University of Geneva
Geneva School of Economics and Management

We are bulletproof:
Banking regulation and crisis contagion in developing countries

Juan David Vega Baquero

Master Thesis

Supervisor:
Prof. Dr. Dietmar Maringer

Submitted on January 23, 2019 for the degree of
Master of Science in Economics
Concentration: Econometrics

Abstract

A model in order to analyze the contagion effect of a crisis from a developed county to emerging markets through the portfolio channel is presented. The model consists of a global economy with commercial and shadow banks allowed to invest internationally, thus exposed to global risk. There seems to be few contagion effect from developed to developing economies, whilst the opposite effect is significant. However, these results should be considered carefully, since there are some stylized facts not accounted for in the model, which have been proven to influence the contagion of crisis.

Key words: Finance and Economics, Crisis contagion, Developed economy, Emerging market, Portfolio channel, Regulation.

Contents

1. Introduction

The financial crisis from 2007 brought about some waknesses of the financial system that were unperceived before, since during bull markets it is easy to be positive and overlook some early warnings. For example, Hellwig (2009) states that the growing dynamics in the housing market led to underestimate the risk in mortgages, but since it represented new opportunities for investors, owners and buyers, nobody was considering the effect a negative shock could have in the future.

The new instruments developed around these mortgages, attracted the attention of investors not only in the US but all around the world. However, total exposure was not evident for external investors (it was not completely clear for domestic investors either), since the small liquidity of these new instruments made it difficult to have accurate estimates of risk, so they relied on the ratings given by rating agencies.

Also, all this investment was based on high leverage, starting from the mortgages (which were issued to borrowers with no or small equity in the house, under the expectation of continuous and long lasting increases in prices) and going to investors (who have been thought to be over-exposed in terms of leverage since long before the crisis). This additional source of risk was also passed by the rating agencies and regulators, coming into scene when the crisis hit.

Even for regulators, the potential risks in the new situation of the economy did not seem to be crucial for the stability of the system as a whole (International Monetary Fund, 2007). However, there were already some concerns about the way internationalization of investment could lead to higher risk if supervisors were not able to account for a bigger picture of the exposure given the new linkages in the global financial system.

One of the main concerns was the flow of investment to emerging markets, guided by the search of higher returns. This led emerging markets to an improvement in macroeconomic indicators, which attracted more investors. This unexpected performance induced agents to believe that the positive trend was to continue and that the receiving economies were to experience high growth rates for a long time. In few words, they believed to be "bulletproof".

Nevertheless, reduction in the housing prices in the US brought to light the high risk in the mortgage market and triggered a chain reaction that showed all the underlying linkages that where unseen until that moment.

Under this perspective, the present document introduces a model for the international portfolio investment in which some stylized facts are to be assessed in order to see if this channel may lead to contagion of a financial crisis. Thus, the idea is to determine whether

the portfolio rebalancing that follows a shock in one economy may lead to a contagion to other economies.

The model will be composed of developed economies (DE) and emerging markets (EM), each with a defined number of investors which may be either commercial or shadow banks. The difference between these two will be in the regulation they are subject to, referring to the ongoing discussion about the way some actors are regulated (especially hedge funds)[1].

As a result, portfolio channel seems not to be the source of contagion of the financial crisis, or at least not to the extent evinced in reality. Also, different hypothesis are tested in order to see how changes in the initial setting may result in a contagion pattern. However, there are various assumptions in the model that may vary the results, which are to be explained along the document.

Thus, Chapter 2 gives a brief background on the topic, especially concerning the facts to be modeled in the present document. Then, Chapters 3 and 4 are devoted to the presentation of the model and the calibration, respectively. The results are to be discussed in Chapter 5 and finally Chapter 6 concludes.

2. Background

The subprime financial crisis in 2007 was generated in the United States, but its effects were transmitted rapidly due to different features, as explained by Hellwig (2009) and Gorton (2008). The different attempts to understand this event and its expansion to the rest of the world can be clasified into empirical and theoretical approaches.

As an example of the first, Reddy (2014) uses a multivariate GARCH in order to estimate the asymmetric dynamic conditional correlations in the stock market indices and explaining the transmition of the US crisis to the BRICs[2], showing that in turmoil periods international diversification does not diminish risk, given the high correlation of markets in high volatility periods.

Likewise, Aloui et al. (2011) use copula functions to examine the intercorrelations between the US and the BRICs including the crisis period, finding that the dependance is stronger for commodity-price dependent markets.

On the other hand, Dooley and Hutchison (2009) analyze the effect of the events during the financial crisis in the US in various emerging markets through a VAR model, concluding that in the begining of the crisis there was some decoupling of the emerging markets, but after some time they recoupled to the US, showing the contagion effects[3].

[1] Danielsson et al. (2005)

[2] Brazil, Russia, India and China.

[3] This goes along with the fact that emerging markets were thought to be unaffected by the crisis at the

Furthermore, Jotikasthira et al. (2012) find that the portfolio changes in the allocation of funds from developed economies into emerging markets may respond to their own flows and thus to requirements for liquidity, through the creation of an index capturing these flows. Also, these flows seem to be correlated to the performance of the stock markets in the home economy.

In the second group, Mendoza and Quadrini (2010) examine the effect of shocks in asset prices on cross-country contagion under an integrated financial environment, through a dynamic model with savers, producers and financial intermediaries. As a result, the authors showed that financial integration rises exposure of developed economies to asset-price spillovers and shed light on how regulation could have magnified the effect of the US subprime crisis by following the mark-to-market principle.

Besides, Ozkan and Unsal (2012) use a DSGE model in order to analyze the transmission of a global crisis into emerging markets, finding that trade openness and foreign currency debt play a key role in the severity of the effect of external crisis in an emerging market.

In addition, Schiavone (2018) uses network analysis to figure out the role of portfolio channel in contgion of a crisis. He concluded that an idiosyncratic shock in a given country (either core or peripherial) may be transmited to other economies by the portfolio rebalancing of overexposed investors.

Finally, possible effects of the changes introduced by Basel III and from applying the same regulations for different actors in the markets[4] are simulated by Lengwiler and Maringer (2015), concluding that the latter may lead to higher systemic risk, thus increasing the probability of failure for all agents.

Given this outlook, the present document intends to approach the subject from a theoretical point of view. The aim will be to see the possible impact of regulation in the portfolio channel of transmission of the crisis, specially for the contagion to emerging markets.

The staring point is a model with developed countries and emerging markets, each with an asset subject to market volatility (risky asset). There are banks which may be commercial or shadow (unregulated) banks, domiciliated in one country and able to invest locally and internationally. Given this, banks are exposed to shocks in other countries and these shocks may be transmitted to their local economies through the portfolio rebalancing.

These changes in investment allocation may come from two sources: i) strategic behavior, based on a chartist/fundamentalist choice or ii) as a response to regulatory requirements in case of non-compliance. While the first one is the most commonly studied source of portfolio

beginning, but then the contagion effects appeared.

[4]Among the variety of discussions, the fact that there exist some players in financial markets i.e. shadow banks and hedge funds, which are not subject to the same regulation as commercial banks has been cited as a key factor during the crisis. This fact was already under analysis before the subprime crisis, for example by Danielsson et al. (2005).

channel transmition of shocks[5], the latter can be an important source of risk, given the possibility of fire sales under extreme cases[6].

3. Methodology

3.1 The global financial market

The model will be a global economy composed of $C = c_b + c_s$ countries, from which c_b will be big (developed) economies and c_s will be small (emerging) ones[7]. Investors will be either commercial banks (CB) or shadow banks (SB). There will be a given number of each type of bank for every big country and for each small country, which may vary within these groups. Thus, there will be $CB = CB_b + CB_s$ commercial banks and $SB = SB_b + SB_s$ shadow banks. Therefore, the total number of agents interacting in the global economy will be $B = CB + SB$.

Each country has its own risky asset, which could be thought of as a representative stock market index. Every agent will invest in any of the assets globally available in proportions depending on the calibration of the model, which follows stylized facts of actual international investments such as home bias and relative sizes of the economies, as will be explained in the following section, devoted to the calibration.

The prices of the risky assets will be independent, so that the contagion effect will be given through portfolio rebalancing. The equation for each of the risky assets will be given by[8]:

$$S_{ct} = S_{ct-1} + r_{ct} + (F_{ct-1} - S_{ct-1}) * v + \alpha_{ct} \tag{3.1}$$

Where r_{ct} is the random change in the prices following a $N(\mu, \sigma_c^2)$, F_{ct} is the fundamental price of the asset, assumed to be constant and v is the velocity of convergence of the current price back to its fundamental. The term α_{ct} corresponds to a market effect, said the effect

[5]This assuming that investors may react to a shock in a country by rebalancing their portfolios in order to reduce risk exposure. See for example Broner et al. (2006), Galstyan and Lane (2013) and Kaminsky et al. (2004).

