Banking with Uninsured Liabilities: Spain in the 1860s*

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Abstract

This paper studies the macroeconomic effects of banks operating with (and without) deposit insurance. We first document a natural experiment regarding the effect of a financial crisis on a banking system where no public intervention (liquidity provision, deposit insurance or bail-outs) takes place. This is the case of Spain in the 1864-1866, in which a financial crisis had the effect of liquidating almost half of the banking system. This, in turn, induced a large credit contraction and a severe recession. Next, we analyze which would have been the effect of the crisis provided that a centralised deposit insurance scheme had been in place. To this end we calibrate a general equilibrium model with banks that broadly reproduces the structure of the Spanish economy at the time and evaluate the counterfactual of introducing deposit insurance. Regulation increases the steady-state level of output, consumption, capital and employment while it reduces the volatility of these variables in the dynamic equilibrium. We also find that an economy with deposit insurance enjoys substantial welfare gains with respect to one that displays an uninsured banking sector.

Keywords: deposit insurance, endogeous leverage, financial crisis, DSGE models, volatility shocks.

JEL classification: N13, N23, E31, E5.

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Introduction

Recently, a debate emerged on the possibility that the European Union sets up a banking union, intended as a European level organ for the supervision of and the intervention in the European banking sector. For instance, in a recent report the President of the European Council, Van Rompuy (2012), suggested some building blocks to ensure a stable and prosperous European Monetary Union. One of these blocks is represented by an integrated financial framework, consisting of two main elements: a single European banking supervision and a common deposit insurance framework. The rationale for having a common deposit insurance framework emerged during the recent financial crisis, in which each member state adopted a different policy to help (or not) its own banks. This fact led to heterogenous responses of financial/banking systems of member states, inducing different effects of a common financial crisis in the various countries. Also, the absence of a common banking regulation and supervision at the European level resulted in some countries displaying very weak banking systems that influenced the likelihood that a country could rollover its sovereign debt. A European level deposit insurance framework would imply that the intervention in the banking sector be decided at a centralized level and be homogeneous across countries. With such a tool in place, each bank operating in Europe would act knowing that in the event of a crisis intervention will not be decided by its own government, which can be more sympathetic with its national banks, but by the banking union according to predetermined parameters that shape the policy intervention. Thus, deposit insurance, together with supervision, should homogenize the behavior of the banking sector in the monetary union.

In this paper we study the macroeconomic effects of centralized deposit insurance in a currency union. To do this, our first step is to document a natural experiment occurred in a currency union in the past, that of Spain in the period 1856-1873. The Bank of Issue Act of 1856 created a system of multiple banks of issue. New banks had the monopoly of emission of banknotes in their cities, while the Bank of Spain had the monopoly of emission in Madrid and in any place where no bank of issue was to be created. Any entrepreneur was free to open a new bank of issue in any Spanish city where there were no existing issuers or a branch of the Bank of Spain. The only regulation imposed to banks was the limit of banknotes emission in a volume of less than three times the amount of their capital. In addition, a large number of joint stock banks were created in every region. In general, those banks conducted mainly local operations typically related with the funding of new railway lines. This system can be seen as an early example of currency union, where union here is referred to regions belonging to the same country which operated with the same unit of account, initially the *real* and then the *peseta*. The monetary system of the time was then a metallic system, in which interest rates were determined by the supply and demand of specie.

With such an environment in place a financial crisis hit Spain and other European countries during the middle part of the 1860s. In face of the crisis some countries, like the UK and Italy, adopted diverse types of policies to save their financial systems, such as the suspension of the convertibility of banknotes to specie or the provision of liquidity in lender of last resort operations. In contrast, no intervention whatsoever applied in Spain. This was in part due to the inactiveness of the government and in part to the decentralized banking system in which the Bank of Spain was a competitor to the rest of banks. We document the Spanish episode because it represents a singular case in which a financial crisis hits a deregulated currency union and no intervention takes place.[1] This historical experience highlights that with no intervention in place, almost half of the Spanish financial system was liquidated during the crisis.

We next turn to analyze the effect of deposit insurance by taking the Spanish experience as a benchmark case. To do this, we use Spanish data to calibrate the general equilibrium model with banks introduced in Nuño and Thomas (2013). The latter work presents a model in which unregulated banks borrow from institutional investors in the form of short term collateralized risky debt. Banks invest in the non-financial corporate firm sector, with both banks and firms segmented across islands. Also, firms receive island specific shocks on the effective amount of capital employed in production. Thus, banks are exposed to island-specific risk so that a fraction of them declares bankruptcy and defaults on its debt in each period. Such a model is able to replicate qualitatively and quantitatively bank leverage cycles in modern US and thus appears appropriate to study regulation on banking. Also, the model displays what we regard as the crucial features of the decentralized Spanish banking system of the 1860s. In particular, banks in the model i) operate on different islands (i.e. regions), ii) are involved in risky activities, iii) make use of leverage and iv) do not face regulation.[2]

We then extend the model by adding a sector consisting of regulated banks. Regulated banks' liabilities are riskless, in the sense that these banks borrow from households in the form of deposits that are insured by the government. Also, regulated banks are subject to a regulatory capital requirement, which is isomorphic to a maximum leverage constraint. Starting from the calibrated one-sector unregulated model, we analyze the effect of introducing deposit insurance together with a maximum leverage constraint on a part of the financial system. In the two-sector model, the exogenous level of leverage imposed to regulated institutions endogenously determines the size of the regulated sector. We find that for any value of exogenous leverage, the introduction of deposit insurance increases the value of output, consumption, employment and investment in the steady state, and reduces the volatility of these variables in the dynamic equilibrium. These effects generate a welfare gain both in the non-stochastic steady state of the model and in the dynamic equilibrium (expected welfare). However, we find that the increase in welfare is entirely due to the change in the steady state of the model. The main reason is that regulation reduces the costs of asymmetric information in the economy, because regulated institutions do not face the participation and incentive compatibility constraints that unregulated institutions have to

[1] This is in contrast for instance with the current crisis in Europe, where several policies have been adopted either by member states or by the European Central Bank to help national banking systems.

[2] We have already mentioned that local banks of issue were subject to regulation regarding their banknotes, but not regarding their deposits.

take into account. This fact increases the amount of credit in steady state and consequently steady state capital, output, consumption, employment and investment.

Our paper relates to the recent macroeconomic literature on banking, financial crisis and regulation. Until recently, few attempts had been made to introduce non-trivial banking sectors into DSGE models (Bernanke and Gertler, 1989, Carlstrom and Fuerst, 1997, Kiyotaki and Moore, 1997). In recent years instead, a wealth of works introducing banking in macroeconomic models have been developed (Christiano et al., 2010, Gerali et al., 2010, Gertler and Kiyotaki, 2010, Gertler and Karadi, 2011, Boissay, Collard and Smets, 2012 among others). Our model complements these contributions by considering deposit insurance and leverage constraints by extending the "unregulated" model presented in Nuño and Thomas (2013). Thus, this paper also intersects the literature on deposit insurance, which focuses mainly on the role of this tool in preventing bank runs, as in the seminal work of Diamond and Dybvig (1983). Most contributions in this area employed models with a given number of periods, as in Chari and Jagannathan (1988), Matutes and Vives (1995), Allen and Gale (1998) and Repullo (2000). Here instead we introduce deposit insurance in a fully fledged DSGE model with banking. This allows us to study quantitatively the benefits (insurance) and costs (moral hazard) of deposit insurance in the calibrated model. Also, our paper relates to the recent economic history literature on financial crises, such as Reinhart and Rogoff (2008), Leaven and Valencia (2008), and Schularick and Taylor (2012). In contrast to this literature, which typically analyzes large historical databases, we focus on a particular episode.

A closely related work is Martinez-Miera and Suarez (2012), who study the effect of deposit insurance and capital requirements in a dynamic model with risk neutral bankers. In their model, bankers can choose to invest either in firms bearing non-systemic (insurable) risk or in firms bearing systemic (non-insurable) risk. Although socially inefficient, investment in systemic firms can be attractive for the banker who enjoys limited liability. Higher capital requirements imply a lower level of credit in equilibrium (which induces a smaller level of output and consumption), but also prevent banks from investing too much in firms bearing systemic-risk. This is because when the level of credit is smaller, the value of bank's capital is larger and this increases the incentive for the banker to make sure that its capital survives the systemic shock. This trade off implies the existence of an optimal level of capital requirement, which is found to be 14% in the calibrated model. While there are several differences with Martinez-Miera and Suarez (2012), in what follows we describe the most relevant. First, in our model leverage is endogenous for unregulated banks, while in Martinez-Miera and Suarez (2012) leverage is exogenously imposed in the model. Second, we focus on the effect of deposit insurance and capital requirements in the presence of both TFP and volatility shocks. The latter have been recently proved to be the relevant drivers of financial business cycles.[3] Third, our economy does not display rare probability events but is analyzed in a standard business cycle environment.

[3] Bloom (2009), Bloom et al. (2011), Arellano, Bai and Kehoe (2012).

The remaining of the paper is as follows. Section 2 describes the Spanish financial system in the 1850-60s, while section 3 is devoted to the 1864-66 crisis in Spain. Section 4 presents the model and section 5 presents the quantitative results. Finally, section 6 concludes.

1 The Spanish Financial System

In this section we describe the main features of the financial system present in Spain in the period 1856-1873 and compare it with those of other European economies. Broadly speaking, European countries at that time experienced a tremendous expansion in money and credit due to the emergence of joint stock banks. A joint stock bank was a new form of financial enterprise to furnish funds for new enterprises upon pledge of their stock. For example, a proposed railway did not have to await the slow process of placing its stock and bonds among investors in order to obtain funds to begin construction, but would deposit these securities in a joint stock bank, which would agree to accept its debts for a specified sum. These joint stock banks were able to sell their own shares and thus obtain the funds to make advances to the railways companies. In addition, these enterprises benefited from the principle of limited liability.

In Spain, it was the Credit Company Act (*Ley General de Sociedades de Crédito,* 1856), that introduced the new form of banking. This law followed the arising of joint stock banks in France (*Crédit Mobilier,* 1852, *Crédit Industriel et Commercial,* 1859, *Crédit Lyonnais,* 1863 and *Société Générale,* 1863) and was enacted the same year as the Joint Stock Companies Act of the UK, which introduced limited liability and the general right of incorporation without a precedent act of the Parliament.[4] The latter led to a significative growth in the number of corporations and the volume of assets. The evolution in the capital invested in limited liability companies in the UK is reported in figure 1. The latter increased from around £25 millions in 1861 to almost £250 millions in 1864.

The Spanish Credit Company Act defined the conditions for the establishment of *sociedades de crédito,* that is, investment banks similar to the French *Crédit Mobilier* and the English joint stock banks. The success of the *sociedades de crédito* in Spain was similar to that in England of the joint stock banks. The consequence was the emergence of a great number of *sociedades de crédito* during the period 1856-1865 (see Table 1). The largest among them were the *Crédito Mobiliario Español*, the *Sociedad Española Mercantil e Industrial*, and the *Compañía General de Crédito en España*, with the three banks accounting for a capital of 162.5 millions of pesetas.

Across Europe, the investments financed through joint stock banks were mainly railroads. In addition, many railroad companies emerged thanks to the limited liability principle. Figure 2 reports the kilometers of railroads installed in the UK, France and Spain. Until 1858, new railroad companies in the UK had to await an authorization from the Parliament. Starting in 1859 instead, stocks could be directly sold on the market. In France the picture was similar. As described in Kindelberger (1984), the *Credit Mobilier* played no big role in manufacturing

[4] Kindleberger, (1984, pp. 112-113).

investment, whereas its main investments were in railroads, banks and other public works. In 1852, the Bank of France acquired the right to lend on railroads securities and the obligations of the City of Paris. "The expensive force of the Credit Mobilier and the Bank of France together pushed so hard that the regents of the Bank came almost to the point in 1856 of resigning themselves to abandoning convertibility of the franc, as they had done in 1848" (Plessis, 1980, p. 7).

