. As such, the model simulates the bank’s response and financial situation under long-lasting crisis conditions and determines whether the prudential regulator is able to offset the negative effects of persistent crisis conditions. We focus specifically on crises emerging from the default of the bank’s debtors when the bank is faced with severe liquidity shortfalls.

We adapt Diamond’s (1984) “Financial intermediation and Delegated Monitoring” framework to a multi-agent setting consisting of the bank, its clients, the prudential regulator (that can coincide with the Central Bank) and, where applicable, an insurance agency that will interact in the economy. We calibrate the model based on IFC data and the data resulting from empirical studies related to the subject.

We put three “classic” visions of regulatory intervention to the test: a simple prudential norm, a tax-subsidy mechanism and a market-based CDS insurance scheme. These instruments will fulfill the prudential objective of the regulator and may be regarded as alternatives to the commonly used prudential measures of the Basel frameworks. We adapt the tax-subsidy mechanism to reflect a “bail-in” instrument, as the one recently proposed to deal with the financial crisis in Cyprus. Whereas it is evident that the bank is always better off when the prudential supervisor intervenes, it would seem that different supervisory techniques are better adapted to various economic conjunctures.

Imposed regulatory norms that include credit-rationing provisions only have temporary stabilizing effects on the economy in crisis situations and inevitably falter and allow the bank to default when the credit rationing becomes more stringent. More advanced monitoring techniques used by the bank can extend the stabilizing effect of the supervisory mechanism to a longer period of time, but with unchanged finality. Still, provided that the bank has access to sufficient market information to formulate a more advanced monitoring plan, the norm’s effect may last long enough to steer the bank out of a crisis situation. Of course, such methods bear the advantage of not imposing any burden on the tax-payer, but require that the prudential institution determine an appropriate numerical value for the norm that would balance the risk level undertaken by the bank with the activity-stifling effects of credit rationing.

A market based CDS mechanism curated or supervised by the regulator can serve as an equally powerful tool and may be even better adapted to situations where the bank is able to integrate sufficient information about its clients to formulate advanced monitoring methods. Unlike the norm which imposes the bank to follow a prescription, this mechanism incites the bank to participate with the prospect of cost-reduction. Being market based, the mechanism allows for price fluctuations of the CDS instrument according to the bank’s demand. The efficiency of such a system that allows the bank to insure against the risk of its clients’ default is highly dependent on the bank’s ability to integrate the price structure of the insurance instrument. Under the assumption of limited bank access to information, it is impossible for the bank to accurately deduce the price structure – which leads to inefficient allocation of (CDS purchase) funds.

2 The bail-in mechanism was proposed by the European Commission and the ECB to deal with the banking sector crisis in Cyprus in March 2013 (see Ewing (2015) and Gumbel (2013) who reported on the issue). Since then, the idea of using bail-in instruments has become more widespread in Europe, as evidenced by the European Bank Rescue Plan (see Petroff (2013) ) and the ongoing efforts of tracking down various bail-in style rescue plan implementations, similar in nature, but sometimes differing in scope or instrumentation from that of Cyprus (see Snyder (2013) ).
Given its unconstrained access to information in the economy, the supervisor’s role is to observe the bank’s decision model and to correct it by serving as an intermediary between the bank and the CDS market, guiding the bank’s decision towards the optimal level. Indeed, provided that the bank has an advanced client monitoring method, it seems that market-based mechanisms are more efficient at stabilizing the bank’s situation and at eliminating the negative effects of the crisis conditions by reducing the bank’s costs associated with the defaults of its clients. In fact, the bank can operate at increasing profit under long-term crisis conditions when such a supervisory system is applied. It must be noted, however, that if the bank operates an uninformed monitoring model, the market based method performs worse that even the regulatory norm. This is caused by the bank’s inability to correctly allocate resources between its monitoring and CDS-purchasing activities. For the same reason, the sole introduction of a CDS mechanism without regulatory supervision to guide the bank in its CDS purchasing choice results in a worsening of the bank’s financial situation.

Finally, the tax-subsidy instrument taking the form of a “bail-in” mechanism in which it is those who benefit from the bank’s credit activities that are also expected to contribute towards saving the bank when it encounters difficulties - seems to be the most powerful tool in the regulator’s arsenal. The role of the supervisor here is to monitor the bank’s financial situation and implement a tax on borrowers when the bank reaches dire conditions. Here, the entirety of the social cost (of the bank’s default) is borne by the production sector. This method is efficient under all circumstances and regardless of the complexity of the bank’s monitoring method and the underlying informational asymmetries present in the economy. The major drawback, however, of this method is that it imposes a very high cost on the firms’ profits, with taxes having, at times, to reach close to 100% of the firm’s profits in order to ensure the safety of the financial intermediary. Also, this method creates very high fluctuations both in the bank’s revenues, as well as in the instrument itself. This can be a negative factor if the prudential regulator is also the Central Bank and pursues a concurrent objective of stability in the economy. It is also noteworthy to mention that whereas the efficiency of this method generally allows the bank to continue operating at a profit under conditions of long-term financial crisis (unlike the only temporary effects of the prudential norm), due to the fluctuations caused by the system, the bank risks plunging into negative territory in terms of liquidity and may require additional punctual credit facility interventions from the Central Bank in order to continue operating.

Therefore, we find that prudential supervision serves to improve the financial situation of banks faced with long-lasting crisis conditions. The method of choice, however, depends on the objectives pursued by the prudential regulator, its interactions with the Central Bank and the monitoring efficiency of the banking sector.

The rest of this paper is structured as follows: Section 1 has provided an introduction into the importance of studying the effects of supervision on the resiliency of the banking sector. Section 2 presents the structure of the model, the various interacting agents, and explains the functioning and processes that determine the dynamics of the model. Section 3 explains the various regulatory set-ups envisaged and provides in-depth simulation results for both the baseline scenario, as well as for the model runs containing prudential supervision. Finally we conclude by presenting the main findings of our paper.
2. Purpose, Agents and Agent Variables

Within the model we will have three “main” types of agents: the firms, the investment bank, the Prudential Regulator and one auxiliary agent: the CDS fund, whose presence is conditional upon the usage of CDS instruments in the Prudential Regulator’s toolset. It is noteworthy that in many advanced economies, the Central Bank coincides with the prudential regulator thereby giving the regulator additional tools that can be used in unison. To this matter, Schoenmaker (2011) presents a detailed depiction of the regulatory structure of multiple countries. However, we note that it is not our objective to study monetary policy and the specific instruments associated with it for the purposes of this simulation, and we will only make brief general remarks about it where necessary.

2.1. Purpose

The purpose of this model is to study the extent to which prudential supervision accompanied by regulatory instruments can serve to improve the bank’s financial situation in terms of profitability and liquidity, as well as the efficacy of such measures in reducing the number of bank default episodes in the context of long-term and short-term crises.

To define a banking crisis we may look at Northcott (2004) who, in a Bank of Canada Working Paper, states that banking crises represent episodes of either financial institution insolvency or illiquidity. Concurrently, Angkinand and Wihlborg (2005) and Duttagupta and Cashin (2008) propose that banking crises appear when the bank loses most or all of its reserve assets, capital or liquidity. Given the setup of our model, we will be focusing primarily on liquidity issues that the bank may face as a result of the crisis situation. We will therefore define a crisis situation as the instance in which a bank is facing a severe liquidity shortfall and has a client portfolio of doubtful quality. These are the two necessary conditions for a crisis to emerge. With respect to the bank’s liquidity, we will allow for the bank to have just enough resources to finance one last group of clients. This condition is required for the model to be able to initialize. However, the presence of lower-quality clients with higher default probabilities in the bank’s portfolio will then contribute to a potential further deterioration of the bank’s financial standing. This will allow us to introduce prudential supervision under different forms and gauge its overall effectiveness under conditions of both short-term and long-term crises.

The length of a crisis will depend primarily on the behavior of the bank’s clients and the risk level of the projects that they decide to undertake. During crises, it is assumed that a significant number of agents have undertaken projects of high risk, thereby compromising the stability of the bank. If, subsequently, the agents tend to rapidly converge towards undertaking projects of moderate or low risk – then we can conclude that we have been faced with a short-term crisis, or a crisis episode. Once the crisis event has passed, the bank should, by means of its regular credit activities, be able to replenish its liquidity reserves and continue operating at a profit. If, on the other hand, we do not see a clear tendency of the agents to converge towards some equilibrium and their project risk levels continue to fluctuate over time, then we are to conclude that the underlying conditions causing the crisis have not dissipated and that we are confronted with a long-term (or enduring) crisis which may have negative long-term effects on the bank’s financial indicators or even pose a threat to the bank’s existence. We do not delve into the factors that have generated the crisis. Instead, we utilize the dynamics of the firms’ project decisions as a consequence of the crisis situation to investigate the bank’s behavior. The firm dynamics influence the
bank’s response to the crisis and allow us to study how the prudential authority can improve the bank’s situation by implementing prudential supervision and instruments.

2.2. Firms

The firms in our model represent the bank’s clients. True to Diamond’s (1984) formulation, each firm requires one unit of bank credit in order to finance a project that has a certain probability of success in the next period. In the event of success, the firm obtains a reward allowing it to reimburse the bank loan and maintain a profit, whereas failure is characterized by a situation in which the firm obtains a reward equal to the loan amount, thus rendering impossible the repayment of the interest on the contracted loan. The structure of the firm’s risk-reward configuration is given by:

\[
V = \begin{cases} 
V_H & \text{with probability: } (1 - p) \\
V_L & \text{with probability: } p 
\end{cases}
\]

(1)

Where \(V_H\) is the “high” reward in the event of success, \(V_L = 1\) is the “low” reward in the event of failure, \(p\) is the probability of default and \((1-p)\) is the probability of success.

We notice that, as in Diamond, the bank is able to liquidate the firm if it does not pay back an amount \(f\) that at the very least equals the bank’s invested unit plus interest spent on crediting the firm. This dispels any attempt of the firm’s management to announce earnings lower than the bank’s expected payoff \(f\), which depends upon the economy’s interest rate \(R\), as well as the default probability \(p\) of the project that was undertaken by the firm. As such:

\[
f = \frac{R}{p} \iff R = p \times f
\]

(2)

As we can see, this condition reflects the risk neutrality of the bank which expects to obtain, on average, the (base) interest rate \(R\) in exchange for crediting a firm’s project of \(p\) riskiness.