[6]As studied by Lengwiler and Maringer (2015), who showed that margin calls could deepen falls in asset prices, thus expanding the effect to other agents.

[7]For simplicity, the terms small economy and emerging market are used as synonyms, as well as big economy and developed economy. However, it is important to note that the size of economies may vary depending on the variable of measure.

[8]This specification adapts the main features from the asset pricing proposed by Tramontana et al. (2015) and Gilli et al. (2011), concerning the chartist-fundamentalist effects on prices, which is part of the investment strategies for the banks that will be explained afterwards.

of supply and demand on the price of the asset. It will take the form:

$$\alpha_{ct} = \sigma_c * \left(\frac{total\ demand_{ct} - total\ supply_{ct}}{total\ capitalization_{ct}} \right) \tag{3.2}$$

Under this specification, the effect of the market behavior will deviate the price upwards (downwards) at most one standard deviation in the extreme case where all the banks are buying (selling) their total possession of the asset. Under this specification, a bank buying or selling a big amount of one asset will have a higher impact than a bank trading a small amount.

3.2 The investors

The balance sheets for each agent will be composed of the assets on one side, which may correspond to the riskless asset (cash) and the risky assets portfolio in random proportions depending on the calibration of the model; liabilities and equity on the other (these proportions may also vary depending on the bank, the regulations in place and the market movements).

Every period banks will set their investment strategies for the next period given the prices for the time going. This implies that banks are price-takers, since they have no direct influence in prices and make their decisions based on the current market prices. However, prices in the next period will reflect these investment decisions through the α_{ct+1} term. The main assumption in this point is that there is a liquidity provider[9] who makes it possible to execute all the orders at the current price[10].

Each agent will be either fundamentalist type (with probability p_f) or chartist type (with problablity $1 - p_f$) in its behavior. This characteristic is assumed to remain unchanged through the experiment for simplicity.

In order to set its strategy for the next period, each agent will value their portfolio, then earnings or losses in the period will enter the balance sheet through the equity and the bank will evaluate if the regulations are met (in case they apply), in which case orders for next period will respond to an investment strategy depending on their type. The amount traded under these strategies will be limited by the calibration of the model. This same strategy applies for non-regulated entities.

[9] As the market maker in Tramontana et al. (2015) and Day and Huang (1990), for example.

[10] This will help avoid illiquidity of markets since orders do not need to match, which also translates into less computational cost. However, introducing a different price setting frame in which orders need to match and these executed orders give the price, may include already the effect captured by α_{ct+1} and could also lead to different dynamics in the prices, which could lead to different outcome.

If the regulations are not complied, the banks will set their strategies in order to meet the requirements. The main assumption is that agents cannot increase their equity in order to comply, so the assets have to be modified either by recomposition or by decreasing.

When the leverage ratio regulations are not met, the bank will repay debt using the riskless asset (cash). If there is not enough cash to cover the necessary repayment amount, risky assets will be sold in order to get cash and repay debt until the proportions adjusts to the requirements[11].

In the case of the risk-adjusted regulation, if the bank fails to comply, the investment strategy for the next period will consist in selling risky assets until the regulation is met[12].

A bank will be considered bankrupt if the equity gets to zero or below. When this happens, the bank will stop participating in the market and will liquidate all its assets to repay debt. In the baseline simulation, each country will have a lender of last resort, who will buy the assets of the liquidated bank in order to maintain stability of the system and alleviate the market pressure of such a sale[13].

4. Calibration

The parameters are to be set mimicking some of the stylized facts of actual international capital markets. For the number of countries, it is important to take into account the trade-off between accuracy with respect to reality (said the biggest the number of countries the best) and the simplicity for analysis as well as the computational cost this would carry. Previous studies on contagion for developed countries and emerging markets have used between one and three developed economies (DE) and between two and seventeen emerging markets (EM)[14]. Given this, the simulations for this study will be done with two DE (could be thought of as the US and Europe) and three EM.

Regardless of this simplifying assumption, the calibration for the remaining parameters of the model will include data from the biggest number of countries available, so the random assignation of the initial setting may belong to any group of countries.

Different reports on the European banking system have estimated the number of com-

[11]The assets to be sold follow the type of investor. Thus, a fundamentalist bank will sell the less desired by the group and the chartist will to the same, so that not all agents are required to sell the same asset, although this would not be so farfetched.

[12]Idem

[13]A pseudo code presenting the process for the experiments is presented in appendix A.2.

[14]Bekaert and Harvey (2003) use three regions (Europe on one side and Asia and Latin America on the other) and Reddy (2014) uses the US, the UK and Japan vs. the BRIC countries, while Bae et al. (2000) use the US and Europe vs. 10 Asian countries (China, South Korea, Philippines, Taiwan, India, Indonesia, Malaysia, Pakistan, Sri Lanka and Thailand) and seven Latin American ones (Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela).

mercial banks in a DE to be on average more than twice as large as in the EM[15]. Considering this and for the sake of simplicity the number of commercial banks will be set to 20 and 10 respectively. With respect to assets, the average commercial bank in an EM has a size of around 40% of the average one in DE. Nevertheless, there is a big dispersion in the size of banks, so the size of each bank will be random within an interval with respect to a reference bank in a developed country[16].

Regarding the shadow banks, the number of this kind of entities is usually below half the number of commercial banks in DE[17], so for this group will be set to 9 and for EM, taking into account the fact that this type of companies are less present, it will be set to 4. The size relationship will be the same as in commercial banks.

As a result, the total number of banks investing in the global economy will be 100.

For the parameters of the distribution of returns, the drift μ will be zero, whilst the volatility σ will be maximum 1% for DE and 3% foe EM[18]. For simplicity, the velocity v will be set to 0.01 and the probability p_f to 0.5.

Concerning the asset composition of the banks, data form the IMF Financial Soundness Indicators (FSI) shows that the proportion of liquid assets in banks from developed countries and emerging markets is approximately the same, varying around the same intervals (from around 10% to 70%), so these will be the limits for the random allocation. Similarly, the US Securities and Exchange Commission (SEC) has reported an average liquidity in private funds of 38.7%[19], so this parameter can be assumed to be within the same interval for both types of banks without losing generality.

Also from the FSI, the average capital to assets for commercial banks in developed countries is 8%, whilst for the emerging markets is is around 11%, but more disperse than in the former. This is also consistent with the average regulatory Tier 1 capital to risk-weighted assets found on average to be 17% and 16% respectively, given the previous calibration for the ratio of liquid assets stated before. This same parameters will be assumed for the shadow banks.

For the composition of the investment portfolio, it is important to note that investors tend to prefer local assets. This phenomenon is called the *home bias*. In order to model this behavior, data from the World Federation of Exchanges (WFE) and the Coordinated Portfolio Investment Survey (CPIS) from the IMF is to be used, partly following Riff and

[15]European Banking Federation (2017) and TheBanks.eu (2017) show similar statistics on the number of banks per country for the majority of European countries. The sample was split into developed countries and emerging markets by using the Bank for International Settlements (2017) classification.

[16]Idem.

[17]Preqin (2017) shows information for a small sample of European countries supporting this.

[18]This following the statistics from MarketWatch (`https://www.marketwatch.com`), which provide volatilities for the main market indexes.

[19]US Securities and Exchange Commission (2017).

Yagil (2016)[20]. The local investment with respect to total investment is then estimated to be of 48% on average for developed countries and 35% for emerging markets.

In the case of international investment, the CPIS shows that investors in developed countries tend to invest 91% of their international portfolio within similar countries, while those from emerging markets invest only 27% in their own group. Given this, the allocation of international investment of banks will be inside an interval following these facts.

5. Results

The evaluation of the results will be done through the estimation of the probability of default for a bank in the global economy under the different scenarios. Also, the results will be separated for commercial and shadow banks and for those in DE and those in EM. Thus, the groupwise analysis will have four groups in order to see the effect of the shocks in the two types of agents and the contagion between the economies.

5.1 Baseline Simulation

The baseline simulation to be used will use the current regulation, said risk-adjusted ratio of 6% on the Tier 1 capital and a leverage-ratio regulation of 3% for commercial banks. Likewise, the economy will have a correct functioning.

The number of periods for the simulation will be set to 100, while an estimation of the number of experiments needed in order to get reliable results is shown in Figure 5.1. The figure shows the point estimates and the 5th and 95th percentiles of the estimated probability of failure.

