Project Report

Default Risk in Currency Unions

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Abstract

We propose a dynamic model of public debt roll-over in currency unions. Agents do not only take information concerning the respective country into account but consider the conditions of the entire union since refinancing conditions in the member countries are correlated. The goal of the paper is to shed some light on interdependencies in currency unions which may affect agents' decision making when it comes to debt roll-over. Hence, we investigate contagious links resulting from aggregating relevant information and from the coordination problem among creditors.

Keywords: Sovereign Debt, Informational Contagion, Agent-Based Simulation

JEL codes: D82, H69

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1 Introduction

In standard economic theory government bond yields capture the country risk, which is, the probability of default, and the exchange rate risk. In a currency union the latter argument ceases to apply and thus, government bond yields from members of a currency union no longer reflect expected currency movements or premia for currency risk (Wyplosz, 2006; De Grauwe and Ji, 2012). Refinancing for such a country might be less prone to currency risk but may be affected by other risks stemming from the currency union setting (De Santis, 2012; Arghyrou and Kontonikas, 2012). In our model we seek to capture the notion of country risk of currency union members.

In our model positive as well as negative spillovers are captured by the fact that agents receive information about the fundamentals (i.e. the refinancing ability) of members of the union. Since we assume that fundamentals are correlated, information about members of the union affects the refinancing ability of the country under consideration. Correlation of fundamentals seems plausible because of several reasons. First, due to centralization of monetary policy the option of nominal exchange rate devaluation is no longer available. Second, the "no-bail-out" principle is – de facto – not credible and the institutional architecture of the Eurozone generates contingent liabilities among the member countries (e.g. the European Stability Mechanism, ESM).

The basic intuition among models in this class is that creditors face a coordination problem when they decide on whether or not to rollover bonds from a sovereign borrower in distress. This problem is similar to that faced by depositors of a bank which is vulnerable to a "run" or that faced by competing political groups that fear the outbreak of a civil war. The coordination problem seems to be particularly appropriate for the case of sovereign default, since there is an important difference between corporate and public debts: the lack of a straightforward supranational legal mechanism to enforce repayment of the sovereign borrower (Panizza et al., 2009). In case of government bonds the investment decisions are motivated by beliefs about fundamentals as well as beliefs about the actions of other creditors - as it is not realistic to assume that economic fundamentals are common knowledge, as it is often done.

The basic idea of debt roll-over by agents facing diffuse information is due to Morris and Shin (2004) who apply the global games technique to the context of sovereign debt and country risk. We borrow the informational structure of their model and extend it to the two country currency union case. In contrast to Morris and Shin (2004), we apply an agent-based simulation[1]

[1] See LeBaron and Tesfatsion (2008) and Hommes (2007) for surveys on agent-based models in macroeconomics.

approach to study debt roll-over in currency unions. This approach appears to be particularly instructive for several reasons. First and foremost, under uncertainty the behaviour of agents can be described particularly well with heuristics or rule of thumbs while rational behaviour in the sense of maximizing expected utility often does not apply (Kahneman and Tversky, 1973; Tversky and Kahneman, 1974). Moreover, with the agent based simulation it is possible to introduce temporal dynamics. This is appealing since refinancing is clearly not a static, but a dynamic matter. Also, comparative statics are easily applicable and provide clear-cut conclusions varying the informational setting.

In the model, agents receive noisy public and private information. Public information is identical while private information is idiosyncratic. Based on this information, agents form beliefs and decide whether or not they are willing to invest in government bonds. The population of agents is structured as a ring-network. In this setting agents are able to observe sentiments in the neighborhood. If agents are not particularly optimistic, they are vulnerable to pessimism in the neighborhood and hence, pessimism might spread. After beliefs in the population are stable, the price of debt agents demand is determined by the portion of the population which is most optimistic. The respective country is able to meet refinancing needs if two conditions are met: First, sufficiently many agents have to be willing to invest and second, the price of debt has to be affordable for the respective country, which is budget constrained. Otherwise the country defaults. Our model enables us to evaluate interest rate volatility, default risk and informational contagion.

The remainder of the project report is organized in the following way: The model is introduced in section 2. Results are presented in section 3 and discussed in section 4. Section 5 concludes.

2 The Model

The model depicts the setting of roll-over in a currency union. The currency union consists of two countries, country A and country B. Finitely many agents have to take the decision whether or not to invest in government bonds from country A, taking information about the union into account. They can either purchase a risk free asset (i.e. the outside option) or invest in government bonds which are risky because there is some uncertainty whether agents will be paid off in full. Such (partial) default materializes if sufficiently many agents refuse to invest or if creditors demand premia which the fiscal authorities fail to effort. Hence, agents face a coordination problem.