A resulting firm variable is the profit that the firm obtains after paying back the bank’s loan. It is expressed as: \(\pi_f = V_H - f\) in the case of success, whereas if the firm defaults and is liquidated by the bank, its profit is null \(\pi_f = 0\).

In our model, the origins of the crisis that the bank is confronted with stem in part from its client portfolio. We assume that in times of crisis, the bank is confronted with clients of different risk levels, with some significant presence of high-risk project-bearing clients. This means that we must depart from Diamond’s framework and divide the clients into multiple risk groups. We find that it is more commonplace to divide bank clients into 3 credit risk-groups: low, medium and high-risk clients, although more detailed classifications also exist. For instance, Experian (2014) and CA Technologies (2014) prefer to use 3 risk groups in their credit risk assessment models and their project risk scores. On the other hand, PricewaterhouseCoopers utilizes a finer categorization totaling 5 risk levels, as described in Gillespie et al. (2010). The theoretical literature also seems more inclined towards the usage of 3 categories. This is best illustrated in an IFC study performed by Dickson and Einstein (2010). For the purposes of our model, we shall retain the 3 group classification as we have no need to delve into the level of precision that a 5 group classification would offer.
With respect to the probability of default variable, we shall calibrate our model based on the data provided in the IFC study. We notice the probabilities of default, which in our model will also determine the firm’s reward, in the following table:

*Table I. Client risk-groups classified by probability of default*

<table>
<thead>
<tr>
<th>Risk-Group</th>
<th>Probability of Default (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>$p_h$</td>
</tr>
<tr>
<td>Medium</td>
<td>$p_m$</td>
</tr>
<tr>
<td>Low</td>
<td>$p_l$</td>
</tr>
</tbody>
</table>

source: Dickson and Einstein (2010)

*Table I presents the probability of default intervals for the bank’s low, medium and high risk clients.*

Besides the firm’s individual probability of default, recognizing the fact that the majority of firms have some sort of linkages with counterparts of various nature (competitors, partners, clients, etc.), as evidenced by Koenig et al. (1979), we introduce a global probability of default calculated as the average of the firms’ individual default probabilities. This global variable will influence the individual probability of default by a measure $\varphi \in [0 ; 1]$ whereby a value of $\varphi = 0$ means that the global variable exerts no influence whatsoever on the individual firm’s probability of default and an extreme value of $\varphi = 1$ would amount to the individual firm’s probability of default value coinciding with the global one.

Deriving from the riskiness of an undertaken project, the reward in case of success ($V_H$) for each firm will be given by:

$$V_H = \frac{R}{1 - \bar{p}_g} + R \times \bar{p}_g$$

Where $\bar{p}_g$ is the average probability of default for the given group $g = \{h, m, l\}$. And we remind that $V_L = 1$ in all instances of default and for all risk groups.

Depending on their probability of default, each period, the firms will either succeed or default. This reflects a one-period credit maturity that applies throughout the model. In the event of success, the firm is likely not to change project risk groups, but we account for a small chance that the firm manager may voluntarily wish to change project types (for personal reasons, because he believes that firms pursuing other project types are more profitable, etc.). This small chance is determined by a group cohesiveness variable ($\gamma$). If the firm defaults, however, a new agent will appear in place of the old one with a potentially different type of project.

2.3. Bank

In our model, the investment bank is the sole source of funding in the economy. It provides entrepreneurs with financing so that they can implement their projects. The bank starts off in a crisis situation with low liquidity reserves and an unsound client portfolio. Our bank acts as an investment bank. Hence to avoid the issues arising from the moral hazard that the bank may manifest as a result of catering both to its investors and acting for its own account, the bank funds clients utilizing only its own resources. This type of modeling approach allowing for a segregation of the bank’s investment activities from its deposit unit
in order to study more minutely the bank’s own investment decisions can be found in papers such as de Walque (2010). By reducing the number of processes and actions to be modeled, this framework presents the advantage of focusing our work on the area of prudential supervision without worrying about adverse selection issues on the bank’s behalf, but prevents us from implementing leverage-dependent regulatory tools.

In terms of its activity, the bank undergoes a series of processes through which it manifests its credit, monitoring and corrective actions.

![Figure 1. Bank decision processes](image)

*Figure 1 displays the two initial decision processes that the bank undergoes with respect to crediting its new clients and subsequently deciding on the number of clients to monitor, as well as the three potential corrective actions that it may take as a result of Central Bank supervision that it undergoes.*

The bank initially finances all of its clients, since it cannot determine which (if any) of its clients undertake high-risk projects.

Subsequently, the bank monitors a portion of its clients. Monitoring is assumed to be costly, as evidenced by the literature on the matter. Booth (1992) confirms Diamond’s (1984) assumption of high monitoring costs. However, monitoring allows the bank to recover the unit invested into the client (firm) and to avoid additional costs (such as costs arising from reputation loss, etc.). In fact, the role of monitoring in reducing client default costs is evidenced in multiple studies. Baxter (1967) estimates bankruptcy costs at around 20% of the market value of a client. Stanley and Girth (1971) and Van Horne (1976) later confirm this result. Furthermore, it would seem that financial institutions must also deal with reputation costs arising from the default of their clients. These costs are also proven to be considerable as shown in Infosys (2012) and Deloitte (2014). However just as with bankruptcy costs, they can be reduced via monitoring, as described by Gopalan (2010) and Lin (2011). Furthermore, Vanston (2012) provides evidence that Central Bank supervision may also serve to reduce reputational costs incurred by the bank as a result of its client’s default. Finally, Barnett and Harder (2014) argues that banks that do not monitor may be faced with negligence charges in lawsuits initiated by the defaulted clients. The only way of eliminating such costs is for the bank to monitor its client. As we have seen, there is ample incentive for the bank to monitor, however depending on information that the bank has of its clients the decision process may be more subtle. In our model we are able to vary monitoring costs in order to determine their impact on the bank’s financial situation and monitoring decision.

The bank disposes of several monitoring techniques that it may use depending on the informational asymmetries associated with the economy in which it operates. If the bank suffers severe informational
asymmetries that prevent it from gaining ex-post precise insights into the risk-level of the clients that it credits, then the bank adopts an approximate method of monitoring based largely on the information that it can obtain from the clients that it monitored in the previous period. If informational asymmetries are relaxed and the bank is able to obtain information about a larger portion of its clients, then the bank can implement more advanced monitoring techniques, such as expecting that some clients will remain stable, being more vigilant towards both high-risk and brand-new clients that emerge as a result of firm defaults. These more advanced techniques allow the bank to better adapt to the economic context that it finds itself in and allow for a more efficient usage of the expensive monitoring process.

With respect to agent variables, for our study of the bank’s financial standing, we focus on three key indicators that reflect the bank’s situation: the number of default episodes, the bank’s total liquidity and the ROI (Return-on-Investment). The ROI follows the evolution of the profit variable very closely and we will primarily be using it as a control variable. As such we will refer to it only very briefly. A default episode is defined as being a time period (year) at the end of which the bank has negative liquidity. This indicator is a measure of the length of the bank’s distress and, consequently, of the severity of the crisis. For simulation purposes we allow the bank to continue operating even at negative liquidity, but count the period with negative liquidity as a “bank default episode” which would otherwise have led to the failure of the bank and a halt of all its operations. Such an assumption would be justified if the bank had access to some form of external credit (perhaps a credit line of last resort) that it could contract in the event of illiquidity. However, as documented by Allen et al. (2009) as well as by Freixas et al. (2011), it is often the case that during systemic banking crises, financial institutions are unwilling to lend to one another and the interbank market often dries up – thus confronting the individual bank with a lack of external funding options. Still, the bank could be allowed to temporarily continue operating at a loss in the instance in which the Prudential Regulator coincides with the Central Bank and has the option of extending exceptional credit facilities to the afflicted financial institution.

The bank’s total liquidity indicator gives us a sense of the bank’s capacity to finance new clients and perform the various monitoring and, if required by the regulator, insurance activities. This is our indicator of the financial institution’s health. The prudential regulator (usually the Central Bank with regulatory functions) may act upon this variable by providing the bank with stimulus, if such an intervention method is chosen. Finally, the ROI may be of interest since it gives us an indication of the bank’s profitability. It is one of the indicators commonly used to compare the performance of both corporate and banking sector entities.

A sketch of the bank’s simplified income statement could be depicted as follows, including the elements related to the regulator’s intervention:
Table II. Bank income statement

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td></td>
</tr>
<tr>
<td>Interest (including principal reimbursement) paid by clients</td>
<td></td>
</tr>
<tr>
<td>Revenue from monitoring in the event of client defaults</td>
<td></td>
</tr>
<tr>
<td>Regulator’s liquidity injections</td>
<td></td>
</tr>
<tr>
<td>Expenses</td>
<td></td>
</tr>
<tr>
<td>Cost of crediting new clients</td>
<td></td>
</tr>
<tr>
<td>Costs of client defaults</td>
<td></td>
</tr>
<tr>
<td>- bankruptcy cost</td>
<td></td>
</tr>
<tr>
<td>- reputation cost</td>
<td></td>
</tr>
<tr>
<td>- negligence cost</td>
<td></td>
</tr>
<tr>
<td>Monitoring costs</td>
<td></td>
</tr>
<tr>
<td>Insurance costs (if required by the regulator)</td>
<td></td>
</tr>
<tr>
<td>Revenue — Expenses</td>
<td>Profit</td>
</tr>
</tbody>
</table>

Table II details how the bank’s profit is formed, by component. As such, it presents the variables that constitute the revenues and expenses of the bank.

As for variables pertaining to the bank’s internal processes the bank also chooses the number of clients to monitor within its monitoring function, and if a CDS insurance mechanism is implemented by the regulator, then the bank will also choose the number of CDS units to purchase. On the other hand, if the prudential authority enforces supervision of a regulatory norm regarding the number of clients that the bank must monitor, then the bank will also dispose of a variable that allows it to calculate the number of clients (if any) that it must abandon in order to conform to the norm, subsequently utilizing an internal process to determine which clients to abandon.