As can be seen, after 10,000 experiments the variance of the estimated average probability of failure stabilizes and the point estimate changes only marginally in the third decimal, so this would be a suitable number of experiments to run. This is also consistent with the estimations for the different groups to be analyzed, as shown in Appendix A.1. Therefore, the number of experiments for the analysis will be set to 10,000.

Consequently, the baseline results are shown in Figure 5.2. Thus, the average probability of failure is 1.6%. It is important to note that the 5th percentile in all cases is equal to zero, so there is some chance of no failure. On the other side, the 95th percentile shows that in the 5% of the worst cases, the average probability of failure can be more than 6.0%.

Furthermore, the point estimates show a higher probability of failure in the shadow banks, especially in the DE (with a point estimate of 7.3% and 2.2% for EM). The difference

[20]The authors used the same data in order to estimate the home bias in a sample of 10 countries and evaluate possible causes of this phenomenon.

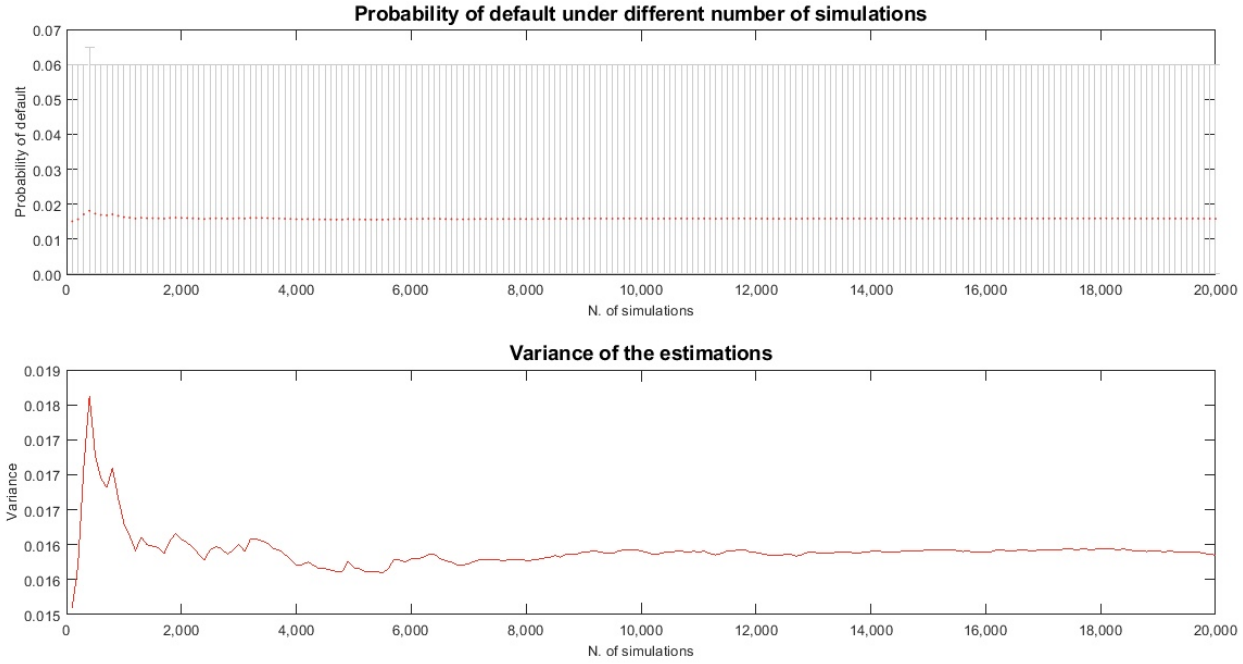

Figure 5.1: Probability of default and Variance of the estimates as a function of the number of simulations.

across the economies can be explained by the higher leverage in DE, which makes them more susceptible to bankrupts after small decreases in prices. This results also show the benefits from regulation, since the probability of failure for commercial banks is very close to zero.

5.2 A shock in the economy

Given the results for the baseline simulation under normal circumstances, now the contagion effect through the portfolio channel is to be tested. In order to do so, a negative shock in the price of the asset in one DE will be applied, the evaluation will consist in analyzing the change in the probability of failure on average and for each group.

The contagion effect will show up if the probability of failure in EM increases given that the shock was applied in a DE and the prices themselves are uncorrelated. In order to assess the impact of different shocks in the global economy, shocks of 1, 2 and 3 times the volatility of the asset will be applied. Results are shown in Figure 5.3.

As can be seen, the probability of failure in commercial banks in DE increases slightly with higher shocks, but still remaining insignificant. However, it is worth noting that the

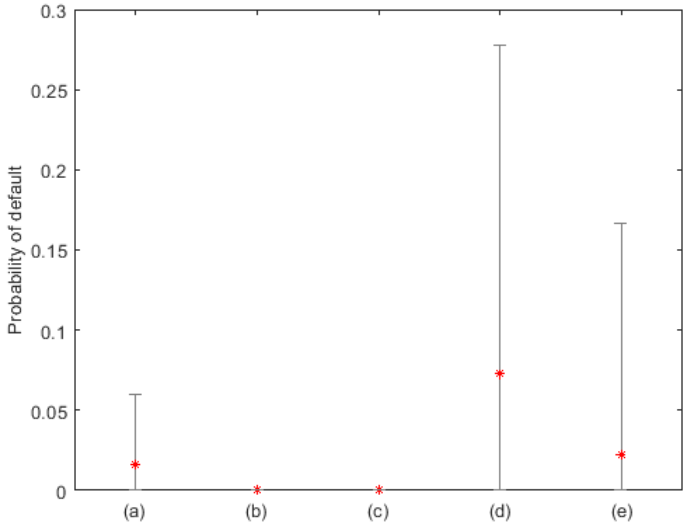

Figure 5.2: Probability of default with 10,000 experiments, average and for each group of analysis.

extreme cases at the 95th percentile increase notably for a 3σ shock. In the case of this investors in EM, the probability of default stays the same independently of how large the shock is, remaining below 0.1%. This leads to think that commercial banks are not contaged of the crisis in the DE through the portfolio channel or can be also attributed to the regulation they are subject to.

In the case of the shadow banks, in DE the probability of failure increases by 4.5 percentage points with a shock of one σ, and increases slightly for higher shocks. Likewise, in EM there is an increase in the point estimate (although much less pronounced), but the confidence interval remains unchanged, which leads to think that there is not much of contagion in these investors.

Considering the magnitude of the shocks, and the effects that this could have in the simulation, for the oncoming experiments the shock to be applied will be set to 2 times the volatility of the asset, which is estimated to occur in around 2.5% of the cases[21].

A shock in the EM

Another hypothesis that could be tested is how a shock in EM may affect the global economy. Given the previous results, it is worth comparing them to the case in which the shock occurs

[21]This given the assumption of normality in the distribution of the returns and since only negative shocks are to be analyzed.

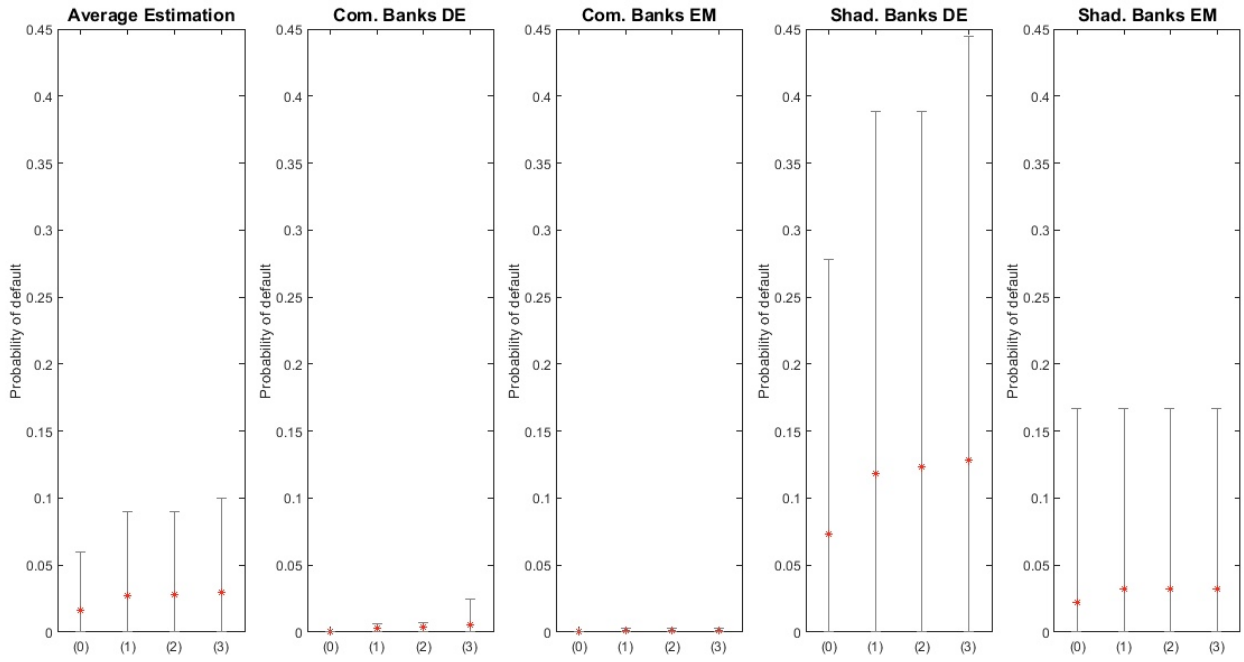

Figure 5.3: Probability of default with (0) no shock, (1) Negaive shock of σ, (2) Negaive shock of $2 * \sigma$ and (3) Negaive shock of $3 * \sigma$ in one DE.