As showed in figure 2, Spain was no exception to the European trend. The General Railway Act (*Ley de Ferrocarriles,* 1855) provided state aid and reduced the administrative burden for building railways lines in Spain, including the possibility of foreign investment in the stock of the railways companies, the total exemption of custom tariffs in the import of iron, machinery, wagons and other transport equipment, and the public subsiding of, at most, the third part of the construction budget. This law soon showed its effectiveness. Prior to 1855, only 440 kilometers had been constructed in Spain; from 1856 to 1866, more than 4,300 kilometers were opened to the traffic. The total railway investment in Spain amounted in 1867 to more than 2,760 millions of pesetas, jointly in stock and debenture bonds. Table 2 shows how most of the capital invested in joint stock companies in Spain went to railways. It was followed by investment in banking, which was typically reinvested in railroads. The manufacturing sector received only a tiny part of the funds.

Whereas the Spanish economy shared several similarities with those of other European countries, a key difference was represented by the banking system. The Bank of Issue Act (*Ley de Bancos de Emisión,* 1856) concerned the establishment of new banks of issue and the regulation of existing ones. At the time, there were three banks of issue of Spain: the Bank of *San Fernando,* and those of Barcelona and Cadiz.[5] The previous legislation of 1851 had strongly limited the maximum emission volume, with deflationary consequences for the economy. The maximum volume of banknotes was limited to the same amount as the capital. In addition, the maximum ratio of banknotes over metallic reserves was set to three and no lending was permitted if the collateral were stocks of the Bank. During the period 1851-1855, the Bank of *San Fernando* always kept a volume of emission equal to the legal maximum, which suggests that the Spanish economy was demanding more liquidity than it was supplied.[6] The law of 1856 finally broke the emission monopoly of the Bank of *San Fernando* by creating a system with multiple banks of issue.

The first point of the law renamed the Bank of *San Fernando* as the Bank of Spain, for an initial period of 25 years. It allowed the establishment of local banks of issue in each Spanish city where there were no existing branches of the Bank of Spain. These new banks had the monopoly of emission in their cities. The law also awarded the Bank of Spain the emission monopoly in Madrid and in any place where no bank of issue was to be created. With respect to the emission volume, the law entitled new and old banks of issue to emit banknotes in a volume of less than

[5] Tedde (1999).
[6] Tortella (1970, p. 26).

three times the amount of their metallic reserves, as in the 1851 law. The novelty was that the volume of banknotes was now limited by three times the amount of the initial capital, that is, a threefold expansion from the existing situation. With the new law the aggregate emission volume never reached its limit: the ratio of banknotes over metallic reserves was always below the legal maximum of three, a distinct feature with respect to the period pre-1856. Finally, the Government was responsible for the appointment of the Governor of the Bank of Spain and of the rest of the banks of issue.

Thus, the two distinctive features of such an environment were the decentralization of the banking system and the absence of a proper central bank. Regarding the former, each bank had the right to operate in a city of the country and was a monopolist of banknotes emission in that city. This implied an heterogeneous credit provision across regions in the economy. Thus, in this respect, such a banking system can be seen as a currency union where banknotes were denominated in *reales* or *pesetas*, the legal unit of account, and in which a single bank of issue and a number of joint stock banks operated in each region of the union. Regarding the second feature, it should be noted that although the Bank of Spain was larger and more involved with the central government than the rest of banks, it was never the banker of other banks. That is, the rest of banks never deposited their metallic reserves at the Bank of Spain (as it was the case with the Bank of England). This fact had two important implications. First, during a financial crisis the Bank of Spain had no mandate, and so no interest, in providing funds to the rest of Spanish banks (i. e. the Bank of Spain would not have employed lender of last resort policies). Second, the reaction of the Bank of Spain to a financial crisis would have been similar to that of the rest of banks: an individual bank found it optimal to withdraw funds from the market in an attempt to improve its balance-sheet position. The potential aggregate effect of this individual behavior of the banks of issue was a dramatic fall in the supply of credit in the economy. Indeed, as we document in the next section, this is what happened in 1864-66 crisis in Spain.

In contrast with the Spanish case, the Bank of England started acting as a lender of last resort since 1847, as documented in a quantitative fashion in Flandreau, Bignon and Ugolini (2012). The same work also provides evidence that the Bank of France employed lender of last resort operations since the 1847-48 crisis. Before that date, and more specifically during the 1817-1847 period, a system of regional banks of issue had emerged in France. Possibly, this is the closest system to the one that emerged later on in Spain. The first regional banks were opened in Rouen, Nantes and Bordeaux in 1817-18. These were subject to restrictions such as the right to issue notes only for their headquarters and possibly one or two additional towns and the limit to their liabilities of three times the amount of their metallic reserves. Their operations were mainly of local nature and they never developed any system of exchange of notes. Nevertheless, in their departments they were quite successful. The Bank of France grew fearful of competition and began itself to open branches between 1841 and 1848, each branch given the monopoly of the note issue in its own town. This system came to an end during the crisis of 1847-48 for reasons that loosely resemble those of the 1864-66 Spanish crisis that we describe in the next section. During the 1848 political crisis, many people tried to hoard specie, thus producing a run on banks. The Government gave *cours forcè* to the Bank of France and allowed it to issue notes of 100 frs. The departamental banks were also given the same nominal facilities, but since their notes were legal tender only within their own respective localities while those of the Bank of France were legal tender all over France, the circulation of the Bank of France gained an overwhelming ascendency over that of the departamental banks. Finally, the Bank of France refused to come to their rescue as a lender of last resort and pressed the Government not to renew their charters. After this crisis, the Bank of France was the only issuing bank in France.[7]

2 The 1864-66 Crisis in Spain

The increase in credit due to the emergence of joint stock banks and the large investments in railroads allowed Spain to maintain sustained growth until 1864 (see figure 3). However, between 1864 and 1866 a severe financial crisis hit Spain. Our aim in this section is to highlight the roots of the crisis and the effects on the Spanish financial and economic system.

According to Tortella (1969, 1973), the main cause of the Spanish crisis has been the low realized returns on railroads investements. In 1864 the Spanish government stopped paying railways subsidies[8] and in October, one of the largest sociedades de credito, la *Compañía General de Crédito de España*, suspended payments. The reason was the low profits obtained in two of its major investments, the railways lines Sevilla-Jerez-Cadiz and Merida-Sevilla. More than 85% of the assets were railways investments and thus, as the crisis began and banks were forced to deleverage, the bank was unable to meet the demands of its depositors and was forced to declare bankruptcy. Almost at the same time, and for similar reasons, the Banco de Valladolid, one of the new local banks of issue, also failed. Rumors were widespread about the weak state of the balance-sheets of most banks of issue and *sociedades de credito*. The stock market plunged in 1864 in the middle of pessimistic expectations about railways prospects.

An alternative view, mostly overlooked in the literature suggests that the financial crisis that hit Spain could be due to international factors.[9] In the first half of the 1860s, the increase in leverage made possible by the emergence of joint stock banks fuelled a European surge in cotton prices and, to a minor extent, in railways.[10] Cotton prices increased fourfold from 1860 to 1864. The rise in cotton prices was a consequence of the American Civil War (1861-1865) that caused the blockade of the Southern ports, which reduced the supply of cotton for European mills, producing a rise in cotton imports from Eastern countries. However, in 1864, the economic

[7] Although the Bank of France operated lender of last resort operations to support the financial system as a whole in the 1847-48 crisis, it never intervened to support local banks of issue which were seen as competitors to the same Bank.

[8] Kindelberger (1984), p. 149.

[9] See Kindelberger (1984), p. 274.

[10] Cotton textiles was a key sector in the industrial revolution. See Kindelberger (1984), p. 198.

climate became more uncertain due to the troubles in European politics caused by the Prussian hegemonic policy inspired by Bismarck. In order to avoid running out of metallic reserves, several central banks were forced to raise their discount rates. The abrupt tightening of monetary policy amid a climate of pessimistic expectations generated the collapse of cotton prices and a stock market crisis.

Whereas in 1865 the international situation seemed to be back in control, in 1866 another huge shock disturbed the financial economy in Europe, especially in the UK, when the bank Overend, Gurney & Co. suspended payments in May 1866 and went into liquidation in June. That happened in a climate of growing uncertainty due to the Austro-Prussian military tensions. During the spring of 1866, an action by Overend was pending in the courts to recover £60, 000. On May 9th the court decided that Overend would not receive any compensation. The decision caused a run upon Overend, and on the afternoon of May 10th the firm suspended payments with more than £18 millions of liabilities. The next day, May 11th, known as *Black Friday*, Lombard Street witnessed a stock market collapse and a banking panic with crowds at the gates of the most reputed banks. On May 11th, when the news about the failure of Overend arrived, the panic extended to many Spanish cities, especially Barcelona. On May 12th, the *Catalana General de Crédito* and the *Crédito Mobiliario Barcelonés*, two *sociedades de credito*, suspended payments. After that, a chain of bankruptcies extended through the country. Thus, in this view it is the highly volatile economic and political situation of Europe that extended to the Spanish financial system and triggered the crisis.

At the time the crisis arrived the Spanish monetary system was composed by 21 banks of issue plus more than 30 sociedades de credito. When the crisis began, these banks reduced the amount of banknotes by contracting loans and discounts in a more conservative way than the Bank of Spain, in order to reduce the risks of a bank-run on banknotes.[11] In addition, the fiscal position of the Government severely constrained the conduct of the Bank of Spain: government pressures prevented the Bank from selling part of its portfolio in order to obtain additional liquidity. Therefore, the Bank of Spain was forced both to drastically reduce the volume of banknotes and to raise interest rates from 6 to 9%.

The consequence was a severe collapse of the financial system in 1866 that amplified initial shocks by reducing the volume of banknotes and current accounts. Figure 3 reports the log-linearly detrended pattern of real GDP and total banks liabilities (banknotes and current accounts) which we use in the next section to estimate the model. The volume of banknotes and current accounts fell abruptly from 1864 to 1866 and remained below trend until 1869. This is a good indicator of how the consequences of the financial crisis extended for most of the second half of the 1860s. The number of Sociedades de Credito fell from 32 in 1866 to only 14 three years later (see table 1). The evolution of real GDP growth instead shows that 1864 is not a recession year, while 1865 and especially 1868 are such. Therefore, the economic crisis did not

[11] See Moro, Nuño and Tedde (2013) for a description of the behavior of Spanish banks' balance sheets in the period 1856-1873.

precede, but followed the financial crisis, in the same line as in other European countries.

The passivity of the Spanish authorities contrasts with other countries such as Italy or England. In Italy, the Government was forced to introduce the *corso forzoso* on May 11th, which represented a suspension of the convertibility of the lira into gold and an additional supply of 250 million *lire* by the Bank of Italy.[12] In England, the Government and the Bank of England cooperated to minimize the crisis and provide extra liquidity during the panic. The Bank Charter Act had been already suspended during the 1847 and 1857 crisis. In these cases the Bank of England acted as a lender of last resort even if it had no explicit mandate about it. In Spain, the Bank of Spain and the local banks of issue considered each other as competitors, so they felt no motivation to help each other.

3 Model

In the previous section we discussed two possible causes of the crisis that hit Spain in the 1864-66, a domestic one and an international one. From a theoretical point of view, the domestic explanation can be interpreted as a negative TFP shock that hit railways enterprises. In this view, lower than expected TFP reduces the returns of firms investments. As a results, banks holding claims of such firms experience a reduction in their equity (net worth) and if the fall in profitability is too large banks are lead to insolvency on their obligations and to bankruptcy.

As an alternative cause of the crisis we discussed international factors. European cotton and railways stock price booms and busts, volatile interest rates set by the English and the French central bank and wars involving European countries (i.e. the Prusso-Danish war of 1864 and the Prusso-Austrian war of 1866) were all factors that contributed to increase uncertainty on the returns of economic activity in Europe. In fact, altough each of these events occurred in a subset of European countries, it is hard to argue that their effects did not affect all economies in Europe. For instance, Kindelberger (1984, p. 274) describes the design of the 1866 crisis that affected several European countries as particulary intricate because it combined the end of the American Civil war, which depressed the price of cotton, and Prussian mobilization against Austria. As none of these major events occurred in Spain, a possible theoretical interpretation of their effect on the Spanish economic and financial system is through what are commonly labeled "volatility shocks". In this view, a war between two European countries not involving Spain did not have a direct effect on the Spanish economy, but it increased uncertainty about the return on investement in that country.[13] Recently, a wealth of macroeconomic and financial literature documented the importance of volatility shocks in generating business cycles and

[12] Similar situations were present in Prussia, Austria and Russia.