2.4. Prudential Regulator

The Prudential Regulator (in the literature, often coinciding with the Central Bank) performs both supervisory and intervention functions. One of the main roles of the regulator is to observe the bank’s financial situation, as well as the decisions that it makes in order to ensure its uninterrupted operation. This means that the regulator will be privy to all the internal operations of the bank, its processes and variables. On the other hand, the regulator may also lead to take corrective action to resolve deficiencies that it observes. Herein lies its second role of actively pursuing the implementation of the chosen regulatory method. We propose three different models of regulatory supervision and intervention that cover the “traditional” intervention mechanisms studied in the literature on market regulation, adjusted for some newer methods of banking crisis resolution circulated within the EU. We provide a brief description of each method here in order to introduce the associated variables and processes and further expand the subject in its appropriate section.

The first regulation method tasks the prudential regulator with supervising the bank’s financial variables and determining if the bank may be faced with a problem of illiquidity. If, indeed this turns out to be the case, then the regulator (either by coinciding or by coordinating with the Central Bank) will perform a
liquidity injection into the bank to save it. We implement the liquidity injection as a “bail-in” instrument to resemble the EU creditors’ proposition in the case of the Cyprus bank defaults of 2014. However in our case we consider a tax on firms’ profits. The reasoning behind this is that, as in any bail-in instrument, it is those who benefitted from the activities of the bank that must contribute towards saving the bank, should the financial institution encounter difficulties. And, in the model we present, it is specifically the firms who benefit from bank credit that enables them to obtain profits. Consequently, it is only fair that they support the burden of the bail-in mechanism. The regulator determines the amount of liquidity needed by the bank in order to avoid a default and imposes a tax on firms’ profits. This tax is stored in a variable that the regulator will control. The tax evolves in fixed increments. As such, if the regulator raises slightly more money than what is required to save the bank, then the remainder of the taxation proceeds is deposited in a reserve fund. If, after having subjected firms to the maximum imposition level, the regulator is still unable to save the bank, then the regulator will utilize the previously accumulated reserve funds. Finally, if after having depleted its reserves, the regulator is still unable to save the bank, then the bank will be allowed to default.

A second method involves the creation of a CDS insurance market to allow the bank to hedge against the risk of default of its clients. An insurance fund is created and will control the CDS price variable which will depend on the bank’s demand for CDS units. The bank, which, as mentioned earlier is confronted with informational asymmetries, is unable to correctly integrate the price structure of the CDS instrument. This opens up the way for the regulator which will now be tasked not only with supervising the bank’s financial indicators, but also with overseeing the CDS market and helping the bank to integrate information about the price structure of the CDS tool. The regulator’s intervention is performed by a sub-model through which it determines the optimal quantity of CDS units that the bank must demand in order to minimize its costs for any given objective level (in terms of risk reduction). This means that within this supervision method, the regulator obtains an additional variable that stores the optimal quantity of CDS units that the bank must purchase. Furthermore, the prudential authority communicates this value to the bank which corrects its own value of CDS units to purchase.

The third regulatory method involves the implementation of a monitoring norm that constrains the bank to monitor a given number of clients each turn. Failure to do so results in an immediate termination of the bank’s activities. In this situation, the norm may be fixed, or it may be enunciated as a percentage of the total number of clients that solicit bank credits. Although time invariant, the norm can be considered as an additional regulator variable that is controllable by the observer and is set at the beginning of the simulation. It must be noted here that a smaller number of clients to monitor reduces the financial strain placed on the bank by the regulator by means of reducing the per client monitoring costs that the bank supports. However, the reduction in the regulatory number of clients to monitor also reduces the efficiency of the method since it increases the chance for non-monitored firm failures to appear. This method could be expanded to include sanctions for non-conformity as opposed to immediate termination, but that would somewhat undermine the strictness of the norm and would allow the bank to disregard regulation as it sees fit – which is contrary to what the regulator hopes to achieve by introducing the norm.
3. Model and Simulations

Before we can proceed to the simulations, we must first take a look into the scheduling of the various processes described in the first part of the article, as their order will impact the functioning of the model.

3.1. Model structure and initialization

Initially, in the very first period \((t_0)\), the bank is endowed with sufficient liquidity to finance all of its clients. Optionally, the bank can be bestowed with some extra liquidity above its strict minimal necessity in order to avoid the bank defaulting in the immediately subsequent period as a consequence of a random or chance event. Still the extra cash assigned must be limited in size given the fact that we are modeling a liquidity-constrained bank in the middle of a crisis. If, because of the selected monitoring algorithm, the bank also needs to expend resources on monitoring during the setup phase, then those costs will also be covered.

Clients are generated according to the setup conditions where the observer determines the proportion of low, medium and high risk clients in the economy. The clients determine their desired risk level within the confines of their risk-group which translates into their individual probability of default. Afterwards their actual probability of default is automatically determined based on their individual characteristic, the global default probability and \(\varphi\).

Finally, the bank credits the new clients and, if required by its algorithm, proceeds to immediately monitor the firms.

The described structure will also be present in the following periods, however a number of new elements will be introduced. The following table illustrates the timing of the processes in all subsequent periods and focuses on the bank’s monitoring processes, as well as on the regulator’s supervision. The line number represents the order in which the events are processed. We begin by determining the project realizations of the firms credited in the previous period and then proceed to operating with the (new) clients that the bank is faced with in the current period.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Event title</th>
<th>Event description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project realizations become known to the firms</td>
<td>Some firms (mostly the ones with higher probabilities of default) will go bankrupt (obtaining (V_L &lt; f)), whereas the others will obtain positive rewards such that (V_H &gt; f).</td>
</tr>
<tr>
<td>2</td>
<td>Statistical data is gathered by the regulator</td>
<td>The regulator now knows information about the defaulted clients, their number, group origins, whether they were monitored by the bank or not, etc.</td>
</tr>
<tr>
<td>3</td>
<td>The bank’s financial situation is updated</td>
<td>All non-defaulted clients pay the bank its expected payoff ((f)), defaulted but monitored clients reimburse the borrowed unit of credit (but without interest) and the bank suffers default penalties for the defaulted and</td>
</tr>
<tr>
<td>Events related to the current period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. New clients appear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- clients are reset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- their new risk group is determined  (if it changed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- their probability of default is determined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defaulted clients will be replaced with new clients. Successful firms will tend to undertake new projects of the same risk-level as before. However, some of the successful firms may decide to change risk level for various random internal reasons or (in the case of more advanced firm rationality algorithms) because of external linkages with other firms.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Bank crediting operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The bank credits its new clients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Bank monitoring occurs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The bank decides how many clients to monitor and (informational asymmetry levels allowing) determines specifically which clients to focus its efforts on.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Regulatory supervision occurs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The prudential authority (or the Central Bank) monitors the bank’s situation and determines its viability. If necessary, the regulator intervenes by utilizing the instruments available to it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Has the bank defaulted?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After all is said and done, we look at whether the bank survived the tribulations of the current period or whether it succumbed to the pressures facing it. We register the eventual default of the bank and either allow the model to continue or stop it (according to our setup).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Verification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>We verify some of the variables dynamically calculated throughout the model to check for errors.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Plotting and graphs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>We display the results of the model within the graphical interface.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table III presents the sequence of events that comprise the foundation of the model. These processes are executed in the same sequence within each time period of the model. The events are grouped into 3 categories: one related to processing previous-period information, another to performing current-period actions and a third that comprises auxiliary functions.

This sequence of events will repeat every time step and will allow us to study the dynamics of the system by observing the outcomes of the agents’ behaviors under different circumstances. In what follows, we will present in detail the simulation results for each of the three regulatory scenarios and will investigate the effect of different parameter values on the evolution of the system. We will be most interested in varying those parameter values for which there is either limited scientific coverage or for which multiple potential values are suggested by the literature.
3.2. Baseline scenario and bank monitoring

We define the baseline scenario, which will later on be expanded by including regulatory supervision, as a model simulation with no bank monitoring or regulatory intervention, taking place in a system characterized by the following parameter values:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Number of clients</td>
<td>121</td>
<td>R</td>
<td>Interest rate</td>
<td>1.05</td>
</tr>
<tr>
<td>NL</td>
<td>Low-risk clients</td>
<td>30%</td>
<td>k</td>
<td>Initial bank liquidity</td>
<td>12</td>
</tr>
<tr>
<td>NM</td>
<td>Medium-risk clients</td>
<td>55%</td>
<td>mc</td>
<td>Cost of bank monitoring</td>
<td>0</td>
</tr>
<tr>
<td>NH</td>
<td>High-risk clients</td>
<td>15%</td>
<td>bc</td>
<td>Bankruptcy costs</td>
<td>0.2</td>
</tr>
<tr>
<td>φ</td>
<td>Influence of global default rate</td>
<td>0.1</td>
<td>rc</td>
<td>Reputation cost</td>
<td>0.2</td>
</tr>
<tr>
<td>γ</td>
<td>Group stability parameter</td>
<td>75%</td>
<td>nc</td>
<td>Negligence cost</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Table IV presents the parameter values used in the baseline scenario of the model, in which neither bank monitoring, nor regulatory supervision are active.

We select a sufficiently large number of clients for the bank, but not too large in order to limit the simulation time. We assume that the crisis-hit system manifests itself through larger number of high-risk clients and medium-risk clients totaling 15% and respectively 55% of the firm population. This leaves low-risk clients at just under a third of the economy. With respect to the financial indicators such as the interest rates and the bank’s costs, we follow Diamond’s prescriptions as well as the ones mentioned in the aforementioned literature. We mention that the costs incurred by the bank as a result of client defaults are highest when neither the bank monitors, nor the regulatory institution supervises. These costs will diminish rather significantly, as stated in Gopalan (2010) and Lin (2011), when the bank starts monitoring. Finally, with respect to γ and φ which are indicative of the interaction amongst firms, we assume that firms have a strong tendency to maintain their project risk level in case of success (as evidenced by the group stability parameter) but, at the same time have default rates that are largely uncorrelated (as indicative of the low φ value).