in an EM. Figure 5.4 shows the probability of failure under: (a) the baseline setting, (b) the shock in the DE, (c) the shock in one EM and (d) a shock in all the EM at the same time. The latter exercise comes from the fact that EM are usually subject to similar shocks that may affect them together, as for example variations in commodity prices.

Contrary to what a shock in a DE showed, a shock in one of the EM tends to be transmitted to the DE (although in a smaller quantity), particularly to the shadow banks, given the almost zero probability of failure of commercial banks in both types of economy. However, when the shock is applied on all the EM at the same time, the effect on the shadow banks in DE is as big as in the case when the shock appears in the DE[22].

This result may come also form the higher leverage of investors in DE, which would make them more vulnerable to shocks both, in the local economy and in other countries, either developed or emerging.

For the shadow banks in EM, as expected, the shock in one EM increases their probability of failure more than in the previous case, and when the shock occurs on all the EM at the same time, the effect is even bigger.

[22]Also note the higher value of the 95th percentile, which implies a higher effect in extreme cases.

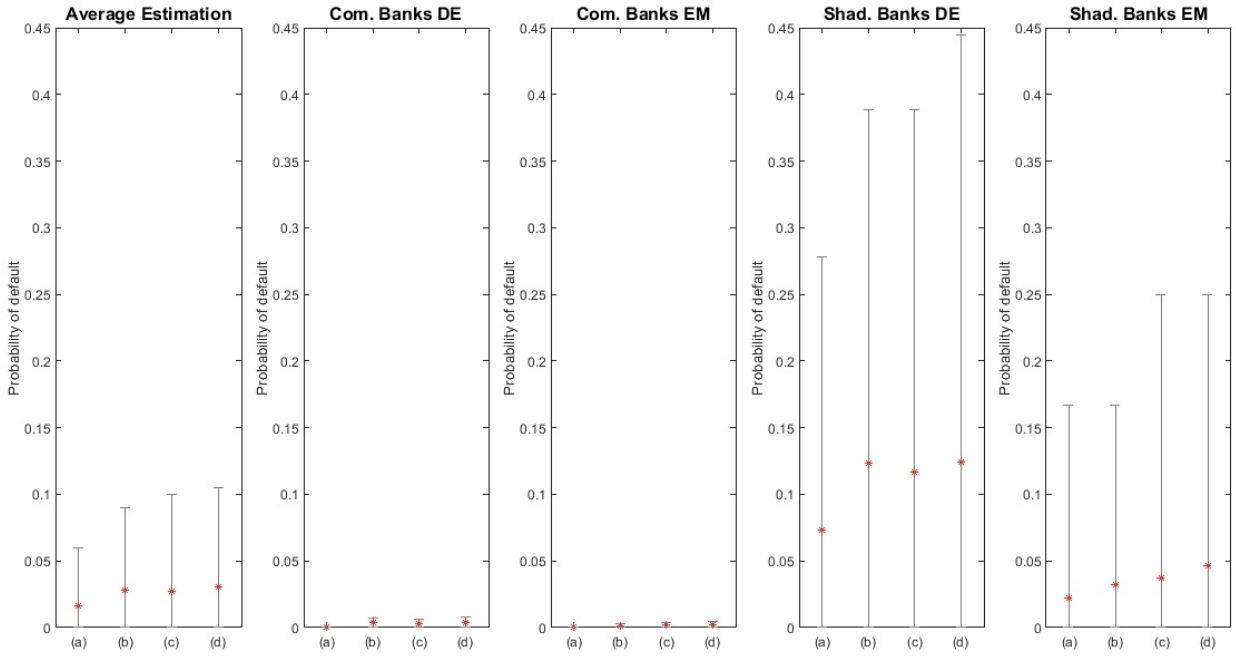

Figure 5.4: Probability of default given a shock in the EM.[a.]

[a.] The plotted data corresponds to (a) the baseline setting, (b) the shock in one DE, (c) the shock in one EM and (d) a shock in all the EM at the same time.

5.3 Basel II

Now, it is also interesting to see if the changes introduced in Basel III helped diminish the risk in the system. In order to do so, a simulation using the regulation in place during the recent financial crisis (Basel II) is to be done. Under this scenario, only the risk-adjusted regulation is applied, at a rate of 4%.

Results in Figure 5.5 show the benefits of a more strict regulation for commercial banks, by comparing the effects of a shock under the Basel II regulations and with the changes introduced in the Basel III agreement. Even though the probability of failure for commercial banks continues to be small (2.0% and 0.9% in DE and EM, respectively) they are no longer negligible and in the worst cases can be as high as for the shadow banks. Also, under this parameterization the shock in the DE is transmitted to the EM, even if it stays below the effect in the DE.

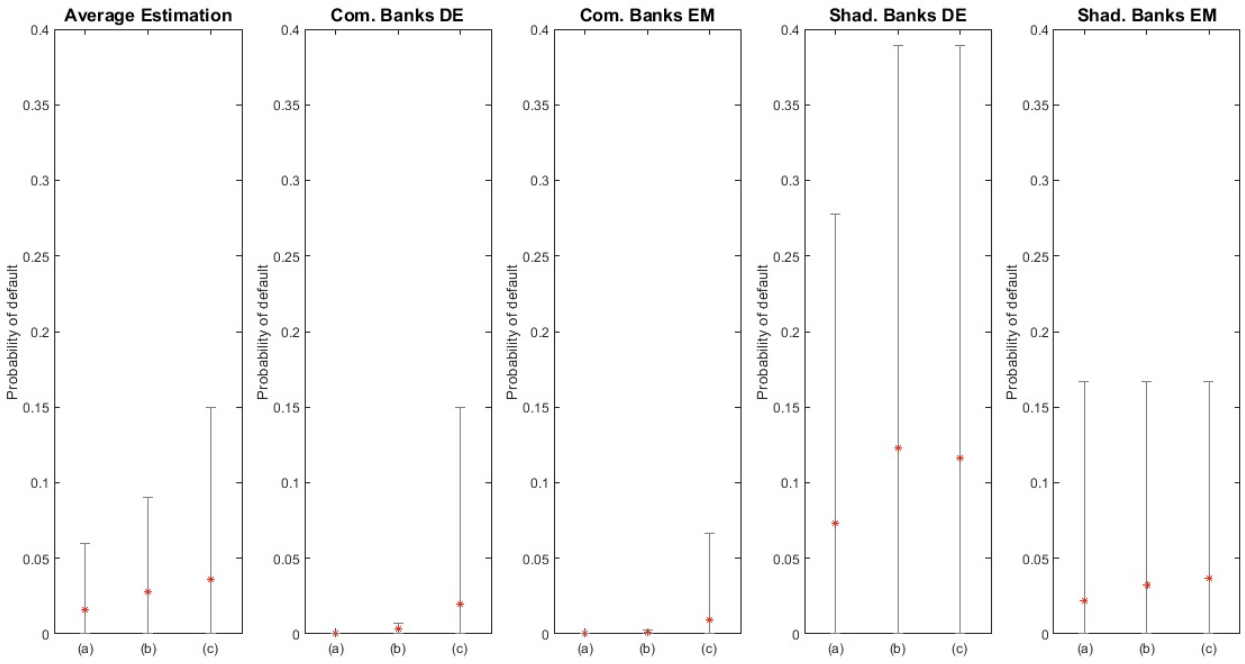

Figure 5.5: Probability of default under the regulations in Basel II.[a.]

[a.] The plotted data corresponds to (a) the baseline setting, (b) the shock in one DE and (c) the same shock applied under the Basel II regulation.