The model is introduced in the following way: First, it is constituted on what kind of information agents rely on. Second, the heuristics as well as the structure of the economy (i.e. the network) are implemented. In a third step, temporal dynamic and a simple endogenization method of the fundamental state are introduced.

2.1 Informational Setting

Let us assume that there is no perfect information in the economy. Instead, agents are confronted with fuzzy information and receive public and private signals which are informative about the state of public finances. Although all agents receive identical public information, private information is idiosyncratic. Hence, they can neither deduce the exact state of world nor the believes of other agents in the economy.

Furthermore, we seek to depict the case of a currency union. To keep our setting simple, we consider a union which is formed by two countries, country A (i.e. the domestic country) and country B (i.e. the foreign country). Agents consider the investment in government bonds from country A. Fundamental states and private signals are correlated. Hence, creditors consider refinancing conditions in both countries. We assume that signals are drawn from bivariate normal distributions because we find the properties of the Gaussian appealing to depict the case of informational dispersion and because it is easy to handle. The fundamental state θ is unknown but agents hold a prior on θ; e.g. θ is normally distributed with known mean and precision. Moreover, player i receives a noisy signal x_i which is informative about θ:

$$x_i = \theta + \epsilon_i$$

where

$$\theta \sim N\left(\begin{pmatrix} y_A \\ y_B \end{pmatrix}, \begin{pmatrix} \frac{1}{\alpha_A} & \frac{\rho_{public}}{\sqrt{\alpha_A}\sqrt{\alpha_B}} \\ \frac{\rho_{public}}{\sqrt{\alpha_A}\sqrt{\alpha_B}} & \frac{1}{\alpha_B} \end{pmatrix}\right)$$

and hence,

$$x_i \sim N\left(\begin{pmatrix} \theta_A \\ \theta_B \end{pmatrix}, \begin{pmatrix} \frac{1}{\beta_A} & \frac{\rho_{private}}{\sqrt{\beta_A}\sqrt{\beta_B}} \\ \frac{\rho_{private}}{\sqrt{\beta_A}\sqrt{\beta_B}} & \frac{1}{\beta_B} \end{pmatrix}\right).$$

The precisions of the domestic and foreign signals are denoted $\alpha_{A,B}$ and $\beta_{A,B}$ and ρ denotes

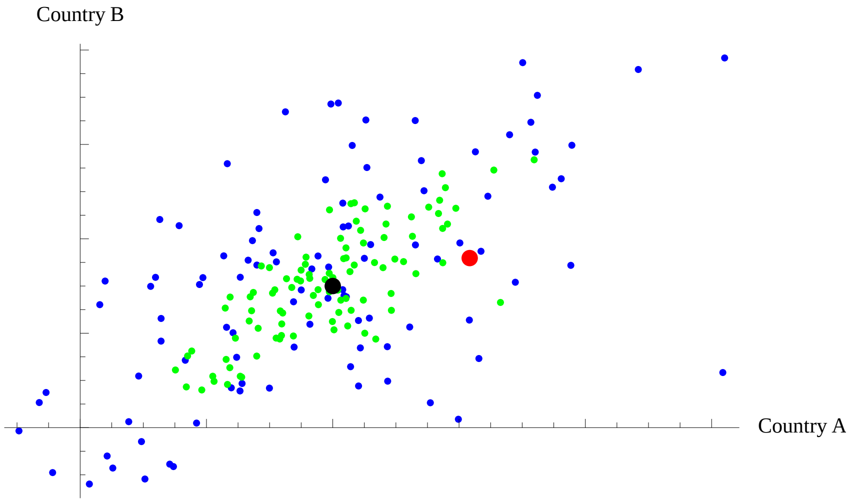


Figure 1: Aggregation of Information

correlation. Agents aggregate information according to Bayes rule[2]. To simplify the notation we denote the precision matrix of the public signal Λ_{public} and $\Lambda_{private}$ denotes the precision matrix of the private signal. Agents aggregate information with the following estimation technique:

$$Estimate = (\Lambda_{public} + \Lambda_{private})^{-1}(\Lambda_{public}y + \Lambda_{private}x_i),$$

where $Estimate$ is the mean of the posterior distribution. Figure 1 illustrates the estimation technique for an arbitrary parameterization and one random draw of θ. Around θ private signals are drawn. The black dot is y, the red one is the unobservable fundamental state θ, the blue dots depict private signals of n agents and their corresponding estimates – the green dots.