We should note that as a result of our model calibration, the time periods that we study here are, in general, expressed as years. However, given the simulated nature of this economy, one must be very careful with the interpretations attributed to the temporality of the model. Also, with respect to the units of measurement of financial variables, they are similarly abstract, but, for convenience can be thought of as millions of a particular currency.

Let us first look at the results produced by the model under both absence of regulatory intervention, as well as the following client monitoring configurations emanating from the bank: (1) a situation of no monitoring whatsoever (the baseline scenario), (2) a context of low-cost monitoring under heavy informational asymmetry, (3) a situation of costly monitoring under heavy informational asymmetry, and (4) a more advanced monitoring method possible due to diminishing informational asymmetries however maintaining the hypothesis of costly monitoring. In all situations in which monitoring occurs, the costs associated with the client’s defaults are automatically diminished for the monitored clients. As such, \( r_c = 0.1 \) and \( n_c = 0 \). What has been described could be visualized graphically in Figure 2.
Figure 2. Baseline model simulation under varying informational asymmetry and monitoring costs

Figure 2 outlines possible simulation scenarios based on varying the costs associated with monitoring, as well as the informational asymmetries that the bank is faced with.

We must note that whereas monitoring costs \( mc \) represent a parameter value that can be modified by the observer, informational asymmetry is a qualitative measure based on the information that the bank has access to in its monitoring function.

In the first scenario characterized by an absolute absence of monitoring, the firms’ behavior is characterized by a significant, although not overly high, attraction towards their risk group, characteristic of entities looking primarily to their internal processes and goals to determine the type of project to undertake. As shown in Figure 3, this results in a rapid decline in the bank’s liquidity reserves past the point at which the bank must declare bankruptcy. The bank’s average profits lie well below zero, which corresponds to the significant number of high-risk client defaults. The described situation is a consequence of the unstable environment in which low-risk and medium-risk projects compete for dominance, however with a relatively large proportion of high-risk projects in the economy. On average, high-risk enterprises constitute 22.18% of the total number of client submitted projects, within the designated study period.
Figure 3. Baseline model simulation without bank monitoring or regulatory supervision

Note: The solid lines represent the mean and the dotted lines denote +/- one standard deviation from the mean, the x-axis denotes time, results are based on 100 repetitions of the simulation.

Figure 3 presents the results of the baseline scenario in the form of the means and standard deviations of the analyzed variables for 100 simulations of the model, over 100 time periods. It reflects the dire situation of the bank in absence of monitoring and regulatory supervision, as bank liquidity declines under conditions of negative profit.

We notice, therefore, that the long-term as well as short-term activity of the bank in these economic conditions is unviable, as by the 7th period, the bank defaults in over 50% of the simulation runs and by the 10th period it defaults in over 2/3 of the total number of repetitions performed. Furthermore, the bank’s profits rarely peak above zero, as the bank’s expenses generally surpass its income. This underscores the necessity for the bank to monitor its clients in order to reduce default-related costs and recover the invested funds from unsuccessful projects.

As part of a second scenario, we now insert bank monitoring into the equation. We first assume that the environment in which the bank performs its monitoring is characteristic of severe informational asymmetries. As such, the bank is entirely oblivious to the new clients that it faces each period. Besides the absence of any sort of signaling information (that the bank may make use of), the bank is also unable to infer any information regarding the future choices of current clients. These two assumptions amount to the bank operating under conditions of very high uncertainty. Still, the bank has access to general statistics regarding the number of clients and their adherence to the existing risk groups. Given this information, the bank’s choice regarding the number of clients to monitor in the current period is based on the proportion of previous period clients from each risk group that the bank detected as part of its monitoring activities. Concurrently, the bank is aware of the value of monitoring a given client group. More precisely, the value of monitoring is equal to the default probability of the given group. As such, the bank monitors that specific group of clients only if the value of monitoring exceeds the cost of monitoring.

\[
M_g^C = \frac{C_g^M t-1}{C_{t-1}^M} \text{ if } \bar{p}_g > mc, \text{ where } C_{t-1}^M = \sum_{g=(h,m,l)} C_g^M t-1
\]
\( M_{g}^c \) is the percent of clients from group “g” that the bank will monitor in the current period. \( C_{t-1}^M \) is the total number of clients that the bank monitored in the previous period, and it is comprised of the sum of clients belonging to each risk group that were monitored in the previous period (\( C_{t-1}^M \)).

In other words, the bank operates under the assumption that what was characteristic of yesterday still holds true today, and makes corrections to its number of clients to monitor based on the new information that it receives each day (information regarding the previous period).

This monitoring method is highly sensitive to the monitoring costs, since these determine the total number of clients that the bank will decide to monitor. If monitoring costs are low, then the bank will monitor most of its clients and, as such, manage to significantly reduce costs and recover most of its investments in the event of client defaults. However, under the assumption of high monitoring costs, it is conceivable that the bank may only wish to monitor its riskier clients. This, however, coupled with the informational asymmetries that prevent the bank from properly determining which individual clients pose a threat to the bank’s operations leads to a deterioration of the bank’s financial situation when compared with the baseline scenario.

Indeed, if we look at Figure 4, we notice that in the case of low monitoring costs (the situation corresponding to point (2) in Figure 2), the bank is able to verify a large proportion of its clients, thereby ensuring that most of the defaulted clients are being monitored. This translates into lower expenses for the bank and higher profits which stabilize at a level sufficiently far away from the null value, that even in relatively extreme cases of profits falling at one standard deviation away from the mean value, bank profits remain positive or null. This has a positive effect on the bank’s liquidity reserves which progress linearly towards infinity with increasing variability. As can be seen from point (c), the bank does not default in this context. The reason for this highly profitable situation is made clear in point (d) where we see that the number of monitored clients largely surpasses the number of defaulted clients at all points throughout the simulation. Although, because of the asymmetries facing the bank, it is not guaranteed that the monitored clients are also those clients who are defaulting, the odds are in favor of the bank when it comes to monitoring a risky client.

The same favorable situation does, however, not remain true for the scenario in which monitoring costs are high. Indeed, the assumption of costly monitoring has for effect a reduction in the number of monitored clients, given that the value of monitoring condition is not satisfied for all client risk groups. Under these circumstances, monitoring of low-risk and medium-risk clients becomes unprofitable for the bank and the bank reduces its monitoring target. The consequences of this decision can be seen in point (h) where the average number of monitored clients stabilizes at roughly 27 clients (constituting around 22% of the total population). The evolution of the average number of monitored clients is now much closer to that of defaulted clients and indeed can fall below the number of defaulted clients.

This means that the bank is now in a much tougher predicament, as it inadvertently faces the increasing risk of not being able to target the correct clients for its monitoring activities.

The situation translates itself negatively on the bank’s profits which now stabilize in negative territory and at lower values that even the base-line scenario containing no monitoring whatsoever. Similarly, the bank’s liquidity reserves register a faster drop as the bank now defaults in over 50% of the simulation.
runs by the 5th period (twice faster than in the case of the baseline scenario). We also see this in point (g) where the average number of default episodes per period is shown to increase linearly, after a short early phase in which the bank’s initial reserves stabilize the situation and prevent the bank from failing.

We thus notice that monitoring can provide a way for the bank to reduce costs and recover investments, only under the assumption of reasonably low monitoring costs. Under the assumption of high monitoring costs, however, the process of costly monitoring itself places the bank in a worse off situation that the baseline scenario. As such, it is not recommendable for, nor indeed should it be expected from, a bank to entertain costly monitoring in an environment of high informational asymmetries. Forcing a bank into monitoring would only produce worse results than attainable in its absence.

For monitoring costs: $mc = 0.05$

For monitoring costs: $mc = 0.3$
Figure 4. Baseline model simulation with high informational asymmetry monitoring

Note: The solid lines represent the mean and the dotted lines denote +/- one standard deviation from the mean, the x-axis denotes time, results are based on 100 repetitions of the simulation.

**Figure 4 presents the results of the baseline scenario in the form of the means and standard deviations of the analyzed variables for 100 simulations of the model, over 100 time periods.** It shows that, if the assumption of costly monitoring holds true, when bank monitoring occurs under high informational asymmetries, the bank’s financial situation is worse off than in the baseline scenario without monitoring or supervision.

In a final monitoring-only scenario, we allow for a decrease in informational asymmetries which allows the bank to better gauge the risk level of its clients. Now, after having monitored its clients, the bank will have enough data regarding their risk level in order to formulate expectations regarding the future risk level of each client. The bank will now be able to target high-risk clients in its monitoring efforts, as well as novice clients who have never yet been credited by the bank. This will allow the bank to better target those clients which pose an actual risk and to avoid squandering precious resources on low and medium risk clients. At the same time, since the bank can now accurately target clients based on their previous risk level, we now no longer impose the value of monitoring constraint on the bank and allow it to monitor as many clients as deemed necessary, provided the bank has enough financial resources for the task. The business environment (or the evolution of the clients) remains unchanged. We will also assume that the bank operates under costly monitoring conditions and will utilize the same parameter value as before.

Given these conditions, upon first look at the evolution of the bank’s financial situation variables, we notice a slight improvement versus the baseline scenario. However, we also remark a significant increase in volatility. Upon closer inspection, we notice that this is because of the duality in the trend of the profits and liquidity indicators. This is best seen in Figure 5, point (b) where we decompose the sample of 100 repetitions into two groups: one containing 47 runs and the other, the remaining 53 ones. In this graph, we notice that in a number of our repetitions, the liquidity indicator, after a short period of volatility (visualized in the average indicator as stagnation, but consisting of both ups and downs, sometimes even in negative territory, symbolizing the default of the financial institution), proceeds to an upward trend of steady growth. This is usually the case when the bank is faced with relatively mild early conditions consisting of lower default rates and/or lower number of high-risk clients. The bank, therefore manages to monitor enough clients in the early periods of its operations to avoid accumulating losses that would send its liquidity reserves below zero. In the event in which the bank faces tougher starting conditions because
of higher default rates and a larger numbers of high-risk clients, its initial losses deplete its liquidity reserves rapidly and case the bank’s cash to dip below zero, which leaves it in the impossibility of further monitoring its clients, thereby sending it into a vicious circle of losses amounting and not permitting it to monitor. If we had elected to terminate simulation upon bank default, we would interpret this result as the inability of the monitoring process to save the bank in over 50% of our simulation runs.