For the shadow banks even if the point estimates of the probability of failure tend to change, the fact that the confidence intervals stay the same for both types of economy leads to think that the effect is the same as in the previous case. The last, could give the idea that more strict regulation on commercial banks will only help themselves reduce the vulnerability to shocks, but unregulated agents do not see any effect.

5.4 Regulating shadow banks

In light of the continuous debate on how the behavior of different agents in the financial markets may affect the stability of the system as a whole, as explained by Danielsson et al. (2005) and analyzed by Lengwiler and Maringer (2015), it would be relevant to consider the case in which the shadow banks are also regulated, especially in light of the previous results, where these kind of investors are more susceptible to failure.

As can be seen in Figure 5.6 regulating shadow banks is beneficial for the economy as a whole, taking into account the reduction of the probability of default both average and for

shadow banks to levels similar to those exhibited by the commercial banks.

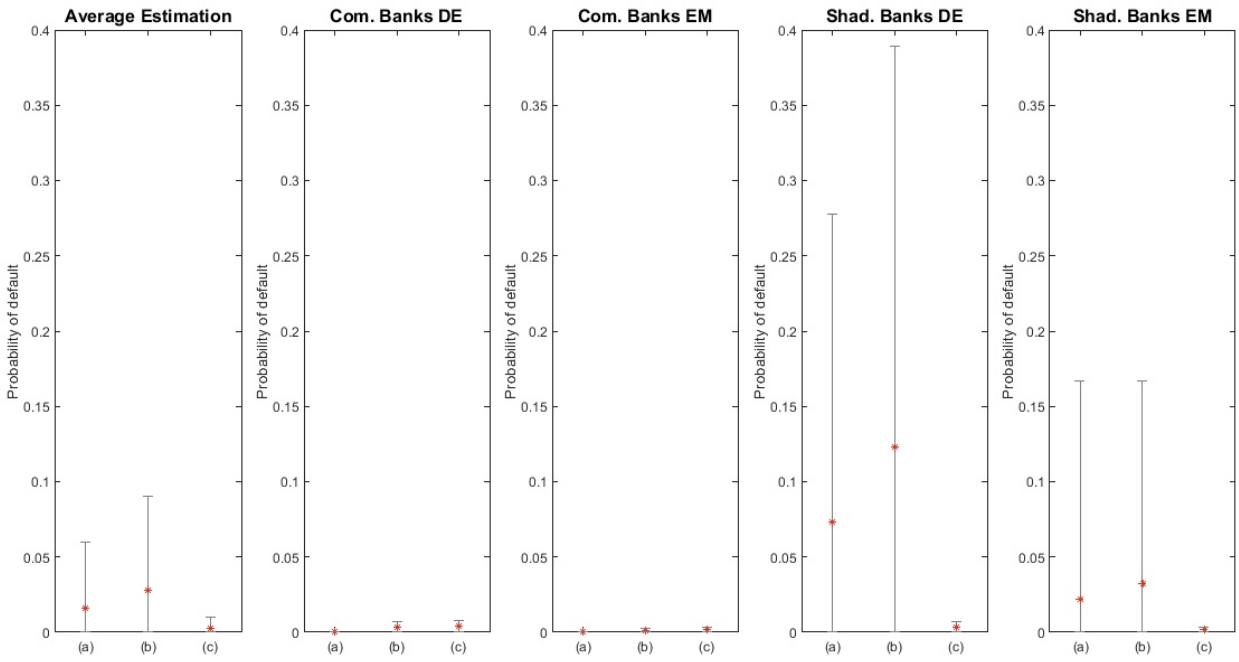

Figure 5.6: Probability of default applying the same regulation for Commercial and Shadow Banks.[a.]

[a.] The plotted data corresponds to (a) the baseline setting, (b) the shock in one DE and (c) the same shock applied when Shadow Banks are regulated.

This differs from the results obtained by Lengwiler and Maringer (2015), who estimate that regulating shadow banks may lead to a higher probability of failure for both, commercial and shadow banks. However, the setting is different, especially since the authors only refer to a single asset in the economy, so every bank is exposed exactly to the same shocks, while in this case, every bank has a different portfolio which may diversify the risk among all the investors.

Also, the calibration of the model by Lengwiler and Maringer (2015) assumes a high leverage (just above the required by regulation), which some banks show in global economy in this document. However, there are also other participants who show a high equity participation, as is the case for the EM in particular, who are usually above the required equity to assets ratio.

Besides, their model includes a third agent, investment funds, which are completely financed by equity, so they are never insolvent.

5.5 Other specifications and robustness

This section is devoted to see the way some changes in the assumptions made by the model could change the results, as well as making some comparison of the obtained results with similar studies in order to confirm or debate on the difference and why they appear. The figures summarizing the results under these different specifications are shown in the Appendix A.3.

The Lender of Last Resort

First, it is usually considered that portfolio rebalancing channel tends to propagate shocks in one asset by putting downwards pressure in the prices of other assets, given de decisions of agents to reduce exposure on some positions, as explained by Schiavone (2018). Also, regulation may contribute to this phenomenon by forcing fire sales in some assets in order for investors to meet the requirements.

In the case of the present model, a lender of last resort is assumed in order to minimize the effect of fire sales when a bank goes bankrupt, since it is forced to liquidate all the positions in order to leave the market. The effect of a shock without these agents is shown in Figure A.3.1.

As can be seen, when the lender of last resort is not present the probabilities of default (average and for each group) only increase marginally, but the 95th percentile of the scenarios increase in a more considerable magnitude for the average result, led by the estimation for the shadow banks in DE.

As a conclusion, assuming a lender of last resort does not change the main results, thus the fact that there is one institution able to absorb the shock from defaulted banks does not affect the portfolio channel of transmission of a crisis.

Alternative chartist-fundamentalist behavior

A second assumption to be tested is the fact that some investors act in a chartist fashion while some others do in a fundamentalist fashion. This property remains unchanged during the whole simulation and the probability of belonging to one or other group was set to 50%. However, this assumption could have some influence in the way the market effect α behaves and how this affects prices and the probability of failure in the presence of a shock.

In Figure A.3.2 it is possible to see how the probability of failure may change if instead of having a probability of being fundamentalist of 50% ($p_{fund} = 0.5$) it is changed for (c) $p_{fund} = 0$ (said all agents are chartists) and (d) $p_{fund} = 1$ or all agents being fundamentalists.

Under the current specification of the model, the chartist behavior seems to reduce the probability of default in presence of a shock in the DE, whilst a completely fundamentalist behavior from the investors may increase dramatically the probability of default, even for commercial banks, which in other settings seemed to be completely "bulletproof". Also it is the only setting in which it is possible to see a transmission of the shock in the DE into de EM.

This result may have an explanation to some extent in the way the asset prices are specified. In fact, the convergence term (with a velocity parameter v) may cause an over-reaction of the behavior of the fundamentalist which is contained in the α term.

However, it is important to note that a mixed behavior among the agents may lead to a more stable market in the sense that if all actors may behave the same, then a negative shock can be increased by a chain reaction, specially in the presence of regulations that may push banks to liquidate positions in high volatility situations.

Assuming a representative investor for each country

One of the concerns stated by Schiavone (2018) is the fact that the assumption of a representative investor does not allow to account for the heterogeneity between the different investors domiciliated in one country. Also, the model assumes an asymmetric rebalancing, said that the decrease in investment in countries where there is over-exposure is not followed by an increase in the participation of under-represented assets (countries) so a negative shock leads also to a shrink in the size of the investment.

Likewise, the model does not consider explicitly the effect of variations in prices, but implicitly in the shock to the economy. Given these differences, the present model can be modified in order to approach the one proposed by Schiavone (2018) to see how the results change under this new setting. Thus, there will only be one commercial bank and one shadow bank as representative investors in each country.

Also, the number of countries is to be modified to match the ones in Schiavone (2018), said 26 DE and 27 EM (53 countries in total). However, the shock will continue to be on the price of the assets, testing for a shock in one DE and a shock in one EM. Also, the rebalancing will respond to regulations and investment strategies, keeping some heterogeneity between the countries and the two representative investors in each one.

The results obtained under this setting are shown in Figure A.3.3. Thus, the failure probabilities increase notably for all the groups of analysis. This could be explained as in Schiavone (2018) from the fact that a shock in a country may lead to investors over-exposed to that country (in this case mostly the home based investors) to rebalance their whole portfolio, contaging other economies ant other investors.