2.2 Interactions, the Economy and Investment Decisions

First, any agent in the economy forms her believe about the fundamental state. Based on this believe, she decides whether or not she considers the investment in government bonds. She refuses to invest in any case, if her estimate is lower than a certain threshold ψ_1, where $\psi_1 = \mu_1 y_A$ and $\mu_1 \in [0, 1]$. The threshold is illustrated in figure 2 (dashed line).

Interaction among agents is due to the network structure of the economy. We choose an intuitively appealing structure which captures the notion of locality: the ring network, where agent $i \in (0, \ldots, n)$ is preceded by agents $i-1$, and succeeded by agents $i+1$. The ring is widely used in network studies because its architecture imposes a minimal, unrestrictive and symmetric structure on the network. In particular, there are no "more central" or "more peripheral" nodes

[2]For properties of the estimation technique see Lehmann and Casella (1998) and DeGroot (2004).

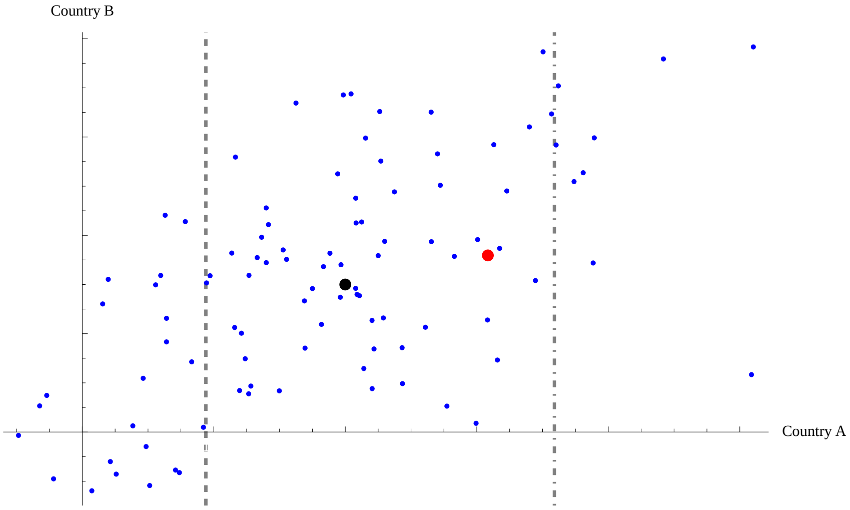


Figure 2: Individual Cutoff

(Whilhite, 2007). Since there is no perfect information, agents are unable to observe realisations of private signals other than their own, but they perceive sentiments in their neighborhood. A neighborhood is a subset of agents consisting of agent's i adjacent neighbours. We restrict the neighborhood of agent i to agents indexed by $i-1$, $i-2$, $i+1$ and $i+2$. The ring network is illustrated in figure 3.

If the adjacent neighbors of agent i are pessimistic about the fundamental state and do not regard to invest because their signals are below the threshold, agent i might also disregard the investment in government bonds because she is irritated by her neighbors' believes. In our model agent i is vulnerable to sentiments in her neighborhood if she is not particularly optimistic, i.e. her signal is below a second threshold ψ_2, where $\psi_2 = \mu_2 y_A$ and $\mu_2 > 1$. The threshold is shown in figure 2 (dotdashed line). If agent i is not particularly optimistic, she also disregard investing if she observes at least half the neighborhood not willing to invest. Note that in this sense pessimism is contagious and might spread across the population.

When the process of believe formation has settled (i.e. believes in the network are stable and not subject to further change after contagion of pessimism has spread across the population), the population is separated into two subsets: the subset of agents *willing to invest* and the subsets of agents *not willing to invest*. In a next step, the price of debt is to be set.

For the price formation three assumptions are crucial. First, only a portion of agents is needed to meet refinancing needs. This seems to be an appropriate reasoning since in the real world only a small portion of potential investors eventually considers to buy bonds from a respective country. Second, from those agents who consider the investment into government