[13] For instance, a war could have increased uncertainty on the demand faced by railways companies. On the one hand a war reduces resources available for consumption and thus reduces the demand for transports including railways. On the other hand a war induces large movements of resources and individuals, which might increase the demand for transports. This view of volatility shocks is consistent with the one given in Arellano, Bai and Kehoe (2012).

financial/leverage cycles.[14]

Here we present a DSGE model with financial institution in which we consider both TFP and volatility shocks. We extend Nuño and Thomas (2013), who show that a combination of TFP and volatility shocks allow their model to account both for the real business cycle and for the cyclicality observed in financial institutions' leverage, assets and equity in modern US. These results suggest that such a model is appropriate to study regulation of financial institutions. Thus, we present a model in which, beside an unregulated banking sector similar to the one in Nuño and Thomas (2013), we introduce an additional financial sector composed of regulated institutions.

More in detail, the model economy we present is composed by six types of agents: households, firms producing the final good, capital producers, institutional investors, regulated banks and unregulated banks.[15] On the financial side, the structure is as follows. Households lend to regulated banks in the form of deposits, and to institutional investors in the form of equity. Institutional investors use the latter funds to lend to unregulated banks in the form of short-term, collateralized debt.[16] Both regulated and unregulated banks combine their external funding and their own accumulated net worth to invest in firms. We assume no frictions in the relationship between banks and firms, such that the Modigliani-Miller theorem applies to firm financing. We assume that firms issue perfectly state-contingent debt only, which can be interpreted as equity. Banks (regulated or not) and firms are segmented across islands, where the latter are subject to idiosyncratic shocks. Banks are thus exposed to island-specific risk, such that a fraction of them declare bankruptcy and default on their debt each period. Regulated banks enjoy deposit insurance, such that deposits are safe. However, unregulated banks' debt is not guaranteed, and is therefore risky. Institutional investors operate economy-wide and diversify perfectly across islands, thus insulating households from island risk.

At the end of each period, after production has taken place, firms use borrowed funds to purchase physical capital from capital producers. At the beginning of the following period, firms combine their stock of capital and households' supply of labor to produce a final good. The latter is purchased by households for consumption purposes, and by capital producers. After production, firms sell their depreciated capital stock to capital producers, who use the latter and the final goods to produce new capital. The markets for labor, physical capital and the final good are all economy-wide.

We now analyze the behavior of each type of agent. All variables are expressed in real terms, with the final good acting as the numeraire.

[14] Brunnermeier and Pedersen (2009), Geanakoplos (2010), Fostel and Geanakoplos (2008), Bloom (2009), Bloom et al. (2011), Christiano et al. (2010), Arellano, Bai and Kehoe (2012).

[15] We denote depository banks as "regulated" as we describe below that they are subject to capital requirements and supervision. In contrast, we denote the rest of banks as "unregulated", even if we include among them the local banks of issue, which were subject to specific regulations regarding banknotes, but not deposits.

[16] An alternative modeling choice would be to integrate institutional investors direcly into households. The results of the model are not affected by this choice.

3.1 Households

The representative household's utility is

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u(C_t) - v(L_t) \right],$$

where C_t is consumption and L_t is labor supply. The budget constraint is

$$C_t + D_t + N_t^{inv} = W_t L_t + R_{t-1} D_{t-1} + R_t^N N_{t-1}^{inv} + \Pi_t^b,$$

where D_t are deposits at regulated banks, R_t is the risk-free gross interest rate on deposits, N_t^{inv} are equity holdings at institutional investors, R_t^N is the return on institutional investor equity (to be defined later) and W_t is the wage. Also, $\Pi_t^b = \Pi_t + \Pi_t^r - T_t$ are dividend payments from the household's ownership of banks. Here Π_t^r is profits of regulated banks, Π_t profits of unregulated banks and T_t are payments to the deposit insurance fund.[17] The first order conditions are

$$1 = E_t \left[\Lambda_{t,t+1} R_t \right],$$
$$1 = E_t \left[\Lambda_{t,t+1} R_{t+1}^N \right],$$
$$W_t = \frac{v'(L_t)}{u'(C_t)},$$

where

$$\Lambda_{t,t+1} = \beta \frac{u'(C_{t+1})}{u'(C_t)}$$

is the stochastic discount factor.

3.2 Firms

The final good is produced by perfectly competitive firms. We assume that firms are segmented across a continuum of 'islands', indexed by $j \in [0, 1]$. These islands are interpreted as regions of the economy. The representative firm in island j starts period t with a stock K_t^j of physical capital, purchased at the end of period $t-1$. The firm then receives an island-specific shock ω_t^j that changes the amount of effective capital to $\omega_t^j K_t^j$. The shock ω_t^j is iid over time and across islands. Let $F(\omega; \sigma_{t-1}) \equiv F_{t-1}(\omega)$ denote the cumulative distribution function of island-specific shocks at time t, where σ_{t-1} denotes the standard deviation of $\log \omega_t^j$. The latter standard deviation follows an exogenous process. Notice that the standard deviation of island-specific shocks in a given period is known one period in advance. We also assume that ω^j has a unit mean, $E\left[\omega^j\right] = 1$.

Effective capital is combined with labor to produce units of final good, Y_t^j, according to a Cobb-Douglas technology,

$$Y_t = Z_t (\omega^j K_t^j)^{\alpha} (L_t^j)^{1-\alpha}, \tag{1}$$

[17] The deposit insurance fund may be interpreted as being financed either directly by households by means of lump-sum taxes, or by compulsory contributions by non-defaulting regulated banks, imposed by the regulator. In the latter case, $\Pi_t^r - T_t$ represents net profits that households receive from regulated banks.

where Z_t is an exogenous aggregate total factor productivity (TFP) process. The firm maximizes operating profits, $Y_t^j - W_t L_t^j$, subject to (1). The first order condition is

$$W_t = (1-\alpha) Z_t \left(\frac{\omega^j K_t^j}{L_t^j} \right)^\alpha . \quad (2)$$

Therefore, the effective capital-labor ratio is equalized across islands: $\omega^j K_t^j / L_t^j = [W_t / (1-\alpha) Z_t]^{1/\alpha}$ for all j. The firm's profits are given by

$$Y_t^j - W_t L_t^j = \alpha Z_t (\omega^j K_t^j)^\alpha (L_t^j)^{1-\alpha} = R_t^k \omega^j K_t^j,$$

where

$$R_t^k \equiv \alpha Z_t \left[\frac{(1-\alpha) Z_t}{W_t} \right]^{(1-\alpha)/\alpha}$$

is the return on effective capital, which is equalized too across islands. After production, the firm sells the depreciated effective capital $(1-\delta) \omega^j K_t^j$ to capital producers at price one. The total cash flow from the firm's investment project, equal to the sum of operating profits and proceeds from the sale of depreciated capital, is given by

$$R_t^k \omega^j K_t^j + (1-\delta) \omega^j K_t^j = \left[R_t^k + (1-\delta) \right] \omega^j K_t^j. \quad (3)$$

The capital purchase in the previous period was financed entirely by state-contingent debt. In particular, the cash flow in (3) is paid off entirely to the lending banks.

At the end of period t, the firm buys K_{t+1}^j units of new capital at price one for production in $t+1$. In order to finance this purchase, the firm issues a number of claims on next period's cash flow equal to the number of capital units acquired, K_{t+1}^j. Following Gertler and Kiyotaki (2010), we assume that the firm can only borrow from banks located on the same island. In particular, the firm sells A_t^j claims to unregulated banks on island j, and the rest, $A_t^{r,j}$, to regulated banks on the same island. The firm's balance sheet constraint is thus simply

$$K_{t+1}^j = A_t^j + A_t^{r,j}.$$

3.3 Capital producers

There is a representative, perfectly competitive capital producer. At the beginning of each period, after production of final goods has taken place, the capital producer purchases the stock of depreciated capital $(1-\delta) K_t$ from firms at price one. Used capital can be transformed into new capital on a one-to-one basis at no cost. Capital producers also purchase final goods in the amount I_t, which are used to produce new capital goods on a one-to-one basis. At the end of the period, the new capital is sold to firms at price one. In equilibrium, capital producers make zero profits.

3.4 Unregulated banks

In each island j there exists a representative unregulated bank. After production in period t, island j's firm pays the unregulated bank its share of the cash flow from the investment project, $\left[R_t^k + (1-\delta)\right] \omega^j A_{t-1}^j$. Therefore, the gross rate of return on the unregulated bank's assets is

$$\frac{\left[R_t^k + (1-\delta)\right] \omega^j A_{t-1}^j}{A_{t-1}^j} = \left[R_t^k + (1-\delta)\right] \omega^j \equiv R_t^A \omega^j.$$

Regarding the liabilities side of its balance sheet, the unregulated bank borrows from institutional investors by means of one-period collateralized risky debt contracts. Under the latter contract, at the end of period $t-1$ the bank sells its financial claims A_{t-1}^j (which serve as collateral) to the institutional investor at price B_{t-1}^j, and agrees to repurchase them at the beginning of time t at a non-state-contingent price $\bar{B}_{t-1}^j$. At the beginning of period t, the proceeds from the bank's assets, $R_t^A \omega^j A_{t-1}^j$, exceed the face value of its debt, $\bar{B}_{t-1}^j$, if and only if ω^j exceeds a threshold level $\bar{\omega}_t^j$ given by

$$\bar{\omega}_t^j \equiv \frac{\bar{B}_{t-1}^j}{R_t^A A_{t-1}^j}, \tag{4}$$

that is, the face value of debt normalized by the bank's assets times their aggregate return. If $\omega^j \geq \bar{\omega}_t^j$ the bank honors its debt, that is, it repurchases its assets at the pre-agreed price $\bar{B}_{t-1}^j$. If $\omega^j < \bar{\omega}_t^j$, the bank defaults and closes down, whereas the institutional investor simply keeps the collateral and cashes the resulting proceeds, $R_t^A \omega^j A_{t-1}^j$. Notice that the threshold $\bar{\omega}_t^j$ depends on R_t^A and is thus contingent on the aggregate state.

For non-defaulting banks, we assume that a random fraction $1-\theta$ of them closes down for exogenous reasons each period, at which point the net worth accumulated in each bank is reverted to the household.[18] The remaining fraction θ of banks continue operating. For the latter, the flow of dividends distributed to the household is given by

$$\Pi_t^j = R_t^A \omega^j A_{t-1}^j - \bar{B}_{t-1}^j - N_t^j, \tag{5}$$

where N_t^j is net worth after dividends have been paid. Also, we assume that households inject equity in new banks, but cannot inject equity in continuing banks. Therefore, continuing banks are subject to a non-negativity constraint on dividends, $\Pi_t^j \geq 0$, or equivalently,

$$N_t^j \leq R_t^A \omega^j A_{t-1}^j - \bar{B}_{t-1}^j. \tag{6}$$

Once the bank has decided how much net worth to hold, it purchases claims on firm profits, A_t^j, subject to its balance sheet constraint,

$$A_t^j = N_t^j + B_t^j.$$

[18] As we show below, in equilibrium unregulated banks have no incentive to pay dividends. The assumption of an exogenous exit probability for non-defaulting banks should thus be viewed as a short-cut for motivating dividend payments by such banks, which would otherwise accumulate net worth indefinitely.