Nevertheless, it is important to note that the assumption of one representative agent in

the economy might be very strong. Indeed, these results differ notably from those from the baseline, in wich the setting may be closer to reality. Therefore, the portfolio rebalancing channel could be less strong than stated by Schiavone (2018) in the transmission of a crisis.

Alternative leverage calibration

On the other hand, in Lengwiler and Maringer (2015) the simulation was done by using a single risky asset, which made all the agents (commercial banks, shadow banks and investment funds) vulnerable to the shocks in the asset in the same fashion. Also, the first two were assumed to have the same structure, which was a highly leveraged financing.

As stated in the calibration for the model in Chapter 4, the parameters include data of the largest amount of countries available. For the case of the balance sheet composition, the participation of the equity is very disperse among countries, going from 1% to 13% in DE and from 5% to 24% in EM. given this, the additional equity the majority of the investors could have in the present model may have protected the system from higher probabilities of failure and contagion, as seen in the restuls exposed by Lengwiler and Maringer (2015).

Taking the last into account, the leverage of investors will be changed from the initial calibration to a range similar to the one in Lengwiler and Maringer (2015), just above the regulation requirements. The results for this setting are shown in Figure A.3.4.

As can be seen, the probability of defaul on average increases under this new setting and goes from 2.8% to 7.2% when the shock is applied. Also, even if it remains small, the probability of failure in commercial banks increases as well as for shadow banks. The most remarkable change in the results under this setting is that the increase is more notorious for EM than it is for their counterparties, especially noting that investors in the first have now higher probabilities of default than in the latter.

This result could reveal a contagion effect to EM. Thus, this would mean that the EM are somehow "bulletproof" because of the lower leverage they have, but a more risky behavior (together with more leverage in DE) may lead to more instability of the whole system, as was already stated in the baseline shock[23].

However, this results still differ from those from Lengwiler and Maringer (2015) who found similar probabilities of failure for both types of agents, which may come from other

[23]It is important to point that in the baseline specification an investor in one DE could be in a non-compliance situation from the begining, given the evidence from data, but also the equity participation could be high for the largest part of the countries. Comparing this to the alternative specification, in which leverage levels were set to be just above the complying values may lead to ambigous effects for DE. Nevertheless, the increase in the failure probabilities is evident for all the groups of analysis.

aforementioned differences in the setting.

6. Conclusions and remarks

The most recent financial crisis has been studied from different angles, researchers and authorities have tried to understand the causes and development of this event, which has effects that can still be perceived. Also, this event led to changes in regulation and its effectiveness has grabbed the attention of academics and policymakers.

The present document aims to contribute to this debate and shed light on the contagion of the crisis from the US to other economies, especially to the emerging markets. In order to do so, portfolio channel is analyzed, under the hypothesis that the recomposition of investment given a shock in one economy may affect other economies, which is largely documented.

The proposed setting intends to surpass the flaws of previous attempts, whilst remaining simple and easy to interpret. Given this, a global financial market with developed and developing economies is set. Each economy has two types of agents: commercial and shadow banks. The main difference between them is that the first are constrained by regulation, while the latter are free to invest and determine their structure.

Under this setting, a shock in the advanced economy shows no significant effect in commercial banks, which can be interpreted as the favorable effect of the regulation, whilst the shadow banks tend to be more affected by the shock. However, the impact on investors in emerging markets seem to be less evident, which contradicts the contagion hypothesis through the portfolio channel.

An explanation for this may come from the fact that banks in emerging markets tend to have more restrictive regulation and tend to be more cautious since they live in presence of higher volatility in their home markets. Also, the exposure to external shocks could be reduced because of the home bias present in their portfolios. So a bank may be overexposed to shocks in its own economy and economies reflecting similar features, while remaining underexposed to variations in other economies, which might "protect" them to some point from external shocks.

Other hypothesis were tested in order to understand if contagion of the crisis could come from other stylized facts not taken into account in the baseline setting. Firstly, the opposite direction of the shock was tested, so the shock was applied in an emerging market. Surprisingly, the shadow banks in developed economies continued to be more affected by a shock than those in emerging markets, which may come from their more risky behavior, especially concerning the leverage they are exposed to.

Secondly, the initial shock was applied under the regulation in place when the crisis occurred (the Basel II agreement). Given this change, the effect in shadow banks is estimated

to be the same as before. However, the effect in commercial banks is no longer negligible, which leads to think that the reforms introduced in the Basel III agreement may help reduce the probability of such an event in the future.

Subsequently, the possibility of regulating shadow banks (as has been discussed even before the recent crisis) was tested. Consistently with the baseline results, regulating shadow banks reduced their exposure and the probability of failure, showing again the stabilizing properties of appropriate regulation.

Finally some other features and hypothesis of the model were examinated, also comparing the results with other studies in the subject. As a result, the proposed model shows some strengths with respect to previous studies in its closeness to reality.

Despite these advantages, it is importat to note the flaws and limitations of the setting, especially regarding the simplifying assumptions done in order to facilitate the analysis. Thus, the assumption of a similar structure in commercial and shadow banks may lead to an underestimation of the results, for example.

Also, the model assumes that trading is facilitated by a liquidity providor, who make sure all orders set are executed. However, in real markets the orders set by investors need to be matched, which may add more pressure in high volatility periods.

Furthermore, there is an assumption of constant behavior in the agents, which may influence the results as well. In this concern, a possible extension could also include adaptative agents, which may change their behavior depending on different facts, such as their environment and the market situation.

Likewise, as seen in some of the related literature mentioned, there are also idiosyncratic elements determining the re-allocation of resources, especially into developing economies. This might be also an important stylized fact to add to the model.

Besides, the prices and interactions between investors in the proposed model omit exchange and interest rates, which have an important role in the transmission of a shock from one country to others. This especially regarding some relationships between developed and developing economies, where it is possible to find exchange rate pegs that might affect the emerging markets more deeply in times of liquidity pressure.

Finally, it is important to note that this model only tests for the portfolio recomposition channel for transmission of the shock, but previous studies have shown that countries are

exposed through different variables to the events occurring in other countries.

Bibliography

Aloui, R., Safouane Ben Assa, M., and Khuong Nguyen, D. (2011). Global financial crisis, extreme interdependences, and contagion effects: The role of economic structure. *Journal of Banking & Finance*, 35:130–141.

Bae, K.-H., Karolyi, G. A., and Stulz, R. M. (2000). A new approach to measuring financial contagion. Working Paper 7913, National Bureau of Economic Research.

Bank for International Settlements (2017). Bis consolidated banking statistics: explanation of the data structure definitions. `https://www.bis.org/statistics/dsd_cbs.pdf`. Accessed on December 6,2018.

Bekaert, G. and Harvey, C. R. (2003). Market integration and contagion. Working Paper 9510, National Bureau of Economic Research.

Broner, F. A., Gelos, R. G., and Reinhart, C. M. (2006). When in peril, retrench: Testing the portfolio channel of contagion. *Journal of International Economics*, 69(1):203 – 230. Emerging Markets.

Danielsson, J., Taylor, A., and Zigrand, J. (2005). Highwaymen or heroes: Should hedge funds be regulated?: A survey. *Journal of Financial Stability*, 1:522–543.

Day, R. H. and Huang, W. (1990). Bulls, bears and market sheep. *Journal of Economic Behavior & Organization*, 14(3):299 – 329.

Dooley, M. P. and Hutchison, M. M. (2009). Transmission of the u.s. subprime crisis to emerging markets: Evidence on the decoupling-recoupling hypothesis. Working Paper 15120, National Bureau of Economic Research.

European Banking Federation (2017). Statistical anex. `https://www.ebf.eu/facts-and-figures/statistical-annex/`. Accessed on December 6,2018.

Galstyan, V. and Lane, P. R. (2013). Bilateral portfolio dynamics during the global financial crisis. *European Economic Review*, 57:63 – 74.

Gilli, M., Maringer, D., and Schumann, E. (2011). *Numerical Methods and Optimization in Finance*. Elsevier.

Gorton, G. B. (2008). The panic of 2007. Working Paper 14358, National Bureau of Economic Research.

Hellwig, M. (2009). Systemic risk in the financial sector: An analysis of the subprime-mortgage financial crisis. *De Economist*, 157:129–207.

International Monetary Fund (2007). Global financial stability report: Market developments and issues.

Jotikasthira, C., Lundblad, C., and Ramadorai, T. (2012). Asset fire sales and purchases and the international transmission of funding shocks. *The Journal of Finance*, 67(6):2015–2050.

Kaminsky, G., Lyons, R. K., and Schmukler, S. L. (2004). Managers, investors, and crises: mutual fund strategies in emerging markets. *Journal of International Economics*, 64(1):113 – 134.