For monitoring costs: \( mc = 0.3 \)

Figure 5. Baseline model simulation with costly low informational asymmetry monitoring

Figure 5 presents the results of the baseline scenario in the form of the means and standard deviations of the analyzed variables for 100 simulations of the model, over 100 time periods. It shows that when the bank monitors its clients under conditions of low informational asymmetry, the decline in the bank’s
liquidity is slower, and there is possibility for the bank to avoid default if it is faced with fewer high risk clients initially.

As for the other indicators showing the bank’s profits and default rate, we must note that, just as in the case of the bank’s liquidity, we can see two separate groups of results, one located roughly between the mean and plus one standard deviation, and the other trend located between the mean and minus one standard deviation. We also notice that the bank is now able to monitor fewer clients than before, while maintaining roughly the same number of clients that were concurrently monitored and that defaulted as in the case of costly monitoring with high informational asymmetry. This amounts to a higher targeting precision for the bank’s monitoring process. In other words, the bank monitors fewer clients, but out of those clients who were monitored it finds just as many who defaulted as in the previous scenario. This means that the bank has become better at finding the risky clients.

Indeed, we notice that even by reducing informational asymmetry, the hypothesis of costly monitoring does not allow the bank to ensure its safety – which raises the question of external intervention in the form of prudential supervision and instruments.

3.3. Prudential supervision and instruments

3.3.1. Supervision with regulatory norm

We will first test the efficiency of bank supervision coupled with a regulatory norm imposing the bank to monitor a certain percentage (m%) of its clients. The regulator will supervise the bank in order to ensure that it monitors the appropriate number of clients. To ensure an absolute lack of moral hazard on the bank’s side, the bank is made aware that its activities will be terminated in the event in which it fails to comply with the norm. Also, the regulator constrains the bank to have sufficient liquidity for monitoring activities and initially informs the bank that it will not receive any form of credit from the Central Bank. This motivates the bank to try to keep its liquidity reserves above zero for as long as it can, only faltering in the event of impossibility to continue to do so. Beforehand unbeknownst to the bank, if the financial institution does indeed falter, then the Central Bank will either allow it to continue operating (as it has done in our previous simulations by extending a special long term credit facility) or it may alternatively choose to terminate the bank (if such action is specified in the model setup). For the bank to be able to satisfy the requirement of having sufficient cash destined towards monitoring purposes, a special mechanism is introduced: the bank is allowed to abandon some of its clients if it does not have enough money to monitor the percentage of total clients prescribed by the regulator. The bank cannot, however abandon clients that it has already willingly decided to monitor (since this would go against the very purpose of the regulator’s intervention). Furthermore, if the bank has negative liquidity, before the bank can monitor the remaining difference of clients between the regulator’s norm and its own internally determined optimal number of clients to monitor, it must abandon a sufficient number of clients in order to obtain the required cash to monitor the discrepancy. To give a simple example of the regulatory intervention, if the regulator imposes the bank to monitor an additional 15% of its clients, but the bank

3 We refer here to the initial clients that request credit from the bank and not to the remaining number of clients after the bank’s abandonment procedure. We enforce this specification since our objective is for the bank to monitor and obtain information about its clients, so that it may use this information to make future decisions. As such, the target number of clients to monitor will be invariable, as long as the total population of clients is fixed.
only has enough resources to monitor 5% of its remaining clientele, then the bank will be forced to abandon (or not credit) as many clients as required in order to, at the end of the day, be able to monitor the discrepancy. We can view the abandonment process as one of two possibilities: the first of which consists in the bank not crediting its clients before having decided on the number of clients that it will be unable to finance. Such a scenario is consistent with the bank being aware of a monitoring rule set forth by the regulator. A second possibility is one in which the regulator does not immediately inform the bank of the existence of the norm, but will rather discretely inform the bank each time step of the existence (or not) of the regulatory norm. In such a case, the bank will first credit its clients and then have to abandon some of the credited clients. This imposes a recovery rate \( rr \), where \( rr \in [0; 1] \), that determines the amount of the initial investment that the bank will be able to recover as a result of abandoning the client. For our simulation purposes we will assume the former case, in which \( rr = 1 \). Also, we notice that supervision is inseparable from the norm since, in the absence of supervision with threat of liquidation, the bank will never be incited to monitor the number of clients prescribed by the regulator, and the simulation results will revert to the baseline scenario with monitoring.

(a) Bank liquidity reserves

(b) Liquidity reserves zoomed in on periods \( t = [0..20] \)

(c) Bank end-of-period profit

(d) Number of default episodes
Figure 6. Supervision with regulatory norm under high informational asymmetry monitoring

Figure 6 presents the results of the scenario in which the regulator introduces a norm accompanied by prudential supervision under high informational asymmetries. The results are presented as the means and standard deviations of the analyzed variables for 100 simulations of the model, over 100 time periods. We notice that when informational asymmetries are high, the norm only has a short-term stabilization effect, after which the bank inevitably defaults. Applying this instrument also produces severe credit rationing.

For our simulation, we will therefore fix the two parameters controllable by the observer as follows: $m^\% = 0.5$ and $rr = 1$. We note that once fixed, the regulatory percentage can no longer be changed internally by the prudential authority, as it becomes a long term rule. Also, from now on, we will only be referring to the hypothesis of costly monitoring.

As we can notice, in the case of supervision with a regulatory norm and monitoring under high informational asymmetry depicted in Figure 6, by means of the regulatory norm, the supervisor is, on average (however, with relatively low deviation), able to stabilize the bank’s financial situation for 11 time periods, after which the negative trend of the bank’s financial resources continues, as in the baseline scenario with monitoring. When, as shown in point (b), we zoom into the liquidity graph to focus on what happens at the very beginning of the simulation run, we notice that although the bank’s liquidity resources fall as a consequence of the high monitoring costs, they are stabilized by the fact that the bank monitors a larger number of clients and therefore reduces its client-default associated costs. We notice that the bank’s liquidity reserves remain low, but positive until period 11, after which they dip irreversibly towards negative infinity.

We also notice that during the period in which the norm is effective, the deviation of indicators is minimal. We notice this both in the very low variance of the bank liquidity indicator, as well as that of the profits and bank default rate indicators. The number of default episodes remains at zero before period 12, which is consistent with the results seen in the bank liquidity indicator graph. We observe an initially higher discrepancy between the norm fixed by the regulator and the number of clients that the bank wishes to monitor on its own, but this discrepancy gradually diminishes and stabilizes, as the bank’s internally determined number of clients to monitor also evens out. We notice that the number of clients to monitor decided on by the bank is not the final number of clients that it will monitor, since the regulator will impose the bank to monitor the difference between the norm’s prescribed number and that decided on by the bank.
We notice that the bank does not get rid of all of its clients and stabilizes its client abandonment number at a number inferior to the maximum. This is a consequence of the bank’s monitoring process which stipulates that the bank always monitors if its monitoring value condition is met. As such, the bank is ready to monitor its internally determined desired number of clients even if it faces default on the short term. This is because, due to the lack of information, the bank expects that by monitoring on the short term it will have long-term benefits in terms of general risk reduction – an expectation rendered unnecessary when the bank gains access to more information and is able to directly form expectations on a client-by-client basis (as in the case of monitoring under low informational asymmetry).

Looking at the situation in which prudential supervision is introduced alongside a regulatory norm and monitoring under low informational asymmetry, as shown in Figure 7, we notice that the stabilizing effect of the norm is much longer. Indeed, we can see in point (a) that after an initially high drop in liquidity owing to losses associated with the bank trying (in the beginning) not to abandon clients (f), the bank’s financial situation is stabilized. We notice low volatility in the bank’s profit, liquidity and default rate indicators up to around period 40. In this period, the bank facing increasing losses compensates by abandoning clients. Client abandonment produces two positive results: it reduces default-related costs and recovers resources for the bank. This process however is not sustainable, as by roughly period 40 the bank runs out of clients to abandon. This can be seen in point (f). In this monitoring method, the bank obtains enough information to form conclusions on a client by client basis and, thus, its monitoring method is not dependent on the monitoring value condition, but rather on the availability of bank liquidity. As we can see from point (e) by period 10, the bank no longer has enough resources to monitor its clients and the discrepancy between the norm and the number of clients willingly monitored by the bank is maximal. The number of clients effectively monitored by the bank will, however, still coincide with the norm as the bank is forced to abandon clients to meet the norm’s requirements. Still, as depicted in point (d), all periods subsequent to time step 10 decrease the revenue obtained by the bank from its monitoring activities, since the bank is forced to abandon an increasingly high number of clients. Also, conditioning regulatory monitoring on available liquidity allows the bank to reduce the number of monitored clients to an extreme – to all but one clients. The finality of the enhanced monitoring method made possible by lower informational asymmetries is that it the regulator was able, through the same norm, to keep the bank running for a period roughly four times larger. This is a positive achievement, as by the time the norm’s efficiency wanes away, the crisis conditions of a real (as in non-simulated) economy may dissipate.

![Graphs showing bank liquidity reserves and end-of-period profit](image-url)
Figure 7. Supervision with regulatory norm under low informational asymmetry monitoring

Figure 7 presents the results of the scenario in which the regulator introduces a norm accompanied by prudential supervision under conditions of low informational asymmetry. The results are presented as the means and standard deviations of the analyzed variables for 100 simulations of the model, over 100 time periods. We notice that the stabilization effect of the norm is now more long-lived, but eventually, the bank still defaults. Applying the instrument produces severe credit rationing.

As we have seen from our analysis, the norm is able to postpone the negative effects resulting from the crisis for a certain period of time. Yet this delay is only achievable by means of severe credit rationing, which is introduced as a method of last resort for the bank to use in absence of any other internal or external instruments to fulfill the norm. The duration of the postponement is dependent on the bank’s internal processes and its effectiveness at detecting and eradicating risk. However, under persisting crisis conditions, the finality remains the same – the bank eventually is no longer able to compensate and defaults due to a lack of liquidity.