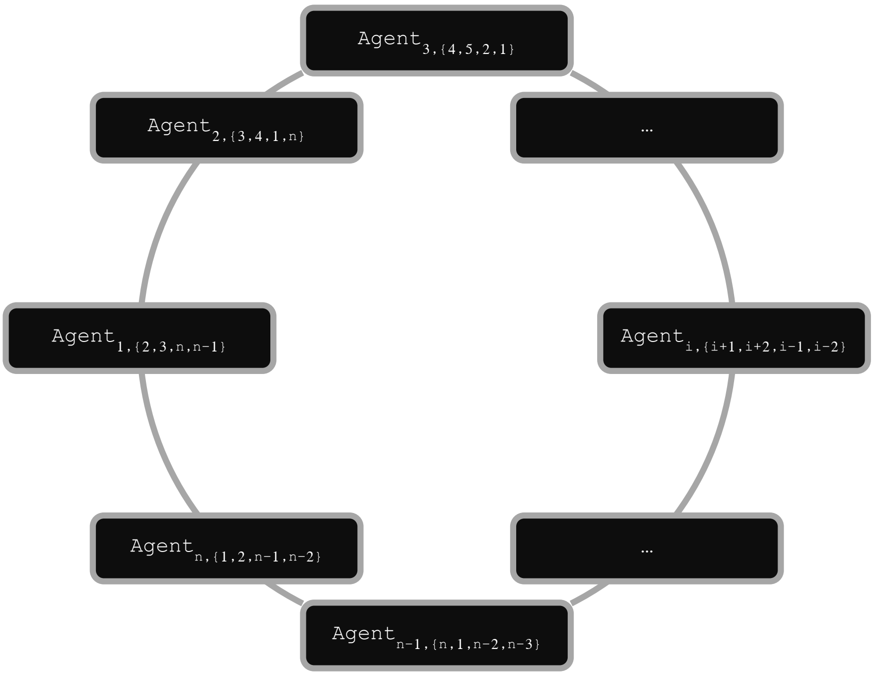


Figure 3: The Ring Network

bonds, the ones with the most optimistic believes accept the lowest returns on their investment. In this sense, the mechanism of government bonds purchase is reminiscent of the actual emission (i.e. government bond auctions). Third, the refinancing ability of a country is determined by the true fundamental state θ_A.

Only part of the population is needed to meet the refinancing needs of the respective country, but this portion δn, where $\delta \in [0, 1]$, has to be both, sufficiently large and all agents have to be willing to invest. Hence, δn has to be as least as large as the cardinality of the subset of agents willing to invest. If this condition is met, those agents will be investing, who are most optimistic on the fundamental state θ_A. If this condition is not met, the respective country is forced into default.

The subset of the most optimistic agents is called the subset of *investing* agents, where cardinality of this subset is δn. If agents belonging to the subset of investing agents are sufficiently optimistic, they will accept a minimum interest rate (i.e. no risk premium). Otherwise agents demand premia. The price of debt is determined in the following way: An average estimate ξ is generated by taking the mean estimate of the subset of investing agents. If this average estimate is larger than a threshold ψ_3, where $\psi_3 = \mu_3 y_A$ and $\mu_3 > 1$, agents accept a minimum price, otherwise they demand a premium:

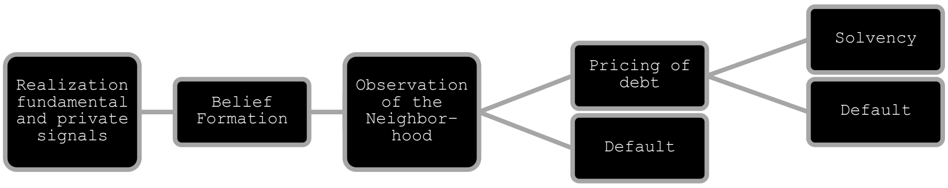


Figure 4: Model Sequence

$$price = \begin{cases} \lambda & if \quad \xi > \psi_3 \\ \lambda + premium & if \quad \xi \leq \psi_3 \end{cases}$$

where

$$premium = -\xi + \psi_3.$$

According to the true realization of the fundamental state the respective country can only afford a certain class of prices. It can only afford prices which do not exceed the fundamental value θ_A. Hence, if $price > \theta_A$ the country is forced into default.

The steps of the model are summarized in figure 4. Note that there are two cases leading to default. First, not sufficiently many agents are willing to invest and second, the respective country cannot afford the price of debt.

2.3 Model Dynamic and Endogenization of the Fundamental State

Refinancing is not a static but a dynamic matter. Therefore, it is instructive to introduce dynamics and chronology into the model. The basic idea is that once a country defaults, it is very likely that this event affects refinancing in the future. In this sense, we believe that history matters when it comes to refinancing. Creditors may loose confidence and bankruptcy might necessitate disruptive measures which weaken the economy and future fiscal positions. In the periods after the default, fiscal positions in the respective country might either turn out to be sustainable despite of the default and creditors regain confidence or a country might get trapped.