Lengwiler, Y. and Maringer, D. (2015). Regulation and contagion of banks. *Journal of Banking Regulation*, 16:64–71.

Mendoza, E. and Quadrini, V. (2010). Financial globalization, financial crises and contagion. *Journal of Monetary Economics*, 57:24–39.

Ozkan, F. G. and Unsal, D. F. (2012). Global financial crisis, financial contagion and emerging markets. Technical report, International Monetary Fund.

Preqin (2017). Preqin special report: Hedge funds in europe. `http://docs.preqin.com/reports/Preqin-Special-Report-Hedge-Funds-in-Europe-June-2017.pdf`. Accessed on December 6,2018.

Reddy, K. (2014). Global financial crisis and contagion: Evidence for the 'bric' economies. *Journal of Developing Areas*, 48:243–264.

Riff, S. and Yagil, Y. (2016). Behavioral factors affecting the home bias phenomenon: Experimental tests. *Journal of Behavioral Finance*, 17(3):267–279.

Schiavone, A. (2018). Estimating the contagion effect through the portfolio channel using a network approach. Technical report, Banca d'Italia.

TheBanks.eu (2017). Banks by country. `https://thebanks.eu/banks-by-country`. Accessed on December 6,2018.

Tramontana, F., Westerhoff, F., and Gardini, L. (2015). A simple financial market model with chartists and fundamentalists: Market entry levels and discontinuities. *Mathematics and Computers in Simulation*, 108:16 – 40. Complex Dynamics in Economics and Finance - Papers of the MDEF 2012 Workshop.

US Securities and Exchange Commission (Q4 2017). Private funds statistics. `https://www.sec.gov/divisions/investment/private-funds-statistics/private-funds-statistics-2017-q4-accessible.pdf`. Accessed on December 6,2018.

A. Appendix

A.1 Groupwise results for baseline simulation

Figure A.1.1 shows the estimations for the probability of default for commercial banks in the first and second rows (for DE and EM, respectively) and for shadow banks in the two bottom rows. As can be seen, the point estimates and the confidence intervals stabilize after 10,000 iterations, as well as the variances. Thus, it is a plausible choice to use in the simulations for the analysis.

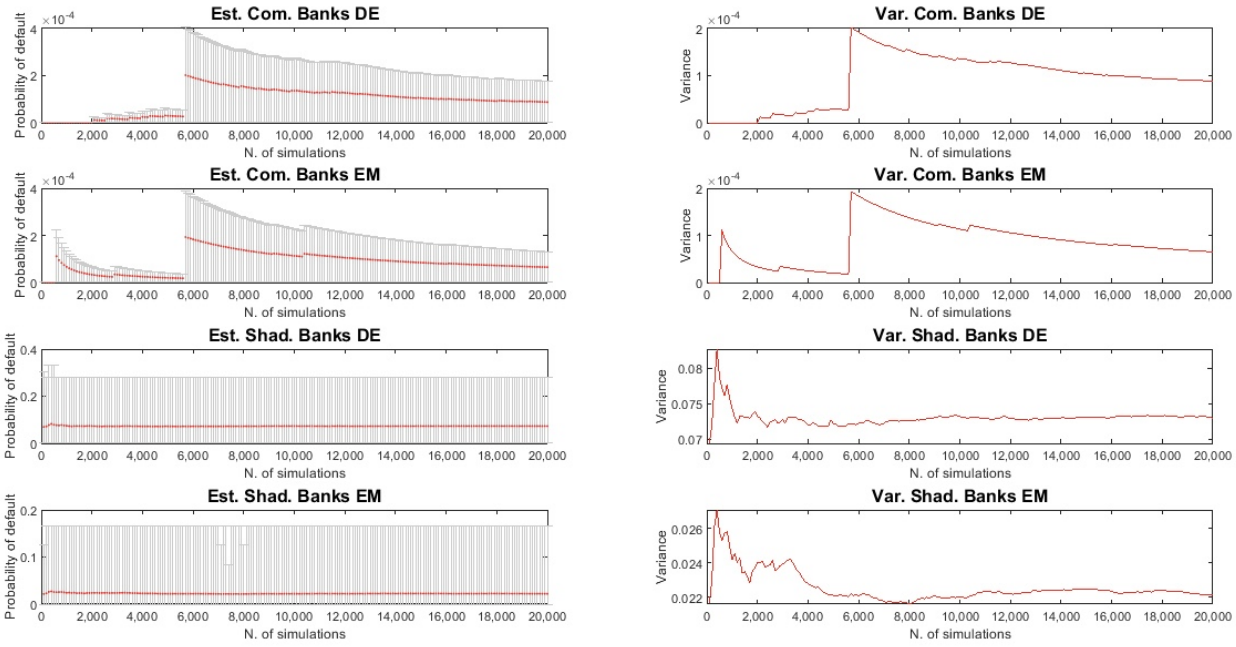

Figure A.1.1: Porbability of default and Variance of the estimates as a function of the number of simulations for each group of analysis.[a.]

[a.] Note the difference in the y-axis scales for the Commercial Banks, which have a nearly zero probability of default.

A.2 Pseudo code for the experiments

Algorithm 1 Experiments

Require: initial parameters

```
for e = 1 : nExp do
    for t = 1 : nPeriods do
        generate prices
        value portfolio
        for b = 1 : nBank do
            if leverage regulation applied then
                if not complied then
                    sell risky asset
                    repay debt
                end if
            end if
            if risk-adjusted regulation applied then
                if not complied then
                    sell risky asset
                    keep cash
                end if
            end if
            if no changes / no regulation applied then
                investment strategy(chartist/fundamentalist)
            end if
            set orders for next period
        end for
        aggregate individual orders
    end for
    store experiment results
end for
aggregate results
```

A.3 Results for alternative specifications

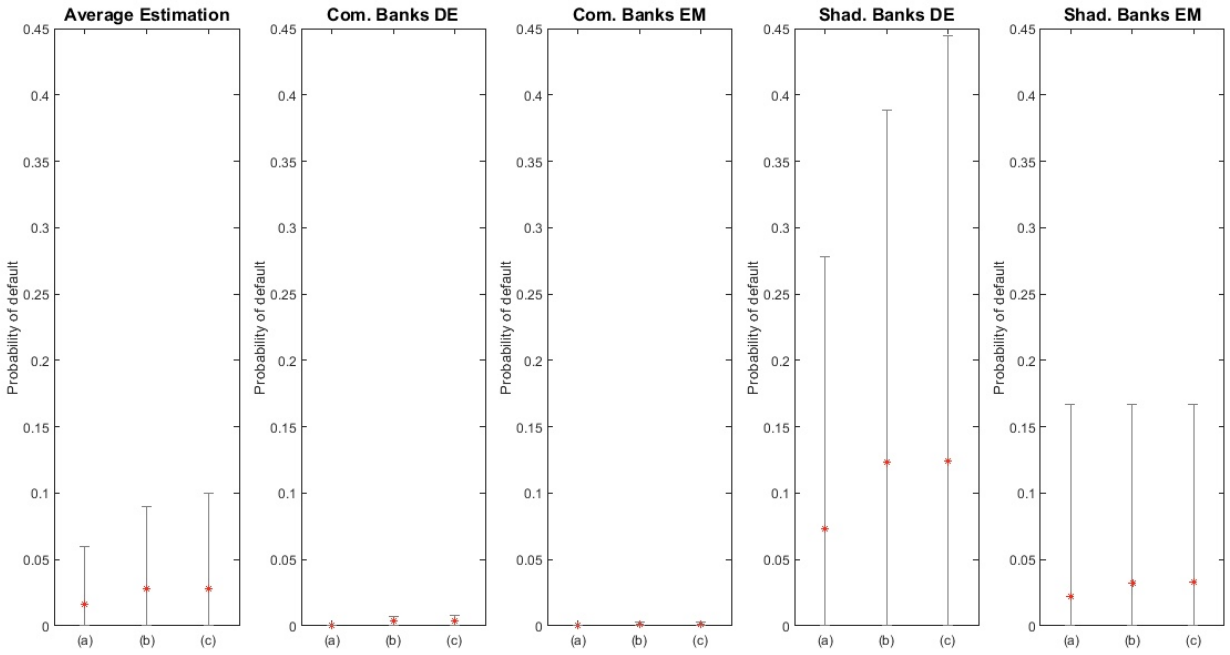

Figure A.3.1: Probability of default in absence of the Lender of Last Resort.[a.]

[a.] The plotted data corresponds to (a) Baseline, (b) Shock under baseline and (c) Shock in absence of the Lender of Last Resort.