When borrowing from the institutional investor, the unregulated bank faces two constraints. First, a *participation constraint* requires that the institutional investor is willing to fund the bank. Indeed, the institutional investor may alternatively lend at the riskless rate R_t. The latter investment has a present discounted value of $E_t \Lambda_{t,t+1} R_t B_t^j = B_t^j = A_t^j - N_t^j$, where we have used the household's Euler equation and the bank's balance sheet constraint. Therefore, the participation constraint takes the form

$$E_t \Lambda_{t,t+1} \left\{ R_{t+1}^A A_t^j \int^{\bar{\omega}_{t+1}^j} \omega dF_t(\omega) + \bar{B}_t^j \left[1 - F_t \left(\bar{\omega}_{t+1}^j \right) \right] \right\} \geq A_t^j - N_t^j. \tag{7}$$

Second, we assume that once the bank has received the funding it may choose to invest in either of two firm segments within its island: a 'standard' segment, and a 'substandard' segment. Both segments differ only in the distribution of island-specific returns, given by $F_t(\omega)$ and $\tilde{F}_t(\omega) \equiv \tilde{F}(\omega; \sigma_t)$ respectively. The substandard technology has lower average payoff, $\int \omega d\tilde{F}_t(\omega) < \int \omega dF_t(\omega) = 1$, and is thus inefficient. Furthermore, $F_t(\omega)$ is assumed to first-order stochastically dominate $\tilde{F}_t(\omega)$: $\tilde{F}_t(\omega) > F_t(\omega)$ for all $\omega > 0$. Therefore, the substandard technology has higher *downside* risk. In order to induce the bank to invest in the standard segment, the institutional investor imposes an *incentive compatibility* (IC) constraint. Let $V_{t+1}(\omega, A_t^j, \bar{B}_t^j)$ denote the value function at time $t+1$ of a continuing bank, to be defined below. Then the IC constraint takes the following form,

$$\begin{aligned} & E_t \Lambda_{t,t+1} \int_{\bar{\omega}_{t+1}^j} \left\{ \theta V_{t+1} \left(\omega, A_t^j, \bar{B}_t^j \right) + (1-\theta) \left[R_{t+1}^k A_t^j \omega - \bar{B}_t^j \right] \right\} dF_t(\omega) \\ & \geq E_t \Lambda_{t,t+1} \int_{\bar{\omega}_{t+1}^j} \left\{ \theta V_{t+1} \left(\omega, A_t^j, \bar{B}_t^j \right) + (1-\theta) \left[R_{t+1}^k A_t^j \omega - \bar{B}_t^j \right] \right\} d\tilde{F}_t(\omega). \end{aligned} \tag{8}$$

The bank's expected net payoff, conditional on a particular aggregate state at time $t+1$, can be expressed as

$$\int_{\bar{\omega}_{t+1}^j} \left(R_{t+1}^A A_t^j \omega - \bar{B}_t^j \right) dF_t(\omega) = R_{t+1}^A A_t^j \int_{\bar{\omega}_{t+1}^j} \left(\omega - \bar{\omega}_{t+1}^j \right) dF_t(\omega).$$

The integral represents the value of a *call option* on island-specific returns with strike price equal to the default threshold, $\bar{\omega}_{t+1}^j$, or equivalently to the (normalized) face value of debt, $\bar{B}_t^j / R_{t+1}^A A_t^j$. Intuitively, limited liability implies that the bank enjoys the upside risk in asset returns over and above the face value of its debt, but does not bear the downside risk, which is transferred to the institutional investor. Furthermore, the value of the call option on island-specific risk may be expressed as

$$\int_{\bar{\omega}_{t+1}^j} \left(\omega - \bar{\omega}_{t+1}^j \right) dF_t(\omega) = \int \omega dF_t(\omega) + \int^{\bar{\omega}_{t+1}^j} \left(\bar{\omega}_{t+1}^j - \omega \right) dF_t(\omega) - \bar{\omega}_{t+1}^j.$$

Therefore, *given* the (normalized) face value of its debt, the bank's expected net payoff increases with the mean island-specific return, $\int \omega dF_t(\omega)$, but also with the value of the *put option* on island-specific returns with strike price $\bar{\omega}^j_{t+1}$,

$$\int^{\bar{\omega}^j_{t+1}} (\bar{\omega}^j_{t+1} - \omega) dF_t(\omega) \equiv \pi_t(\bar{\omega}^j_{t+1}) \equiv \pi(\bar{\omega}^j_{t+1}; \sigma_t).$$

The put option value under the substandard technology, which we denote by $\tilde{\pi}_t(\bar{\omega}^j_{t+1})$, is defined analogously, with $\tilde{F}_t$ replacing F_t. Given our assumptions on both distributions, it can be shown that $\tilde{\pi}_t(\bar{\omega}^j_{t+1}) > \pi_t(\bar{\omega}^j_{t+1})$.[19] Therefore, when choosing between investment strategies, the bank trades off the *higher mean return* of investing in the standard firm segment against the *lower put option value*. Furthermore, letting $\Delta\pi_t(\bar{\omega}^j_{t+1}) \equiv \tilde{\pi}_t(\bar{\omega}^j_{t+1}) - \pi_t(\bar{\omega}^j_{t+1})$ denote the difference in put option values, we have that $\Delta\pi'_t(\bar{\omega}^j_{t+1}) = \tilde{F}_t(\bar{\omega}^j_{t+1}) - F_t(\bar{\omega}^j_{t+1}) > 0$: the incentive to invest in the riskier firm segment increases with the (normalized) debt commitment.

Let $\bar{b}^j_t \equiv \bar{B}^j_t / A^j_t$ denote the face value of debt and deposits normalized by the bank's assets, which allows us to express the default threshold as $\bar{\omega}^j_t = \bar{b}^j_{t-1}/R^A_t$. Nuño and Thomas (2013) show that when model parameters satisfy

$$0 < \beta R^A - 1 < (1-\theta)\,\beta R^A \int_{\bar{\omega}^j} \left(\omega - \bar{\omega}^j\right) dF(\omega),$$

where R^A and $\bar{\omega}^j$ are the steady-state values of R^A_t and $\bar{\omega}^j_t$, respectively, the equilibrium dynamics of unregulated bank j in a neighborhood of the non-stochastic steady state are characterized by the following features:

1. The bank optimally retains all earnings,

$$N^j_t = \left(\omega^j - \frac{\bar{b}_{t-1}}{R^A_t}\right) R^A_t A^j_{t-1}, \tag{9}$$

   where $\bar{b}_{t-1}$ is equalized across islands.

2. The IC constraint holds with equality. In equilibrium, the latter can be expressed as

$$1 - \int \omega d\tilde{F}_t(\omega) = E_t \left\{ \frac{\Lambda_{t,t+1} R^A_{t+1} (\theta\lambda_{t+1} + 1 - \theta)}{E_t \Lambda_{t,t+1} R^A_{t+1} (\theta\lambda_{t+1} + 1 - \theta)} \left[\tilde{\pi}(\bar{\omega}_{t+1}; \sigma_t) - \pi(\bar{\omega}_{t+1}; \sigma_t)\right] \right\}, \tag{10}$$

   where $\bar{\omega}_{t+1} = \bar{b}_t / R^A_{t+1}$ and λ_{t+1} is the Lagrange multiplier associated to the participation constraint. Both $\bar{\omega}_{t+1}$ and λ_{t+1} are equalized across islands.

3. The participation constraint holds with equality,

$$A^j_t = \frac{1}{1 - E_t \Lambda_{t,t+1} R^A_{t+1} \left[\bar{\omega}_{t+1} - \pi(\bar{\omega}_{t+1}; \sigma_t)\right]} N^j_t \equiv \phi_t N^j_t. \tag{11}$$

[19] Using integration by parts, it is possible to show that $\pi_t(\bar{\omega}^j_{t+1}) = \int^{\bar{\omega}^j_{t+1}} F_t(\omega)\, d\omega$. First-order stochastic dominance of $F_t(\omega)$ over $\tilde{F}_t(\omega)$ implies second-order dominance: $\int^x \tilde{F}_t(\omega)\, d\omega > \int^x F_t(\omega)\, d\omega$ for all $x > 0$. It thus follows that $\tilde{\pi}_t(\bar{\omega}^j_{t+1}) > \pi_t(\bar{\omega}^j_{t+1})$ for all $\bar{\omega}^j_{t+1} > 0$.

According to (10), the (normalized) repurchase price $\bar{b}_t$ is set such that the gain in mean return from investing in the standard firm segment exactly compensates the bank for the loss in the put option value. According to (11), the bank's demand for assets equals its net worth times a *leverage ratio* ϕ_t which is equalized across islands. Once $\bar{b}_t$ and ϕ_t have been determined, it is straightforward to obtain the actual loan size, $B_t^j = (\phi_t - 1) N_t^j$ and its face value, $\bar{B}_t^j = \bar{b}_t A_t^j = \bar{b}_t \phi_t N_t^j$.

3.5 Regulated banks

Regulated banks are segmented across islands too, and are thus indexed by $j \in [0,1]$. Regulated banks differ from unregulated ones in three aspects. First, regulated banks borrow in the form of deposits, D_{t-1}^j, which are remunerated at the perfectly competitive gross rate R_{t-1}, and the face value of which is protected by deposit insurance should the bank default. In particular, the representative regulated bank on island j defaults at the beginning of period t if and only if

$$R_t^A \omega^j A_{t-1}^{r,j} < R_{t-1} D_{t-1}^j \Leftrightarrow \omega^j < \frac{R_{t-1} D_{t-1}^j}{R_t^A A_{t-1}^{r,j}} \equiv \bar{\omega}_t^{r,j},$$

where $A_{t-1}^{r,j}$ are the regulated bank's assets purchased at the end of period $t-1$. Deposit insurance implies that regulated banks are not subject to a participation constraint, because households are always willing to invest in safe bank deposits.

Second, regulated banks are subject to a regulatory capital requirement. In particular, the bank's net worth, $N_t^{r,j}$, must be at least a fraction $1/\phi^r$ of its assets: $N_t^{r,j} \geq (1/\phi^r) A_t^{r,j}$. This is equivalent to establishing an upper bound on its leverage ratio: $A_t^{r,j}/N_t^{r,j} \leq \phi^r$. If the capital requirements were not present, regulated banks would choose to take the maximum possible leverage due to the lack of market discipline. Third, we assume that regulated banks are subject to bank supervision and thus they do not have access to the substandard firm segment, which eliminates the possibility of moral hazard issues. Analogously to unregulated banks, regulated banks are subject to a balance sheet constraint, $D_t^j + N_t^{r,j} = A_t^{r,j}$, and to a non-negativity constraint on dividends, $N_t^{r,j} \leq R_t^A \omega^j A_{t-1}^{r,j} - R_{t-1} D_{t-1}^j$.

The appendix lays out and solves the regulated bank's maximization problem. Here we summarize the main results. Assume the model parameters satisfy

$$0 < \beta R^A \phi^r \int_{\bar{\omega}^r} \left(\omega - \bar{\omega}^{r,j}\right) dF(\omega) - 1 < \beta R^A \phi^r \left(1 - \theta^r\right) \int_{\bar{\omega}^{r,j}} \left(\omega - \bar{\omega}^{r,j}\right) dF(\omega),$$

where $\bar{\omega}^{r,j}$ is the steady-state value of $\bar{\omega}_t^{r,j}$. Then both the non-negativity constraint on dividends and the leverage constraint bind in equilibrium,

$$N_t^{r,j} = R_t^A A_{t-1}^{r,j} \left(\omega^j - \bar{\omega}_t^r\right),$$
$$A_t^{r,j} = \phi^r N_t^{r,j},$$

where the default threshold equals

$$\bar{\omega}_t^r = \frac{R_{t-1}}{R_t^A}\frac{\phi^r - 1}{\phi^r}$$

and is thus equalized across islands.