3.3.2. How supervision renders a CDS-market operational

We again take to the baseline scenario with monitoring and, this time, inquire as to whether market-based regulation would be more efficient at improving the bank’s situation. We thus introduce a market-based CDS instrument purchasable by the bank to insure against the risk of client default. We study two scenarios: one in which the regulator simply introduces the CDS mechanism and one in which the regulator actively supervises the market and the bank’s actions to help it make optimal decisions. We thereby determine whether supervision improves or hinders the functioning of the market.
The regulator creates an insurance company (which we will refer to as the CDS fund). This CDS fund
emits CDS units that the bank can purchase. We model the introduction of our CDS units in a manner that
is inspired by Coase’s (1960) vision for the distribution of rights on the environment. We similarly create
a market structure in which the bank can freely trade, only in our case it is not buying pollution rights, but
it’s buying insurance rights (i.e. the bank buys the right to not default). The bank decides regarding the
number of CDS units that it wishes to purchase. The CDS price is determined and the bank buys the
desired number of CDS units, provided that it has sufficient funds to do so. Otherwise, the bank buys as
many CDS units as possible within its liquidity constraints. The bank buys CDS units ex-ante, basing its
choice only on the information that it has regarding previous period clients. The bank goes to the CDS
market to solicit a quantity of CDS units equal to the number of non-monitored and defaulted clients
\( B_{CDS,D} = C^{M \cap D} \), where \( B_{CDS,D} \) is the bank’s demand for CDS units and \( C^{M \cap D} \) is the number of clients
who were both left un-monitored in the previous period and subsequently defaulted. The bank purchases
CDS units at a variable price from the CDS fund. One CDS unit insures that the bank obtains
\( R \) (the risk-free interest rate) from a defaulted client. CDS units are assigned to individual clients, are non-
transferable among clients and expire at the end of the period. The money accumulated in the CDS fund is
used to pay the bank a total of \( B_{CDS,R} = R \cdot C^D \) in the next period (when we find out if the clients that
the bank bought CDS units for have defaulted or not). Here, \( B_{CDS,R} \) is the bank’s reward from purchasing
CDS units and \( C^D \) is the number of defaulted clients. We now give an example of how the bank’s reward
functions on a per client basis. If the bank did not monitor the client, then the difference between the per
client reward that the bank would have obtained in the event it used the CDS instrument and that in which
it didn’t use the instrument is: \( R - 0 = R \) which is a clear gain for the bank since \( R > 0 \). However, if the
bank did monitor a client and also decided to ensure him (because, for instance, the bank had purchased a
very large number of CDS units), then the bank’s per client reward would be \( R - vl > 0 \) since \( R > vl \).
We notice that the bank still obtains positive gains, albeit smaller than in the previous case.

To implement the described regulatory mechanism, we make two assumptions. The first is that the bank
knows the risk-group of all clients after they pay back the bank loan. The second is that the bank does not
know the price structure of the CDS instrument. Only the regulator is aware of this price structure.

As such, we must therefore look at the price formation mechanism that exists on the CDS market. Black
and Scholes (1973) and Merton (1974) set the basis for relating the pricing of instruments to the key
economic determinants of financial distress and the loss given default. Further works expand upon their
theoretical models to specific instruments such as CDS. Indeed, if we look at the main theoretical
determinants of the CDS premium, as evidenced and verified empirically by Ericsson et al. (2005), we
find that the risk-free interest rate plays an important part. In particular, three key variables are
mentioned: firm leverage, volatility and the riskless interest rate. In what follows, we will propose a
formula that integrates these three components into the CDS price.

First, the CDS insurance fund, in order to ensure its own sustainability establishes a minimum and a
maximum price for the CDS units that it offers. The maximum price must correspond to the amount that it
will have to pay in the event in which the bank only purchases one CDS unit from the insurer. Since, the
damages that the CDS fund must pay to the bank in the event of the default of one client equals the risk-
free interest rate, it follows that the maximum price of a CDS unit paid when the bank only purchases 1
unit equals \( R \). The minimum price must allow the CDS fund to pay the promised amount \( B_{CDS,R} = R \cdot C^D \)
to the bank in the event in which the bank purchases CDS funds to insure all of its clients (C).
However, the CDS fund cannot know how many of the bank’s current clients will default (since it cannot see into the future), so it must base its decisions on the default statistics of previously credited bank clients. We assume that the fund can obtain these statistics directly from the bank or by some other external means (i.e. ratings agencies, etc.). The formula allowing us to satisfy these two conditions is the following:

\[
CDS.P = R - R \times \frac{B_{CDS,D}}{C} + CDS.minP \times \frac{B_{CDS,D}}{C}
\]

(5)

\[
CDS.minP = R \times \frac{C^D}{C},
\]

(6)

where \(CDS.P\) is the CDS price established on the market based on the bank’s CDS unit demand \((B_{CDS,D})\), and \(CDS.minP\) is the minimum CDS price that the fund requires from the bank and is based on the number of defaulted clients that the bank registered \((C^D)\). We remind that \(R\) also represents the maximum CDS unit price and that \(C\) represents the maximum number of buyable CDS units, since the bank will never buy more CDS units than it has clients (which derives from the aforementioned condition that the CDS units expire).

The proposed formula conforms to the literature, as it contains:

- the risk-free interest rate
- the risk level of firms (this uses \(C^D\) to encompass the "volatility" and "firm leverage" indicators that are not directly present in our model, but are prescribed by Ericsson et al. (2009) ).

The bank, however, is not aware of this formula, nor is it able to integrate it into its demanded quantity of CDS units announcement decision. This means that the bank, inevitably reaches sub-optimal decisions when it comes to the number of desired CDS units to announce. As a consequence, the CDS price that the bank has to pay is oftentimes larger than the one it would actually have to pay in the event in which it could integrate the price-structure in its decision-making processes. Regulatory supervision should help the bank to overcome this impediment as the supervisor monitors the bank’s decision and informs it of the optimal CDS unit quantity that the bank should announce on the market.

Figure 8 shows the per CDS unit purchase price for varying amounts of CDS unit demand on the bank’s behalf, on the left axis. We notice that this is a linearly decreasing amount which starts off at the maximal value of \(R = 1.05\), as per our model calibration, and descends up until the minimal price point which depends on the number of defaulted clients that the bank was previously faced with (in this exemplifying graph, the minimal CDS unit price is slightly less than 0.2). The graph also shows us the total cost of purchasing the desired amount of CDS units on the right axis. As we can see, this sum increases until a certain point, after which it begins to decrease as the decreasing price allows for savings on the bank’s behalf. We, thus, notice that (in this exemplifying graph) any quantity of CDS units demanded by the bank in the interval \(B_{CDS,D} \in [23; 121]\) is suboptimal since if the bank demands any quantity of CDS units in this interval, due to the price that the CDS fund will fixate, the bank will end up paying more for the desired amount of CDS units than it would pay if it purchased the maximum amount of CDS units purchasable (equal, as per our model specification to \(C = N = 121\)), which is the optimal CDS demand amount \((B_{CDS,D}^*)\) for this interval. We notice that if the bank were to, say, wish to purchase 70 CDS units,
then it would end up paying about 37.5, whereas if it purchased 121 CDS units, it would only pay 21. At
the same time, all CDS demand choices in the interval $B_{CDS} \in [0; 23]$ are optimal because the bank
would pay less than the total cost for $C$ CDS units.

As we can see, the role of the supervisor is to guide the bank’s CDS demand announcement to ensure the
optimality of its CDS purchasing decision. The bank should benefit, and the CDS fund should be able to
maintain its sustainability (at least, as is the case for most CDS issuing entities, for a while).

![Figure 8. Number of CDS units requested by the bank and total purchase cost](image)

Note: On the x-axis we have the number of clients for whom the bank purchases CDS units; on the left-y-
axis we have the price for one CDS unit determined by the CDS fund according to its formula; on the
right-y-axis we have the total cost in monetary units for purchasing the respective quantity of CDS units.

*Figure 8 shows the price structure of the CDS instrument. It reflects the declining per unit cost of the
CDS instrument when the purchased quantity increases. It also shows the total cost for any given solicited
quantity of CDS units.*

As such, if supervision is introduced to complement the CDS mechanism, the regulator helps the bank to
make better CDS buying decisions, by sharing with the bank its knowledge of the CDS price structure.
The regulator integrates into the scheme described by Figure 9. We notice that when supervision is
introduced, three steps are added in the functioning of the CDS market. Specifically, a feedback process
between the bank and supervisor is inserted which allows the supervisor to inform the bank of the optimal
CDS demand for the bank.
Figure 9. Integrating supervision into the regulatory CDS mechanism

*Figure 9 explains how supervision is integrated into the model and explains the steps that the regulator takes to ensure that the bank makes the optimal choice regarding the quantity of CDS units to purchase.*

Let us now turn our attention to what happens in practice when we apply this new form of regulatory intervention to the baseline scenario with monitoring. We first look at the situation with bank monitoring under high informational asymmetry. In this case, shown in Figure 10, we notice that the monitoring inefficiency characteristic of the difficult to gauge business environment hinders the bank’s ability to hedge against risk both when the regulator only introduces a CDS mechanism without supervision, as well as when the added supervisory role is assumed by the regulator. The main reason for this outcome is the high costs of monitoring coupled with the inefficiency of the bank’s ability to target risky clients. In absence of supervision, the demand for CDS units expressed by the bank on the CDS market leads to the establishment of a high price equilibrium. This, in turn, rapidly pushes the bank’s liquidity reserves into negative territory which no longer allows the bank to participate on the CDS market, thereby rendering the regulatory instrument inactive as the quantity of CDS units purchased by the bank drops to zero, as seen in Figure 10 point (c). A consequence of this is the rapid fall in liquidity (a), profit values stabilizing at negative values (around -3) and a rapidly increasing number of bank defaults (b). As for the CDS fund, since the bank is no longer able to purchase CDS units, the CDS fund’s resources freeze. They remain at a positive number since the fund has not yet operated for a sufficiently long time and so it has principally collected resources and thus far hasn’t distributed them.