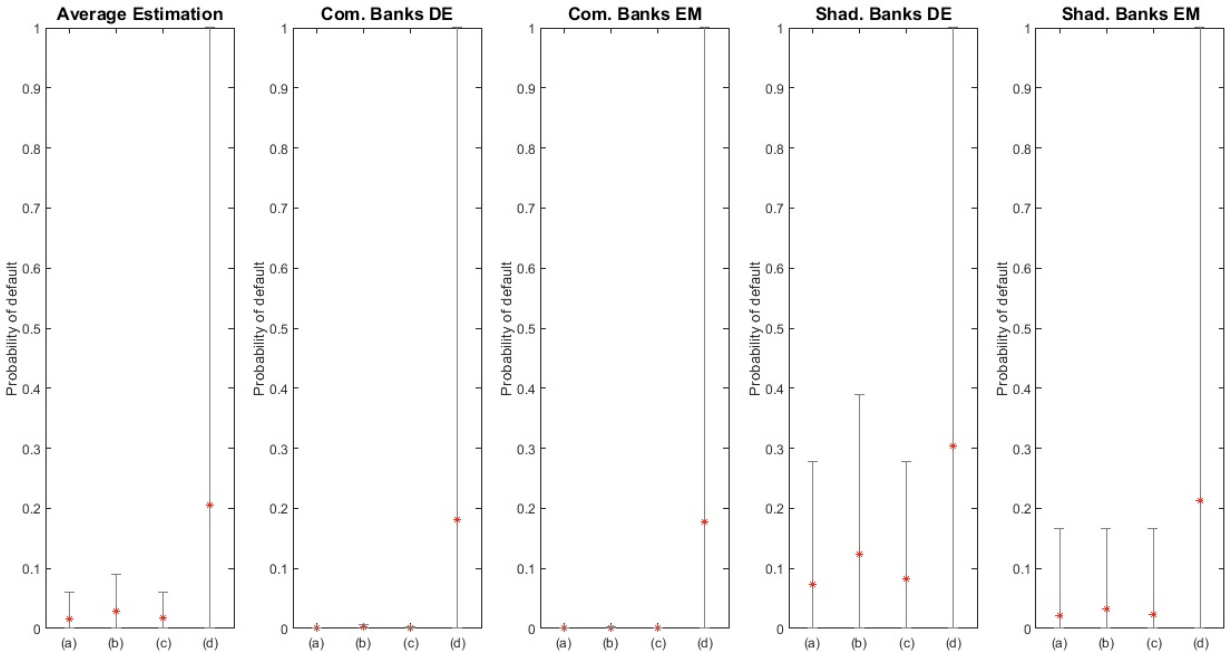

Figure A.3.2: Probability of default with different types of investors.[a.]

[a.] The plotted data corresponds to (a) Baseline, (b) Shock with $p_{fund} = 0.5$, (c) Shock with $p_{fund} = 0$ and (d) Shock with $p_{fund} = 1$.

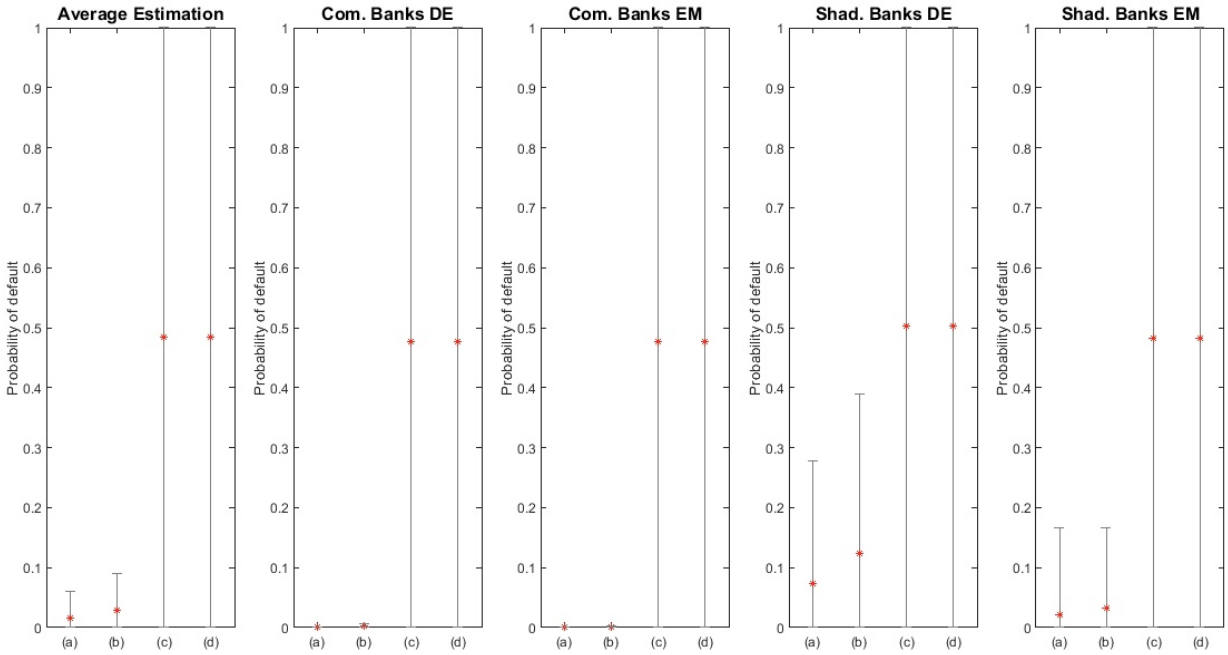

Figure A.3.3: Probability of default with one representative investor of each type.[a.]

[a.] The plotted data corresponds to (a) Baseline, (b) Shock under baseline, (c) Shock in a DE with representative investor per country and (d) Shock in an EM with representative investor per country.

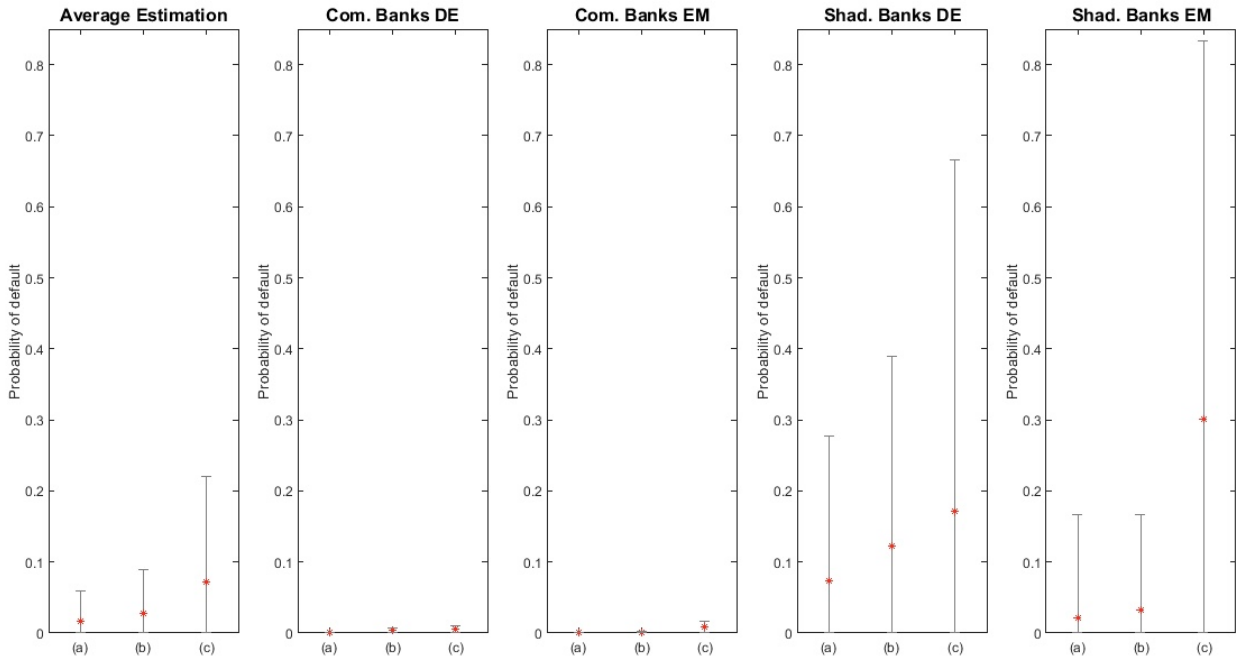

Figure A.3.4: Probability of default for banks with higher leverage.[a.]

[a.] The plotted data corresponds to (a) Baseline, (b) Shock under baseline and (c) Shock with leverage just above requirements for all banks.