3.6 Institutional investors

A representative institutional investor collects funds from households in the form of equity, and lends these funds to unregulated banks through short-term collateralized debt. Its balance sheet is simply $N_t^{inv} = B_t$, where $B_t = \int_0^1 B_t^j dj$. The institutional investor operates economy-wide and hence perfectly diversifies its portfolio across islands. The institutional investor's return from financing the island-j unregulated bank is

$$\min\left\{R_t^A \omega^j A_{t-1}^j, \bar{B}_{t-1}^j\right\} = R_t^A A_{t-1}^j \min\left\{\omega^j, \frac{\bar{b}_{t-1}}{R_t^A}\right\} = R_t^A \phi_{t-1} N_{t-1}^j \min\left\{\omega^j, \bar{\omega}_t\right\}.$$

Aggregating across islands we obtain the return on the institutional investor's equity,

$$R_t^N N_{t-1}^{inv} = R_t^A \phi_{t-1} \int_0^1 N_{t-1}^j \min\left\{\omega^j, \bar{\omega}_t\right\} dj = R_t^A \phi_{t-1} N_{t-1} \left\{\left[1 - F_{t-1}\left(\bar{\omega}_t\right)\right]\bar{\omega}_t + \int^{\bar{\omega}_t} \omega dF_{t-1}\left(\omega\right)\right\},$$

where in the second equality we have used the fact ω^j is distributed independently from N_{t-1}^j, and where $N_{t-1} \equiv \int_0^1 N_{t-1}^j dj$ is aggregate net worth of unregulated banks.

3.7 Aggregation and market clearing

Aggregate net worth of unregulated banks at the *end* of period t, N_t, is the sum of the net worth of continuing banks, N_t^{cont}, and that of new banks, N_t^{new},

$$N_t = N_t^{cont} + N_t^{new}.$$

From (9), $\bar{b}_{t-1}/R_t^A = \bar{\omega}_t$ and $A_{t-1}^j = \phi_{t-1} N_{t-1}^j$, we have that $N_t^j = R_t^A\left(\omega^j - \bar{\omega}_t\right)\phi_{t-1}N_{t-1}^j$. Aggregating across islands, we obtain the total net worth of continuing unregulated banks,

$$N_t^{cont} = \theta R_t^A \int_{\bar{\omega}_t} \left(\omega - \bar{\omega}_t\right) dF_{t-1}\left(\omega\right) \phi_{t-1} N_{t-1},$$

where we have used the fact that ω^j is distributed independently from N_{t-1}^j. Banks that default or exit the market exogenously are replaced by an equal number of new banks, $F_{t-1}\left(\bar{\omega}_t\right) + \left[1 - F_{t-1}\left(\bar{\omega}_t\right)\right]\left(1-\theta\right) = 1 - \theta\left[1 - F_{t-1}\left(\bar{\omega}_t\right)\right]$. We assume that new unregulated banks are endowed by households with a fraction τ of total assets at the beginning of the period, $A_{t-1}^T \equiv A_{t-1} + A_{t-1}^r$, where $A_t \equiv \int_0^1 A_t^j dj$ and $A_t^r \equiv \int_0^1 A_t^j dj$ are total assets of unregulated and regulated banks, respectively. Therefore,

$$N_t^{new} = \left\{1 - \theta\left[1 - F_{t-1}\left(\bar{\omega}_t\right)\right]\right\}\tau A_{t-1}^T.$$

We thus have

$$N_t = \theta R_t^A \int_{\bar{\omega}_t} (\omega - \bar{\omega}_t)\, dF_{t-1}(\omega)\, \phi_{t-1} N_{t-1} + \{1 - \theta [1 - F_{t-1}(\bar{\omega}_t)]\} \tau A_{t-1}^T. \tag{12}$$

New banks leverage their starting net worth with the same ratio as continuing banks. We thus have

$$A_t = \phi_t \left(N_t^{cont} + N_t^{new}\right) = \phi_t N_t.$$

Aggregation for regulated banks is performed analogously. Their total net worth, N_t^r, and their total assets evolve as follows

$$N_t^r = \theta^r R_t^A \int_{\bar{\omega}_t^r} (\omega - \bar{\omega}_t^r)\, dF_{t-1}(\omega)\, \phi^r N_{t-1}^r + \{1 - \theta^r [1 - F_{t-1}(\bar{\omega}_t^r)]\} \tau^r A_{t-1}^T, \tag{13}$$

$$A_t^r = \phi^r N_t,$$

where (θ^r, τ^r) may differ from (θ, τ). Aggregate net dividends to households from unregulated and regulated banks are given, respectively, by

$$\Pi_t = (1-\theta)\, R_t^A \int_{\bar{\omega}_t} (\omega - \bar{\omega}_t)\, dF_{t-1}(\omega)\, \phi_{t-1} N_{t-1} - N_t^{new},$$
$$\Pi_t^r = (1-\theta^r)\, R_t^A \int_{\bar{\omega}_t^r} (\omega - \bar{\omega}_t^r)\, dF_{t-1}(\omega)\, \phi^r N_{t-1}^r - N_t^{new,r},$$

where $N_t^{new,r}$ is defined analogously to N_t^{new}. Total net dividends from banks to households are $\Pi_t^b = \Pi_t + \Pi_t^r - T_t$, where lump-sum payments to the deposit insurance fund are $T_t \equiv R_t^A \int^{\bar{\omega}_t^r} (\bar{\omega}_t^r - \omega)\, dF_{t-1}(\omega)\, \phi^r N_{t-1}^r$, which is the amount needed to cover the current period's gap between the face value of deposits and asset returns in defaulting regulated banks.

Market clearing for capital requires that total demand by firms equals total supply by capital producers, $\int_0^1 K_t^j dj = K_t$. The aggregate capital stock evolves as follows,

$$K_{t+1} = I_t + (1-\delta) K_t.$$

The total issuance of state-contingent claims by firms must equal total demand by banks (regulated and unregulated),

$$K_{t+1} = A_t + A_t^r.$$

From (2), firm j's labor demand is $L_t^j = [(1-\alpha) Z_t / W_t]^{1/\alpha} \omega^j K_t^j$. Aggregating across islands and imposing labor market clearing, we have

$$\int_0^1 L_t^j dj = \left(\frac{(1-\alpha) Z_t}{W_t}\right)^{1/\alpha} \int_0^1 \omega^j K_t^j dj = \left(\frac{(1-\alpha) Z_t}{W_t}\right)^{1/\alpha} K_t = L_t, \tag{14}$$

where we have used the fact that ω^j and K_t^j are distributed independently and the fact that ω^j has unit mean. Equations (2) and (14) then imply that $\omega^j K_t^j / L_t^j = K_t / L_t$. Using the latter and (1), aggregate supply of the final good by firms equals

$$Y_t = \int_0^1 Y_t^j dj = Z_t \left(\frac{L_t}{K_t}\right)^{1-\alpha} \int_0^1 \omega^j K_t^j dj = Z_t K_t^\alpha L_t^{1-\alpha}.$$

Finally, total supply of the final good must equal consumption demand by households and investment demand by capital producers,

$$Y_t = C_t + I_t.$$

4 Quantitative Analysis

4.1 Banking without deposit insurance

In this section we focus on a particular case of the model in which there is no deposit insurance, that is, all the banks operate with non-insured liabilities ($A^r = 0$). We calibrate this one-sector model to replicate some features of the Spanish economy for the period 1856-1873. Parameter values are shown in table 3. We may divide the parameters between those that are standard in the real business cycle (RBC) literature, and those that are specific to the financial structure of the model. From now onwards, we let variables without time subscripts denote steady-state values. The model is set in quarterly terms.

Due to the lack of data about most of the main macroeconomic series for the period, we set RBC parameters to standard values in the literature. In particular, we set $\beta = 0.99 = 1/R$, $\alpha = 0.36 = 1 - WL/Y$, $\delta = 0.025 = I/K$, which are broadly consistent with long-run averages for the real interest rate, the labor share, and the investment to capital ratio. For future use, we note that the steady-state return on banks' assets is $R^A = \alpha\,(Y/K) + 1 - \delta$. We target a capital-output ratio of $K/Y = 8$, which is consistent with a ratio of investment over GDP of 20 percent, roughly in line with the historical evidence. We then have $R^A = 1.02$. Our functional forms for preferences are standard: $u\,(x) = \log(x)$, $v(L) = L^{1+\varphi}/\,(1+\varphi)$. We set $\varphi = 1$, in line with other macroeconomic studies (see e.g. Comin and Gertler, 2006). We assume an AR(1) process for the natural log of TFP,

$$\log\left(Z_t/Z\right) = \rho_z \log\left(Z_{t-1}/Z\right) + \varepsilon_t^z,$$

where $\varepsilon_t^z \overset{iid}{\sim} N(0, \sigma_z)$. Z is chosen such that steady-state output is normalized to one.

Regarding the parameters related to the financial side of the model, our calibration strategy is as follows. We choose to set the steady-state leverage ratio ϕ to match the average leverage ratio of the regional banks of issue during our sample period. To this end we consider all the bank debt to be composed by banknotes and current accounts and we use the paid-up capital as a proxy for the book equity. Ideally, we would also like to take into account information from *sociedades de credito*, but this information is not available. Thus, we set the leverage constraint equal to three, $\phi = 3$. We also target a spread in bank debt contracts over riskless debt of 25 annualized basis points. This value is taken to reflect the small discrepancy between the return of current accounts and that of public debt at the period. Nevertheless, we acknowledge that banknotes, which represented a significative share of the liabilities, did not pay any interest. This implies a default threshold of $\bar{\omega} = 0.6606$.

Island-specific shocks are assumed to be lognormally distributed. In particular, the distribution of island-specific shocks to the standard and the substandard firm segment is given by

$$\log \omega \overset{iid}{\sim} N\left(\frac{-\sigma_t^2}{2}, \sigma_t\right),$$
$$\log \tilde{\omega} \overset{iid}{\sim} N\left(\frac{-\eta\sigma_t^2 - \psi}{2}, \sqrt{\eta}\sigma_t\right),$$

respectively. Therefore, $F(\omega;\sigma_t) = \Phi\left(\frac{\log(\omega)+\sigma_t^2/2}{\sigma_t}\right)$, where $\Phi(\cdot)$ is the standard normal cdf. The parameters $\psi > 0$ and $\eta > 1$ control, respectively, the mean and the variance of the substandard technology relative to the standard one. Notice in particular that

$$E[\omega] = 1 > E[\tilde{\omega}] = e^{-\psi/2}.$$

These distributional assumptions imply the following expressions for the values of the unit put options on island-specific risk,

$$\pi(\bar{\omega}_t;\sigma_{t-1}) = \bar{\omega}_t \Phi\left(\frac{\log(\bar{\omega}_t) + \sigma_{t-1}^2/2}{\sigma_{t-1}}\right) - \Phi\left(\frac{\log(\bar{\omega}_t) - \sigma_{t-1}^2/2}{\sigma_{t-1}}\right), \tag{15}$$

$$\tilde{\pi}(\bar{\omega}_t;\sigma_{t-1}) = \bar{\omega}_t \Phi\left(\frac{\log(\bar{\omega}_t) + \left(\psi + \eta\sigma_{t-1}^2\right)/2}{\sqrt{\eta}\sigma_{t-1}}\right) - e^{-\psi/2}\Phi\left(\frac{\log(\bar{\omega}_t) + \left(\psi - \eta\sigma_{t-1}^2\right)/2}{\sqrt{\eta}\sigma_{t-1}}\right). \tag{16}$$

The standard deviation of island-specific shocks is assumed to follow an AR(1) process in logs,

$$\log(\sigma_t/\sigma) = \rho_\sigma \log(\sigma_{t-1}/\sigma) + \varepsilon_t^\sigma,$$

where $\varepsilon_t^\sigma \overset{iid}{\sim} N(0,\sigma_\sigma)$. In order to calibrate σ, we notice that the participation constraint (7) in the steady state implies $\pi(\bar{\omega};\sigma) = \bar{\omega} - (1 - 1/\phi)/\beta R^A = 0.00041$. Using the steady-state counterpart of (15), we can then solve for $\sigma = 0.1744$. The default rate of banks in the steady state then equals $F(\bar{\omega};\sigma) = 1.10\%$.

Regarding the parameters of the substandard technology, ψ and η, we make use of the IC constraint in the steady state,

$$1 - e^{-\psi/2} = \tilde{\pi}(\bar{\omega};\sigma) - \pi(\bar{\omega};\sigma),$$

where $\tilde{\pi}(\bar{\omega};\sigma)$ is given by expression (16) in the steady state. We thus have one equation for two unknowns, ψ and η. We arbitrarily choose to set ψ to 0.001 as in Nuño and Thomas (2013), and use the IC constraint to solve for $\eta = 1.2327$.