If supervision is introduced, the regulator now monitors the situation on the market and intervenes to guide the bank’s CDS demand decision. This allows for a lower price equilibrium to emerge on the CDS market (c-right). This extends the period in which CDS units continue to be purchased by the bank (d-right) since it removes some of the negative pressure on the bank’s liquidity reserves. This has for effect a
dampening of the rapidity in the bank’s liquidity reserve decline (a-right), the stabilization of profits at an initially higher but still negative level, which further declines in time, and an increase in the volatility of the default rate indicator (b-right) signaling that under certain client risk level configurations the bank may avoid default for at least 10 periods. Since the CDS fund is forced to cover the high costs associated with the bank clients’ defaults and the bank’s CDS unit purchases gradually decline after a significantly higher purchase volume (because of liquidity constraints on the bank’s side), the CDS fund finds that it does not sell enough insurance units to be able to reimburse the bank for its clients’ defaults.

As such, the fund’s operations become unsustainable as the reimbursements it faces surpass its revenues. Therefore, under this scenario, the regulator would be faced with the dilemma of saving or letting the fund default very quickly after its introduction.

It is noteworthy to remark that in this monitoring context, the regulator is unable to improve the situation vis-à-vis the baseline scenario regardless of whether supervision is implemented or not. Supervision does help to attenuate the bank’s losses, but fails to bring the bank back to profitability.

The next step in our analysis is to investigate the situation in which the regulator introduces a CDS market in presence and absence of supervision when the bank’s access to client-related information is improved so that the bank can form anticipations regarding the quality of the clients it will have in the following period. It is expected that the better risk management that the bank is endowed with should lead to an improvement in the bank’s situation.
Figure 10. CDS market with (right) and without (left) supervision under high asymmetry monitoring

Figure 10 presents the results of the scenario in which the regulator introduces a CDS market under conditions of high informational asymmetry. The results are presented as the means and standard deviations of the analyzed variables for 100 simulations of the model, over 100 time periods. We notice the positive effect that the presence of supervision produces on the bank’s resilience, but conclude that high informational asymmetries prevent the bank from operating profitably.
Figure 11 presents the results of the scenario in which the regulator introduces a CDS market under conditions of low informational asymmetry. The results are presented as the means and standard deviations of the analyzed variables for 100 simulations of the model, over 100 time periods. We notice the positive effect that the presence of supervision produces on the bank’s resilience, as the bank’s profit becomes positive and potentiates profitable bank operations.

We notice that, now, even under lack of supervision, the bank fares better than in the baseline scenario, as both profits and liquidity are higher. Figure 11, point (a) confirms this. Because of the lack of supervision, as before, the price of a CDS unit stabilizes at a high level and the number of CDS units effectively
purchased is also low (d). However, this time, it is rather rare for the purchase of CDS units to completely stop thereby rendering the CDS mechanism inactive. Furthermore, now, under the best of conditions, the bank’s default is postponed until around period 20 (bottom dashed line in point (b)). Notice that this result obtained in the absence of supervision is a marked improvement over the result obtained when supervision was implemented but in an environment of high asymmetry monitoring. Finally, because there is no supervision to help the bank to integrate the price structure, the CDS fund takes advantage of the situation to improve its financial standing and accumulate resources. Indeed, whereas the bank’s default is postponed more than in previous CDS market scenarios, it would seem that the only absolutely safe institution in this economy is the insurance agency (the CDS fund).

When supervision is introduced however, the tables are turned on the CDS fund. Since, the bank’s CDS unit demand announcement is influenced by the supervisor which now informs it of the optimal quantity, the price of CDS units stabilizes at a lower point (point (c-right). Now, no longer able to demand exorbitant prices for the CDS instrument it sells because of the regulator’s supervision of the market, the fund must content itself with lower revenues. This translates into the lower CDS Fund cash variable depicted in point (e-right). However, we notice that despite the lower values, the fund remains sustainable for a relatively long time – specifically, for approximately 60 periods of our simulation run. We might ask ourselves why this is the case when in the presence of supervision with high asymmetry monitoring, the CDS fund defaulted miserably within five turns of the start of its operations. In fact what changed is that because of the lower liquidity constraints that the bank faces under low asymmetry monitoring, it is able to purchase the entirety of the announced CDS demand quantity (whereas before it was limited by its lack of liquidity). As such, the bank ends up purchasing a very high number of CDS units (d-right). And since CDS unit purchases constitute the revenue of the CDS fund, the insurer is now able to fulfill its obligations for a much longer time. Still, eventually, because of the bank’s client defaults, the CDS fund runs out of resources and may need to be saved, or replaced with a new insurance fund. As expected, in this scenario, the bank’s liquidity reserves are now largely positive (a-right) and the number of bank default episodes is significantly reduced (b-right). Now, the bank will default only rarely. Still there is significant volatility in the number of default episodes, as the bank is still dependent on the initial configuration in terms of client risk levels. Multiple periods characterized by high upper-risk client density and high client default rates may still cause the bank to default. Regardless of singular incidents, the situation is significantly improved when compared to the baseline scenario. Furthermore, this is the first time that we are able to ensure sustainable (and profitable) bank operations under persistent crisis conditions.

As we have seen, the introduction of a CDS market is not enough to stabilize the financial situation of a bank facing persistent crisis conditions. Not only does mechanism unable to save bank, but the insurance fund also risks either termination by abandonment or default. The key towards ensuring the sustainability of the bank’s operations is to concurrently ensure supervision of the introduced instrument’s market, as well as to perform all possible actions towards reducing the informational asymmetry present in the economy. If such steps are taken, then the bank will operate at a profit on the long-term. This is an improvement not only over the baseline scenario, but also over the regulatory norm which manages to stabilize the bank for a shorter time-span, albeit with lesser fluctuations, but, on the other hand, with very severe credit rationing and close to zero profits for the entirety of the duration of the stability period of bank operations. We therefore conclude that a CDS market without supervision will always produce worse results than a regulatory norm. With supervision also in the mix, the CDS market stands a chance
of producing better results than the norm, provided that the bank has access to sufficient information allowing it to form anticipations regarding the risk levels of its future clients.

3.3.3. Supervision with taxation. Can a bail-in mechanism save the bank?

Our last supervisory set-up includes a tax in the form of a bail-in mechanism. This means that it is those who benefit from the bank’s activities that must contribute towards saving the bank. In our model it is the bank’s clients (or the firms) who reap the rewards of the bank’s operations. As such, the regulator introduces a tax that they must bear. For our tax to be fair, however, the regulator will have to keep in mind two key elements that derive from the bail-in mechanism formulation. The first regards the category of beneficiaries that must be taxed – in our case it is very straightforward that clients of all risk groups who have benefitted from the tax must contribute. And the second is slightly more subtle in that only those clients who were successful must be taxed, thereby excluding from our taxation the defaulted clients. We may ask ourselves why some of the clients should be excluded from the tax. Indeed, why is those clients who will have led to the crisis that must escape from repairing the damages? The simple answer to this is that we are implementing a punctual tax that only applies in the event of difficulties faced by the bank. As such, the supervisor who will be monitoring the bank’s and the firm’s situation has no way of knowing which clients will default or even if a tax will be necessary in the given time period. Therefore, since we are not implementing a permanent tax that is collected regardless of the bank’s financial state, the supervisor collects the tax from firms ex-post, after the bank will have financed the clients and only when the bank’s default will have become imminent. Another consequence of this implementation of the tax is the necessity of supervision of the bank’s financial situation by the regulator. In the absence of supervision, the regulator would not be able to coordinate the tax level with the bank’s deficit. Furthermore, since the regulator is unable to raise money from defaulted firms, only successful clients can contribute in a bail-in mechanism. This is similar to the European Commission’s and ECB’s proposals for the Cyprus bail-in scheme whereby only “successful” clients having deposit accounts of more than 100000€ were forced to contribute towards saving the bank. In order to avoid defaulting successful firms, we introduce the bail-in mechanism as a tax on firm profits (and not revenues). The regulator’s taxation is dependent on the financial situation of the bank. As such, if the supervisor detects that the bank is in a situation of negative liquidity, immediate action is taken. A tax corresponding to the amount needed to save the bank is raised. The tax is distributed proportionately to all clients’ profits. This means that clients from all risk groups have to dedicate the same percentage of their profits towards saving the bank. The regulator calculates which percentage of profits is to be contributed towards paying the tax by the process depicted in Figure 12. As we can see, the loop which will determine the tax contains an increment size (A) which will be responsible for the accuracy of the tax value. An increment value of A = 0.05 means that the regulator would jump from tax size 0% to 5% to 10%, etc. If the bank were to need, for instance a tax of 12% of firm profits to be saved, then the regulator would collect 15% and the remaining 3% would go towards establishing (or replenishing) the reserve fund.
Figure 12. Bail-in mechanism tax determination process

Figure 12 presents the steps followed by the regulator in the bail-in scenario.

Larger values of $A$ allow for larger reserve fund accumulations, but also more rapid simulation run times. On the contrary, lower values of $A$ allow for more precise taxation, but slow down the accrual of funds in the regulator’s reserve.

For simulation purposes we will maintain a relatively large value of $A = 0.05$ which allows the reserve fund to play a role in saving the bank in the event of a 100% tax on firm profits not being enough to replenish the bank’s liquidity reserves.
Figure 13. Supervision with bail-in mechanism in high asymmetry environment

Figure 13 presents the results of the scenario in which the regulator introduces a bail-in mechanism under conditions of high informational asymmetry. The results are presented as the means and standard deviations of the analyzed variables for 100 simulations of the model, over 100 time periods. We notice the positive liquidity levels maintained by the bank even under the harsh conditions of high asymmetries. Also, we notice the decline in the number of default episodes.

Now that we are aware of the functioning of the bail-in mechanism, we can investigate its effects on the bank’s financial standing and compare the results with the other supervisory implementations that we have discussed. At the same time, it is also interesting to investigate what will transpire as a result of the prudential instrument with the firms’ profits. We would like to know whether saving the bank can be achieved with moderate levels of taxation or if we must jeopardize the welfare of the firms to save the bank. This, naturally, raises the issue of striking a balance between keeping the productive sector sheltered from regulatory interventionism in the form of over-taxation and ensuring the continuity of the banking sector’s activities.