The exogenous bank continuation rate θ is set to 0.95, implying a possibility of a non-renewal of the bank charter (an exogenous closure of the bank) over an average period of 5 years. Finally, the bank equity injection parameter τ is calibrated as follows. In the steady state, the law of motion of bank net worth (12) becomes

$$\frac{1}{\phi} = \theta R^A \int_{\bar{\omega}} (\omega - \bar{\omega})\, dF(\omega;\sigma) + \{1 - \theta[1 - F(\bar{\omega};\sigma)]\}\tau, \tag{17}$$

where we have normalized by A. We then use (17) to solve for $\tau = 0.0672$.

The parameters governing the dynamics of island-specific volatility $(\rho_\sigma, \sigma_\sigma)$ and the aggregate TFP shocks (ρ_z, σ_z) are estimated directly from the data using Bayesian methods. To estimate the parameters of the two shocks, we employ two data series: GDP (Y_t) and banks' liabilities (B_t). The liabilities include current accounts and banknotes and are log-linearly detrented before estimation. The data is presented in figure 3. GDP is taken from Prados de la Escosura (2003). As the data frequency is annual, we recast the model in annual terms by rescaling the parameter values. The prior distributions for the two annual autocorrelation coefficients $(\hat{\rho}_\sigma, \hat{\rho}_z)$ are beta distribution functions centered around 0.5 with standard error 0.2. In the case of the standard deviations of the shocks $(\hat{\sigma}_\sigma, \hat{\sigma}_z)$, the priors are taken to be inverse gamma distributions with means $(0.02, 0.02)$. The posterior distributions are computed by a Monte Carlo Markov Chain (Metropolis-Hastings) algorithm with 10,000 replications and two parallel chains.[20] Results are displayed in table 4. The posterior means are $(0.46, 0.015)$ for the autocorrelations and $(0.024, 0.023)$ for the standard deviations. We assume that each annual observation corresponds to the last quarter in the year. Under this assumption, if the estimated autoregressive coefficient and standard deviation of shocks are $\hat{\rho}$ and $\hat{\sigma}$ at the yearly frequency, we obtain $\hat{\rho}_q = \hat{\rho}^{1/4}$ and $\hat{\sigma}_q = \hat{\sigma}/(1 + \rho_x^2 + \rho_x^4 + \rho_x^6)$ at the quarterly frequency for each stochastic process. This implies $\rho_\sigma = 0.8219$, $\rho_z = 0.3136$, $\sigma_\sigma = 0.0059$, and $\sigma_z = 0.0087$.

Before turning to analyze impulse reponse function, it is worth describing how volatility shocks work in the model.[21] A (positive) volatility shock induces banks to deleverage through a mechanism similar to the one described in Adrian and Shin (2011). A bank with limited liability enjoys the upside risk in asset returns over and above the face value of its debt, but does not bear the downside risk, which is transferred to the investor. When uncertainty increases, the bank finds it more attractive to invest in highly risky activities, even if they have a smaller expected value than less risky ones. In the model, the larger is debt, the larger is the probability of default, so the incentive of banks to invest in risky activities increases with the face value of their debt. As investors cannot directly control banks' investments, they react to an increase in uncertainty by raising the haircut on banks' debt. On the other hand, an increase in uncertainty increases the downside risk of assets that serve as collateral, which reduces the investors' expected payoff. To induce investors to lend, the bank reduces its demand for funds as a fraction of its net worth, that is, it reduces its leverage. In the end, a volatility shock produces a decline in the face value of debt of banks, a decline in leverage, an increase in the number of defaulting banks, and a contraction in the capital stock and output.

Figures 4 and 5 display the impulse responses to a negative TFP and a positive volatility shock, respectively. On impact, the fall in TFP produces a sharp fall in the return on assets, which increases the number of bankruptcies. The fall in the profitability of banks' investments reduces their equity. The leverage ratio barely reacts; indeed, the latter responds mainly to

[20] We have employed the dynare package.

[21] For a fully fledged analysis of the one-sector model refer to Nuño and Thomas (2013).

expected changes in the default threshold (see eq. 7), which is virtually back to baseline after the impact period. Since their leverage remains stable, banks' assets basically reproduce the response of their net worth; i.e. the effects of TFP shocks on unregulated bank credit operate mainly through the equity channel. Since net worth responds relatively little, so do assets.

In contrast, in the case of volatility shocks, there is a sharp reduction in the (normalized) face value of debt of unregulated banks right after the impact period. This fall in the debt commitment, together with the increase in uncertainty, produces a drastic reduction in the leverage ratio of banks, of about 10 percentage points with respect to the steady state level. Unregulated banks' net worth increases after the impact period, due to the reduction in the default threshold $\bar{\omega}_t$ and hence in the number of defaulting banks. The fall in leverage and the increase in net worth generate opposing dynamics on banks 'assets: the net effect is an initial fall in banks assets followed by a fast recovery. The changes in leverage affect the return on assets and the consumption-leisure substitution, making households work less on impact, which depresses output. After that there is a recovery in capital accumulation, labor supply and output for the following periods.

The combination of both shocks explains the dynamics observed in the data. A variance decomposition yields that 86% of the volatility in output is due to TFP shocks and 14% to volatility shocks. In the case of banks liabilities, the picture is reversed and only 30% is due to TFP shocks, being the remnant 70% consequence of volatility shocks. This is showed in figures 4 and 5, which highlight the contribution of TFP and volatility shocks to the evolution of output and liabilities in the data. Thus, the estimated model suggests that both hypothesis on the roots of the Spanish crisis discussed in section 3 are at least partially correct. TFP shocks explain most of the changes in real economic activity while volatility shocks are responsible for most of the evolution of financial variables.

4.2 Banking with deposit insurance

In the previous subsection we used the model to shed some light on the dynamics of the Spanish crisis and found that both TFP and volatility shocks contributed in a non-trivial way to shape the evolution of the real and the financial economy of those years. The question we ask in this subsection is then the following: if a part of the Spanish banking system at that time had been regulated through deposit insurance and capital requirements, would the effect of the crisis had been the same as we observed? To answer this question we consider the fully fledged version of the model with two sectors, an unregulated and a regulated one, and study how the introduction of deposit insurance modifies the steady-state and the dynamics of the model. All parameters of the regulated sector are calibrated to be the same as those in the case with only one sector, so $\tau^r = \tau$ and $\theta^r = \theta$. Therefore, the main differences between the unregulated and regulated sector is that the latter enjoys deposit insurance, is subject to a regulatory minimum ratio of net worth over assets $1/\phi^r$, and it is assumed to be supervised, so it cannot invest in the substandard technology.

By introducing regulation on a part of the financial sector both the steady state and the dynamic properties of the model change. Also, given the assumption that parameter values are the same as in the one-sector model, the value of ϕ^r determines the relative size of the regulated sector with respect to the unregulated one. Our first step is thus to look for the value of the regulatory minimum capital ratio that maximizes steady state welfare. Figure 8 displays percentage deviations of welfare, output, consumption, labor, investment and leverage of unregulated institutions with respect to the one-sector model for values of ϕ^r ranging from 1.01 to 5.16 (with 0.05 grid intervals). Also, the figure reports the relative size of the unregulated sector for the different values ϕ^r. Welfare is measured as steady-state consumption equivalent in the one-sector model. As the top-left panel shows, welfare displays a maximum at $\phi^r = 4.61$. Note that welfare gains with respect to the one-sector model are substantial. Even for the smallest regulatory minimum capital ratio considered, 1.01, for which regulated institutions are basically not allowed to take any leverage, there is a welfare gain of 0.37%. As ϕ^r raises, welfare gains increase up to 12.63% for the optimal $\phi^r = 4.61$. Thus, to replicate the same level of welfare in the one-sector model it would be required to increase steady state consumption by 12.63%. The rationale for this result is that the emegence of regulated institutions reduces the cost of credit in the economy, because regulation allows to overcome the asymmetric information costs as all investments are safe (insured) in the regulated sector. This implies a larger amount of credit in the steady state, which in turn implies a larger amount of capital.

However, for the optimal ϕ^r the model economy does not satisfy Blanchard-Kahn conditions for a dynamic stable equilibrium to exist. The shaded area in figure 8 highlights the set of values of ϕ^r not satisfying such condition. Only for values up to $\phi^r = 3.01$ a dynamic equilibrium exists. Note that this value is very close to steady state leverage of unregulated institutions. We find that this result is robust to different choices of steady state leverage of unregulated institutions.[22] By varying the latter and keeping all other parameter values unchanged, the dynamic equilibrium satisfies Blanchard-Kahn conditions only up to a value of ϕ^r marginally larger than steady state leverage of unregulated institutions.

We now turn to compare more in detail the two-sector model with the one-sector model and a standard RBC model calibrated with the same value of parameters β, α, δ, φ, $\bar{Z}$ and the same stochastic TFP process. We set a conservative value for regulated leverage of $\phi^r = 2$. Table 5 compares steady state values of the three models.[23] As expected, because of the absence of asymmetric information the RBC model displays a larger value of the capital, consumption, labor, output and welfare with respect to the one-sector model. As anticipated by figure 8, the two-sector model also displays a larger welfare with respect to the one-sector. Put it differently, the two-sector model displays a steady state which is closer to the RBC than the one-sector.

[22] Results are available upon request.

[23] Recall that the steady-state level of TFP in the one-sector model is set such that steady state output equals one.

Output is 2% larger than in the one-sector while welfare is 1.17% larger.

Consider now the business cycles implications of introducing regulation. Table 6 compares real-business cycles moments in the one-sector, in the two-sector, and in the RBC model for the same calibration as in table 5.[24] First, note that business cycles in the one-sector model are broadly in line with those commonly obtained in standard one-sector RBC models calibrated with modern data.[25] With respect to the one-sector model, the RBC displays a larger volatility of output and labor but a smaller volatility of investment and less than half the volatility of consumption. The main effect of introducing regulation is to reduce the volatility of the economy with respect to the one–sector model. Volatility of output declines from 1.20% to 1.19%, that of consumption from 0.28% to 0.26%, that of investment from 5.82% to 5.56% and finally that of labor from 0.58% to 0.57%. Interestingly, the two-sector model displays a volatility of employment which is lower than in the RBC model.

Table 5 also reports the correlations of consumption, investment and labor with output. The introduction of regulation does not appear to change the comovement of variables with output. This is also confirmed by impulse response functions to a TFP and a volatility shock reported in figures 4 and 5. The responses to a TFP shock of real variables are very close in both models. Differences between models emerge in the response of leverage, assets and equity of unregulated institutions. In particular, after a TFP shock leverage increases on impact in the one-sector while it declines in the two-sector model. Also in the case of a volatility shock impulse responses look very close in the two cases, suggesting that the introduction of the type of regulation considered in this paper does not imply dramatic changes on business cycle comovement.

Finally, we consider welfare gains due to regulation in the dynamic equilibrium (i.e. expected welfare in the stochastic model) rather than in the steady state.[26] By affecting the volatility of the economy, it is possible that the welfare gains obtained by considering the dynamic welfare are different from those obtained by looking at steady state welfare. Figure 9 shows that this is not the case and that welfare gains are equivalent both when considering steady state and dynamic welfare. Thus, it appears that the main effect of regulation works through its effects on the steady state of the model, rather than on its dynamic properties. Put it differently, the gain in welfare that is obtained through smaller volatility is negligible compared to the gain in the level of capital, output and consumption in the steady state. This result is reminiscent of Lucas (1987).

[24] To compare models we report statistics of percentage deviations from an HP trend of simulated data.

[25] Compare for instance with Cooley and Prescott (1995). Arguably, the correlation of consumption with output is small, but this is due to the small autoregressive coefficient estimated for TFP, 0.3136, which makes this correlation small also in the RBC model reported in the last column of table 5.

[26] To do this we consider second order approximations around the steady state.

5 Conclusions

In this paper we propose an analysis on the macroeconomic effects of a particular sort of regulation consisting in deposit insurance together with a given capital requirement for banks. The approach we take to study this issue is first to provide empirical evidence of the effect of a financial crisis on a currency union when no regulation is present and no intervention occurs. This for instance is not the case of the current crisis in Europe, in which several types of intervention have taken place both by member states and the ECB. Instead, we provided evidence that it was the case of the Spanish economy in the 1860s.

We then presents a DSGE model with banks that complements the most recent models of financial intermediation with heterogeneous financial institutions. The key point here is that the model, when fed with both TFP and volatility shocks, can account well for leverage cycles in the modern US financial sector and thus it is an appropriate one to study regulation on banking. In addition, the model displays what we document to be the key features of the Spanish economic system of the time: banks in the model operate in different regions, are involved in risky activities, make use of leverage and do not face regulation.

When the model is estimated with Spanish data of the 1860s we find that both TFP shocks and volatility shocks contribute to explain the real and the financial cycle of the 1856-1873 period. By introducing a regulated sector in which banks enjoy deposit insurance and are imposed a certain exogenous capital requirement, welfare in steady state and in the dynamic equilibrium increase with respect to the unregulated model. Also, welfare gains due to deposit insurance are attributable to changes in the steady state of the model rather than to the smaller volatility induced by this instrument.

The paper is one of the first attempts to study deposit insurance in a DSGE model. Thus, the model represents a useful tool to analyze the effects that a common European deposit insurance agreement would have on macroeconomic variables of a currency area such as the Euro area.

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Appendix: The regulated bank's problem

The maximization problem of a regulated bank differs from that of an unregulated in that (i) the bank is subject to a maximum leverage ratio ($A_t^{r,j}/N_t^{r,j} \leq \phi^r$), and (ii) it is not subject to the IC or participation constraints. Otherwise, the problem is analogous to that of an unregulated bank. Let $d_{t-1}^j \equiv D_{t-1}^j/A_{t-1}^{r,j}$ denote the loan-to-value ratio, such that $\bar{\omega}_t^{r,j} = R_{t-1}d_{t-1}^j/R_t^A$. Also, the bank's balance sheet constraint can be written as $A_t^{r,j}(1-d_t^j) = N_t^{r,j}$. The regulated bank's maximization problem is

$$V_t^r\left(\omega, A_{t-1}^{r,j}, d_{t-1}^j\right) = \max_{N_t^{r,j}} \left\{ \Pi_t^{r,j} + \bar{V}_t\left(N_t^{r,j}\right) + \mu_t^{r,j}\left[\left(\omega - \frac{R_{t-1}d_{t-1}^j}{R_t^A}\right) R_t^A A_{t-1}^{r,j} - N_t^{r,j}\right]\right\}, \tag{18}$$

subject to the expression for dividends, $\Pi_t^{r,j} = (\omega - R_{t-1}d_{t-1}^j/R_t^A)R_t^A A_{t-1}^{r,j} - N_t^{r,j}$, and

$$\bar{V}_t^r\left(N_t^{r,j}\right) = \max_{A_t^{r,j}, d_t^j} \left\{ \begin{array}{c} E_t\Lambda_{t,t+1}\int_{R_t d_t^j/R_{t+1}^A}\left[\theta^r V_{t+1}\left(\omega, A_t^{r,j}, d_t^j\right) + (1-\theta^r)\left(\omega - \frac{R_t d_t^j}{R_{t+1}^A}\right) R_{t+1}^A A_t^{r,j}\right] dF_t(\omega) \\ +\lambda_t^{r,j}\left[\phi^r N_t^{r,j} - A_t^{r,j}\right] + \xi_t^{r,j}\left[N_t^{r,j} - A_t^{r,j}\left(1 - d_t^j\right)\right] \end{array} \right\},$$

where now λ_t^j and ξ_t^j are the Lagrange multipliers associated to the leverage and balance-sheet constraints, respectively. The first order condition with respect to $N_t^{r,j}$ is given by

$$\mu_t^{r,j} = \bar{V}_t^{r\prime}(N_t^{r,j}) - 1.$$

We now guess that $\bar{V}_t^{r\prime}(N_t^{r,j}) > 1$. Then $\mu_t^{r,j} > 0$ and the non-negativity constraint on dividends is binding, such that a continuing bank optimally decides to retain all earnings, $\Pi_t^{r,j} = 0$, or

$$N_t^{r,j} = \left(\omega - \frac{R_{t-1}d_{t-1}^j}{R_t^A}\right) R_t^A A_{t-1}^{r,j}. \tag{19}$$

From (18), we then have $V_t^r(\omega, A_{t-1}^{r,j}, d_{t-1}^j) = \bar{V}_t^r((\omega - R_{t-1}d_{t-1}^j/R_t^A)R_t^A A_{t-1}^{r,j})$. Using the latter, we can express the Bellman equation for $\bar{V}_t^r(N_t^{r,j})$ as

$$\bar{V}_t^r\left(N_t^{r,j}\right) = \max_{A_t^{r,j}, d_t^j} \left\{ \begin{array}{c} E_t\Lambda_{t,t+1}\int_{R_t d_t^j/R_{t+1}^A}\left[\theta^r \bar{V}_{t+1}^r\left(\left(\omega - \frac{R_t d_t^j}{R_{t+1}^A}\right) R_{t+1}^A A_t^{r,j}\right) + (1-\theta^r)\left(\omega - \frac{R_t d_t^j}{R_{t+1}^A}\right) R_{t+1}^A A_t^{r,j}\right] dF_t(\\ +\lambda_t^{r,j}\left[\phi^r N_t^{r,j} - A_t^{r,j}\right] + \xi_t^{r,j}\left[N_t^{r,j} - A_t^{r,j}\left(1 - d_t^j\right)\right] \end{array} \right.$$

The first order conditions with respect to $A_t^{r,j}$ and d_t^j are given by

$$0 = E_t\Lambda_{t,t+1}R_{t+1}^A\int_{\bar{\omega}_{t+1}^{r,j}}\left[\theta^r \bar{V}_{t+1}^{r\prime}\left(N_{t+1}^{r,j}\right) + (1-\theta^r)\right]\left(\omega - \bar{\omega}_{t+1}^{r,j}\right) dF_t(\omega) - \lambda_t^{r,j} - \xi_t^{r,j}\left(1 - d_t^j\right).$$

$$0 = -E_t\Lambda_{t,t+1}R_t\int_{\bar{\omega}_{t+1}^{r,j}}\left[\theta^r \bar{V}_{t+1}^{r\prime}\left(N_{t+1}^{r,j}\right) + (1-\theta^r)\right] dF_t(\omega) - E_t\Lambda_{t,t+1}\theta^r\frac{R_t\bar{V}_{t+1}^r(0)}{R_{t+1}^A A_t^{r,j}} f_t\left(\bar{\omega}_{t+1}^{r,j}\right) + \xi_t^{r,j},$$

respectively, where we have used $R_t d_t^j/R_{t+1}^A = \bar{\omega}_{t+1}^{r,j}$. We also have the envelope condition

$$\bar{V}_t^{r\prime}\left(N_t^{r,j}\right) = \lambda_t^{r,j}\phi^r + \xi_t^{r,j}.$$

At this point, we guess that in equilibrium $\bar{V}_t^r(N_t^{r,j}) = (\lambda_t^{r,j}\phi^r + \xi_t^{r,j})N_t^{r,j}$, and that the multipliers $\lambda_t^{r,j}$ and $\xi_t^{r,j}$ are equalized across islands: $\lambda_t^{r,j} = \lambda_t^r$, $\xi_t^{r,j} = \xi_t^r$ for all j. The first order conditions then become

$$0 = E_t \Lambda_{t,t+1} R_{t+1}^A \left[\theta^r \left(\lambda_{t+1}^r \phi^r + \xi_{t+1}^r\right) + (1-\theta^r)\right] \int_{\bar{\omega}_{t+1}^{r,j}} \left(\omega - \bar{\omega}_{t+1}^{r,j}\right) dF_t(\omega) - \lambda_t^r - \xi_t^r \left(1 - d_t^j\right). \tag{20}$$

$$0 = -E_t \Lambda_{t,t+1} R_t \left[\theta^r \left(\lambda_{t+1}^r \phi^r + \xi_{t+1}^r\right) + (1-\theta^r)\right] \left[1 - F_t\left(\bar{\omega}_{t+1}^{r,j}\right)\right] + \xi_t^r, \tag{21}$$

where in (21) we have used the fact that, according to our guess, $\bar{V}_{t+1}^r(0) = 0$. Equations (20) and (21) jointly determine the path of the two Lagrange multipliers, λ_t^r and ξ_t^r. We now guess that the leverage constraint binds in equilibrium ($\lambda_t^r > 0$), such that $\phi^r N_t^{r,j} = A_t^{r,j}$. This, together with the balance sheet constraint, implies $d_t^j = 1 - 1/\phi^r$ for all j, which in turn implies that $\bar{\omega}_{t+1}^{r,j} = R_t (1 - 1/\phi^r) / R_{t+1}^A = \bar{\omega}_{t+1}^r$ for all j. But then, from (20) and (21), we have that both Lagrange multipliers are equalized across islands, thus verifying our previous guess. Using the fact that $1 - d_t^j = 1/\phi^r$ in (20), we have that

$$\lambda_t^r \phi^r + \xi_t^r = E_t \Lambda_{t,t+1} R_{t+1}^A \phi^r \left[\theta^r \left(\lambda_{t+1}^r \phi^r + \xi_{t+1}^r\right) + (1-\theta^r)\right] \int_{\bar{\omega}_{t+1}^r} \left(\omega - \bar{\omega}_{t+1}^r\right) dF_t(\omega).$$

In the steady state,

$$\lambda^r \phi^r + \xi^r = \frac{(1-\theta^r)\beta R^A \phi^r \int_{\bar{\omega}^r} (\omega - \bar{\omega}^r)\, dF(\omega)}{1 - \beta R^A \phi^r \int_{\bar{\omega}^r} (\omega - \bar{\omega}^r)\, dF(\omega) + (1-\theta^r)\beta R^A \phi^r \int_{\bar{\omega}^r} (\omega - \bar{\omega}^r)\, dF(\omega)} \equiv \Xi, \tag{22}$$

Provided the parameter values satisfy

$$0 < \frac{1 - \theta^r \beta R^A \phi^r \int_{\bar{\omega}^r} (\omega - \bar{\omega}^r)\, dF(\omega)}{(1-\theta^r)\beta R^A \phi^r \int_{\bar{\omega}^r} (\omega - \bar{\omega}^r)\, dF(\omega)} < 1,$$

then $\lambda^r \phi^r + \xi^r > 1$, which implies that the non-negativity constraint binds in the steady state. Provided aggregate shocks are sufficiently small, we will also have $\lambda_t^r \phi^r + \xi_t^r > 1$ along the equilibrium path, thus verifying our guess that $\bar{V}_t^{r\prime}(N_t^{r,j}) > 1$. Once we have solved for $\lambda^r \phi^r + \xi^r$, we can use the steady-state counterpart of (21) to calculate

$$\xi^r = [\theta^r \Xi + (1-\theta^r)]\,[1 - F(\bar{\omega}^r)] > 0.$$

Using the latter in (22), we obtain

$$\lambda^r = \frac{\Xi - \xi^r}{\phi^r} = \frac{[1 - \theta^r + \theta^r F(\bar{\omega}^r)]\,\Xi - (1-\theta^r)\,[1 - F(\bar{\omega}^r)]}{\phi^r} > 0,$$

where the inequality follows from $\Xi > 1$. Therefore, the leverage constraint binds in the steady state. For small enough shocks, we also have $\lambda_t^r > 0$ out of the steady state, thus verifying our previous guess.[27]

[27] The calibration of the two-sector model in table 3 implies $\lambda_t^r = 0.0120$ in steady state.