In the event in which the bail-in mechanism is introduced in a context of great difficulties for the bank to obtain information about its future clients, the high costs and monitoring inefficiency lead to, on average, a higher liquidity deficit than the regulator can compensate for via the bail-in mechanism, point (d) in Figure 13. Indeed, even with a tax of 100% of the firm’s total profits, the regulator is at times incapable of saving the bank. Unfortunately, due to our representation of averages and standard deviations, we cannot remark the cases in which the tax constitutes 100% of firm profits. This is the case because it is very rare that for any given time period (t) all 100 of our model repetitions should produce the same result of a 100% tax on profits decided by the regulator. There is, in fact, a very great volatility of the regulatory
instrument which risks swinging between 0 and 100% from one period to the next, as depicted by the upper and lower bounds of the possible interval at one standard deviation from the mean. Indeed graph (e) slightly misrepresents the reality by not including the peaks of 100% which, under this configuration, are the only instance in which the number of default episodes indicator (c) can increase. Still, when we look at the number of defaults, we realize that the bank now defaults much less often than in the previous scenarios. Indeed, only the CDS market with supervision could produce better long-run results in terms of default risk reduction. The regulatory norm also provided highly efficient short-term default risk relief, but in the end faltered as the final number of default episodes after 100 time periods surpassed the number produced by the taxation method. The generally positive bank liquidity reserves shown in point (a) also attest to this. We do, however, remark that the liquidity reserves initially increase, but afterwards are attracted towards zero and have good odds of falling in negative territory, as the lower bound is well below zero. When looking at the bank’s profits (b), we also find that the indicator fluctuates around zero. When we look at the reserve fund cash indicator, we notice that the reserve fund is continually expanding (it is on a slowly increasing trend). We would expect to see this if the regulatory instrument were continuously used. Since, because of the bank’s heightened instability, this is indeed the case, we confirm our expectations. However, it must be noted that this indicator cannot rise indefinitely, as there is only so much firm profit to tax.

We now switch to the bail-in mechanism introduced in an environment of low informational asymmetry, whereby the bank can extract more information about its clients, thereby enhancing its monitoring method. In this instance, the higher monitoring efficiency, as before leads to lower scarce resources being wasted and therefore reduces the bank’s overall expenses. This means that crisis control on the supervisor’s behalf becomes a lot more manageable. As we can see from Figure 14, point (d), it is now the case that the bank’s deficit is almost always identically matched by the regulator’s instrument, as sufficient resources can be collected via the tax. We also notice that the bank’s deficit tends to have a higher volatility than that of the instrument which is a welcome finding. In the previous bail-in mechanism scenario, we noticed that the regulatory instrument manifested very high volatility and would therefore be proscribed if the prudential authority coincided with the Central Bank and promoted a concurrent stability objective. In this case, as evidenced by both point (d) and (e), we observe much lower volatility in the prudential tool, and indeed, we see periods in which volatility is reduced to zero, as the instrument is at very low percentage values or is left completely unused. We notice a more intense usage at the beginning of the simulation period, as the bank faces the severe liquidity shortage that is characteristic of the crisis environment. However, as the supervisor manages to stabilize the bank’s situation, the bank is able to accumulate resources and, eventually, no longer necessitates the regulator’s intervention. In order to confirm this, we extend the model simulation period to 1000 and look at the instrument’s usage levels. We notice that by period 200, the instrument ceases to be used which denotes that the bank has managed to push through the crisis and can now continue to operate individually, without external help, even under persistent crisis conditions. Indeed, the riskiness of the new clients that the bank will be facing will not have changed, but, due to the increasing reserves, the bank’s ability to withstand client default related shocks will have increased past the point at which the bank no longer faces any risk of failure. To confirm this, we also find, in point (g), that the bank’s liquidity deficit will have permanently gone down to zero by period 200.
Figure 14. Supervision with bail-in mechanism in low asymmetry environment
Figure 14 presents the results of the scenario in which the regulator introduces a bail-in mechanism under conditions of low informational asymmetry. The results are presented as the means and standard deviations of the analyzed variables for 100 simulations of the model, over 100 time periods. We notice the positive profits, liquidity and close to null default rate of the bank. Furthermore, when we run this scenario over 1000 time periods, we notice that given the improvement in the bank’s financial situation, regulatory intervention becomes completely unnecessary after around 200 time periods, even under persistent crisis conditions.

Finally, we remark that the bank’s liquidity reserves (a) are on an increasing trend and stay positive throughout the simulation run. The number of default episodes (c) is less than 0.4 which is the lowest value seen so far and which means that, on average, the bank will default 0.4 times over the simulation period. This is the best result so far, with the exception of the low monitoring cost baseline scenario which is deemed unlikely by the literature. As for the reserve fund (f), it increases up to a point after which a small correction occurs after period 60 when the last significant incidence of liquidity deficits occurs. Afterwards, the fund remains largely stable, as the usage of the bail-in mechanism declines.

We, therefore, have seen that under conditions of costly monitoring, the bail-in mechanism, implemented as a tax on bank clients, is the strongest possible tool. It manages to stabilize the bank’s situation and significantly reduce the number of bank defaults in an environment where informational asymmetries are predominant. The cost, however, is felt in terms of two major shortcomings of this method: the high tax levels that firms must incur (sometimes having to cede the entirety of their profits in order to save the bank), as well as the very high volatility of the prudential instrument. If it is possible to increase the bank’s access to information by means of policies conductive of market transparency, then it is the bail-in mechanism not only stabilizes, but also ensures long-term bank operation sustainability at positive profits and increasing liquidity reserves. The more fortunate economic climate diminishes the negative effects of the regulatory instrument by reducing its fluctuations, as well as by significantly lessening the burden placed on the production sector.

4. Conclusion

In this paper, we have studied the effectiveness of prudential regulation in terms of supervision coupled with three different regulatory tools: a norm, a CDS insurance market and a bail-in mechanism taking the form of a tax on bank clients. Taking as given the both theoretically stipulated, as well as empirically verified hypothesis of costly monitoring, we placed the bank in an environment of high informational asymmetry where its client monitoring abilities are severely hindered by its inability to obtain sufficient information about its clients. We then relaxed this constraint to allow for more market transparency and saw that the bank generally fared better, as the increased availability of client information allowed it to engage in more efficient monitoring activities. Still, we noticed that without regulatory intervention, the bank was eventually drawn into a bankruptcy situation at some point of our simulation run. As such, in order to ensure the bank’s sustainability, we resorted to utilizing prudential instruments coupled with supervision. We started with a norm that imposed the bank to monitor a fixed proportion of its clients. The initial simulation results were promising, as the bank’s financial situation was stabilized, but we noticed increasing credit rationing throughout the period of stability. Indeed, at the point at which credit rationing reached critical levels, the bank finally faltered and its liquidity reserves turned negative with a long-term trend towards negative infinity. This meant that saving the bank was now out of the question.
The only difference that the informational asymmetry environment made was that of the length of the default postponement, with lower asymmetry levels allowing the bank to operate for a longer period of time under conditions of almost-zero, but positive profitability. We then turned to a more advanced market-based instrument – a CDS fund. In this scenario, the regulator introduced a supplementary agency, a CDS fund, which allowed the bank to purchase CDS to insure against the risk of its clients’ default. Introduced without supervision, the CDS market would crash leaving behind not only a defaulted bank, but also a failed CDS-emitting agency. When the regulator, however, decided to concurrently become involved in supervising the market by calculating both the amount of resources required for the CDS-fund to survive, as well as the quantity of CDS units needed by the bank in order to avoid failure, we noticed a stabilization of the CDS market. When information was scarce, the CDS fund failed to compensate for the bank’s monitoring inefficiencies, which lead to the survival of only the fund. When access to information was facilitated, the bank was able to make good use of the extra instrument available for it to efficiently manage its client risk levels. Indeed, in an environment of transparency, the CDS market produced better results than the regulatory norm. Finally, we introduced a tax-based instrument in the form of a bail-in mechanism that saw the regulator taxing the bank’s clients in the event of difficulties encountered by their creditor. Here, we noticed the strength of taxation as the instrument was both able to handle environments devoid of information, and shone when asymmetries were rooted-out of the economy. Indeed, in the latter case, the taxation instrument proved that it was able to protect the bank sufficiently long enough for the financial institution to be able to stand on its own in an environment of persistent crisis. We noticed that after a lengthy period of intervention, the bank was eventually able to operate without external intervention and returned to long-term profitable activity. All in all, we have seen instruments with a very good short term effect, but with nefarious consequences on credit rationing, as well as efficient market instruments dependent, however, on particular set-ups and economic conditions. However, our results suggest that the tax remains a very powerful instrument that the regulator can use to reach a desired outcome. Furthermore, by means of a bail-in mechanism, it is those who benefit from the bank’s activities that contribute towards saving the institution, and not the tax-payer. Not without its own faults, however, the tax requires fluctuations in the regulatory instrument, as the prudential authority must constantly adjust the instrument to the ever changing financial landscape. Also, the bail-in part of the mechanism raises the question of whether the regulator does well to sacrifice the profitability of the productive sector in order to save the financial institution, in particular, when it is the productive sector who is the beneficiary.
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<table>
<thead>
<tr>
<th>Document ID</th>
<th>Authors</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-01</td>
<td>Laetitia Chaix &amp; Dominique Torre</td>
<td>The Dual Role of Mobile Payment in Developing Countries</td>
</tr>
<tr>
<td>2015-02</td>
<td>Michaël Assous, Olivier Bruno &amp; Muriel Dal-Pont Legrand</td>
<td>The Law of Diminishing Elasticity of Demand in Harrod’s Trade Cycle (1936)</td>
</tr>
<tr>
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<td>Sarah Guillou &amp; Lionel Nesta</td>
<td>Markup Heterogeneity, Export Status and the Establishment of the Euro</td>
</tr>
<tr>
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<td>Stefano Bianchini, Jackie Krafft, Francesco Quatraro &amp; Jacques Ravix</td>
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</tr>
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