6 Table and Figures

Table 1. Number of Banks and *Sociedades de Credito*

	Banks of issue	*Sociedades de Credito*	Total
1856	4	6	10
1857	10	6	16
1858	10	7	17
1859	10	7	17
1860	11	8	19
1861	11	12	23
1862	12	17	29
1863	14	20	34
1864	21	34	55
1865	21	35	56
1866	21	32	53
1867	21	26	47
1868	20	21	41
1869	19	14	33
1870	16	14	30
1871	16	14	30
1872	16	14	30
1873	16	14	30

Source: Tortella, (1973, p. 9).

Table 2. Capital invested in joint stock companies by sector (millions of pesetas)

	Manufacturing	Sociedades de Credito	Railways
1859	99.8	93.3	943.9
1861	96.0	105.1	517.4
1864	98.4	242.7	654.8
1866	66.5	229.2	698.9

Source: Tortella (1973, p. 170)

Table 3. Model parameters

Parameter	Value	Description	Source/Target
RBC parameters			
β	0.99	discount factor	$R^4 = 1.04$
α	0.36	capital share	$WL/Y = 0.64$
δ	0.025	depreciation rate	$I/K = 0.025$
φ	1	inverse labor supply elasticity	macro literature
$\bar{Z}$	0.5080	steady-state TFP	$Y = 1$
Non-standard parameters			
σ	0.1744	steady-state island-specific volatility	average leverage ($\phi = 3$)
η	1.2327	variance substandard technology	$\left(\bar{R}/R\right)^4 - 1 = 0.25\%$
ψ	0.001	mean substandard technology	Nuno and Thomas (2012)
τ, τ^r	0.0672	equity injections new banks	$I/Y = 0.2$
θ, θ^r	0.95	continuation prob. banks	average life 5 years

Table 4. Estimation of shock parameters

Parameter	Prior			Posterior		Quarterly value	
	type	mean	st. error	mean	Conf. interval		
$\hat{\rho}_\sigma$	beta	0.5	0.2	0.46	$0.44 - 0.47$	ρ_σ	0.8219
$\hat{\rho}_z$	beta	0.5	0.2	0.015	$0.0012 - 0.0279$	ρ_z	0.3136
$\hat{\sigma}_\sigma$	Inv.Gamma	0.02	–	0.024	$0.0042 - 0.0572$	σ_σ	0.0059
$\hat{\sigma}_z$	Inv.Gamma	0.02	–	0.023	$0.0048 - 0.0596$	σ_z	0.0087

Table 5. Comparison between the model with and without deposit insurance

	One Sector (no insurance)	Two-Sectors (deposit insurance)	RBC
Steady-state			
output (Y)	1.00	1.02	1.19
share regulated sector (A^r/A)	0.00	0.38	–
consumption (C)	0.80	0.81	0.89
employment (L)	0.89	0.90	0.93
leverage unreg. sector (ϕ)	3.00	2.99	–
capital (K)	8.00	8.29	12.23
capital ratio (K/Y)	8.00	8.46	10.26
unreg. assets ratio (A/Y)	8.00	6.02	–
welfare	1	1.0117	1.0754

Table 6. Business Cycles across models

	One-sector		Two-sectors		RBC	
	$\sigma_{x,1}$	$\rho(x_1, y_1)$	$\sigma_{x,2}$	$\rho(x_2, y_2)$	$\sigma_{x,3}$	$\rho(x_3, y_3)$
Output	1.20%	1	1.19%	1	1.21 %	1
Consumption	0.28%	0.24	0.26%	0.28	0.13%	0.48
Investment	5.82%	0.98	5.56%	0.99	4.55 %	0.99
Labor	0.58%	0.97	0.57%	0.98	0.58%	0.99

Notes: σ_x is the standard deviation of percentage deviations from HP filter of variable x, y is GDP, $\rho(x, y)$ is the correlation of variable x with GDP. Regulated leverage in the two-sector model is set to 2.

Figure 1: Capital Invested in Limited liability companies in the UK (millions of pounds). Source: Foucaud (2006).

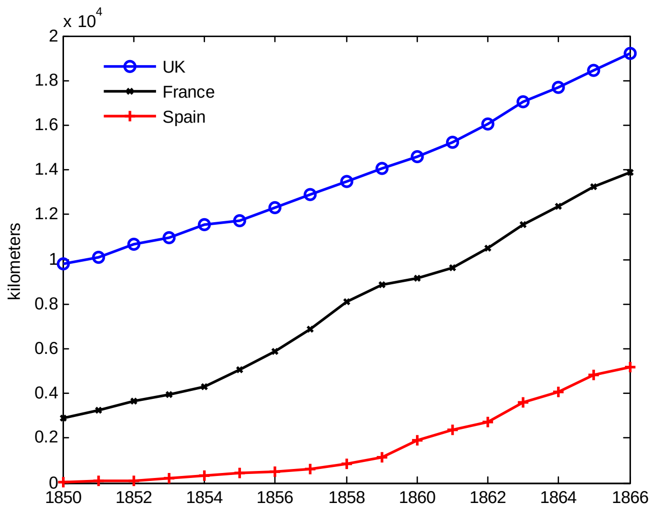

Figure 2: Kilometers of installed railroads in the UK, France and Spain. Source: Mitchell (2007).

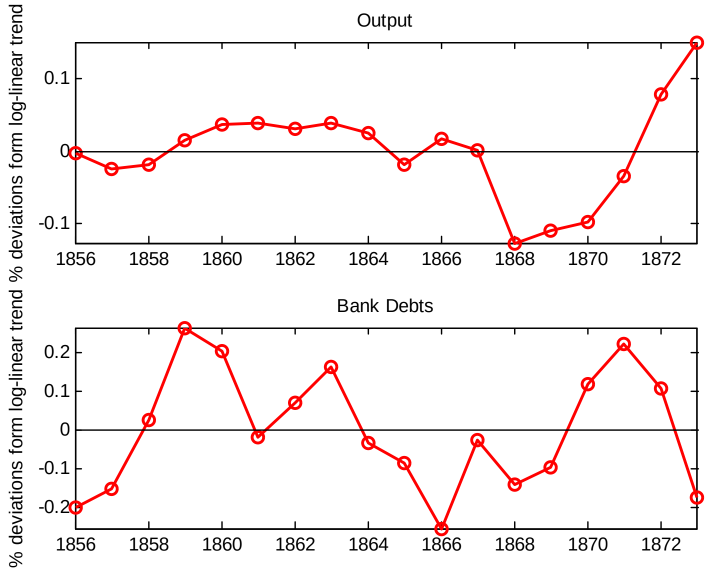

Figure 3: Output (GDP) and banks' liabilities, Spain 1856-1873.

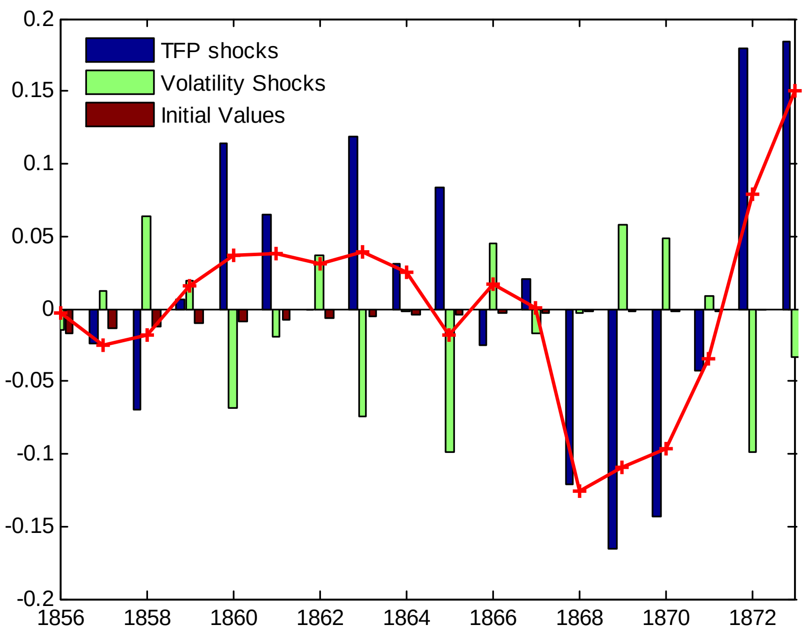

Figure 4: Contribution of TFP shocks and volatility shocks to the evolution of GDP in the data.

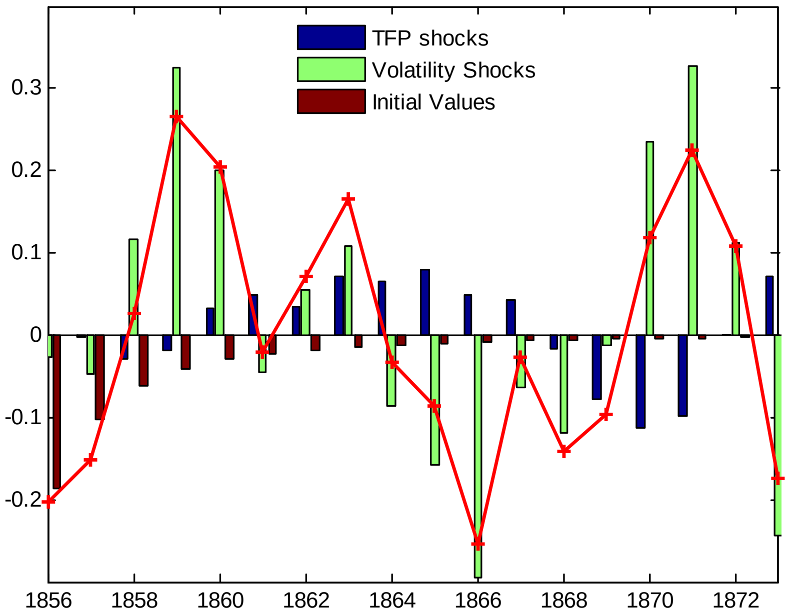

Figure 5: Contribution of TFP shocks and volatility shocks to the evolution of banks liabilities in the data.

Insurance/Tex/NKL3YY05.wmf

Figure 6: Impulse responses to a TFP shock for the case of only one (unregulated) banking sector or two sectors (regulated and unregulated).

Insurance/Tex/NKL3YY06.wmf

Figure 7: Impulse responses to a volatility shock for the case of only one (unregulated) banking sector or two sectors (regulated and unregulated).

Insurance/Tex/NKL3YY07.wmf

Figure 8: Percentage deviations of welfare, output, consumption, employment, investment, leverage and capital in the two-sector model with respect to the one-sector, and relative size of the unregulated sector, for different values of ϕ^r.

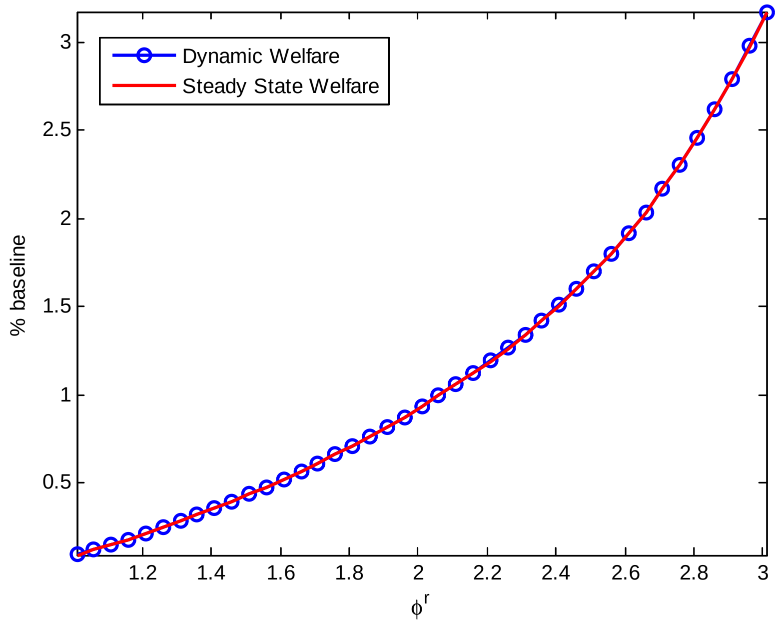

Figure 9: Percentage deviations of welfare in the two-sector with respect to the one-sector model.