We introduce the time dimension simply by iterating the model from above, but there is a link between the periods. Whenever a country defaults, this affects the strength of public finances for τ periods by decreasing y_A, the mean of the distribution from which θ_A is drawn:

$$y_A \kappa^{count}$$

where $\kappa \in [0, 1]$. Each default adds 1 to *count*, but *count* decays linearly with every entry into a new period:

$$count = \begin{cases} 0 & if \quad count_{old} \leq \nu \\ count_{old} - \nu & if \quad count_{old} > \nu \end{cases}$$

where $\nu \in [0, 1]$. This way, preceding defaults affect current refinancing conditions.

3 Numerical Experiments

Numerical experiments are carried out in order to draw conclusions on how the currency union set-up affects refinancing. Therefore, the dynamic model is set in motion with different parameterizations. We perform different classes of experiments, where only a certain set of parameters is altered, while all other parameters are held constant to obtain comparative statics. Essentially, we are interested in price volatility[3] (i.e. variance of prices), incidents of sovereign default and informational contagion due to pessimism spreading over the population. This kind of informational contagion is measured in the percentage change of the number of agents not willing to invest before and after information about the neighborhood is revealed to agents.

For illustration of the model dynamics consider figure 5 which shows dynamic refinancing with arbitrary parameterization[4] and a horizon of 100 periods. The green line represents the fundamental value θ_A, the blue line represents the price of debt and the dashed line represents the benchmark price λ. Note that whenever the price drops to zero, not sufficiently many agents were willing to invest. The second possibility for default is that price of debt exceeds the θ_A.

In the numerical experiments presented in detail below, the model is set in motion m times with identical parameterization and n agents and for t periods (i.e. iterations). From each simulation we retain price volatility (variance)[5], the quantity of sovereign default the percentage change of agents not willing to invest before and after exposure of sentiments in the neighborhood. Note that all experiments focus on refinancing of country A.

[3] Because of the simulation approach it appears to be more informative on agents risk assessment than absolute prices.

[4] α_A=0.25, the rest of the parameters is as specified in table 1.

[5] Zero-prices are dropped, hence volatility is only calculated for positive prices.

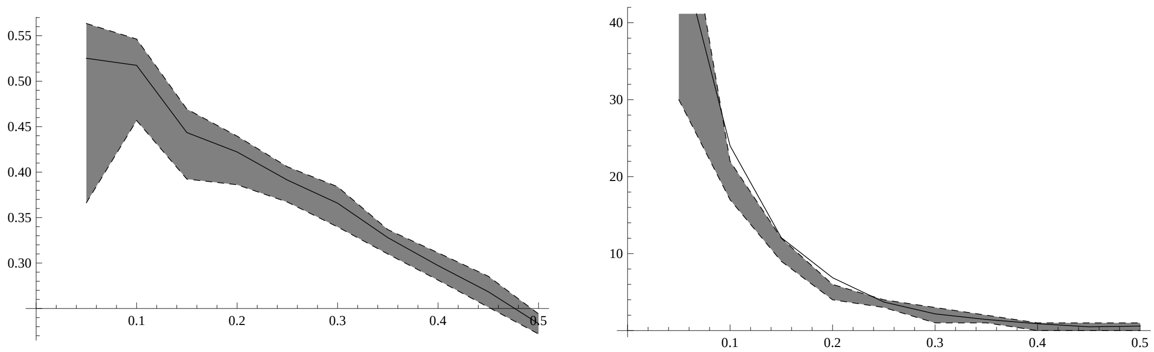
Figure 5: Dynamic Refinancing for Arbitrary Parameterization

3.1 Varying precision of the public information from the domestic country

Table 1: Parameter Table

Parameter	Value
y_A	106
y_B	105
α_A	$i \in (0.05, 0.1, \ldots, 0.5)$
α_B	0.25
β_A	0.2
β_B	0.2
ρ_{public}	0.7
$\rho_{private}$	0.5
m	100
n	100
t	100
μ_1	0.98
μ_2	1.03
μ_3	1.02
δ	0.1
κ	0.99
ν	0.5

Precision of the public information α_A in country A runs from 0.05 to 0.5 with steps of 0.05 (paramterization is shown in table 1). This reduces uncertainty about θ_A. An increase of the precision affects both, the price of debt as well as sovereign default. Note that y_B is slightly lower than y_A. Although default risk appears to decrease monotonically, this is not so clear for average volatility of prices. In the first place, average prices volatility seems relatively



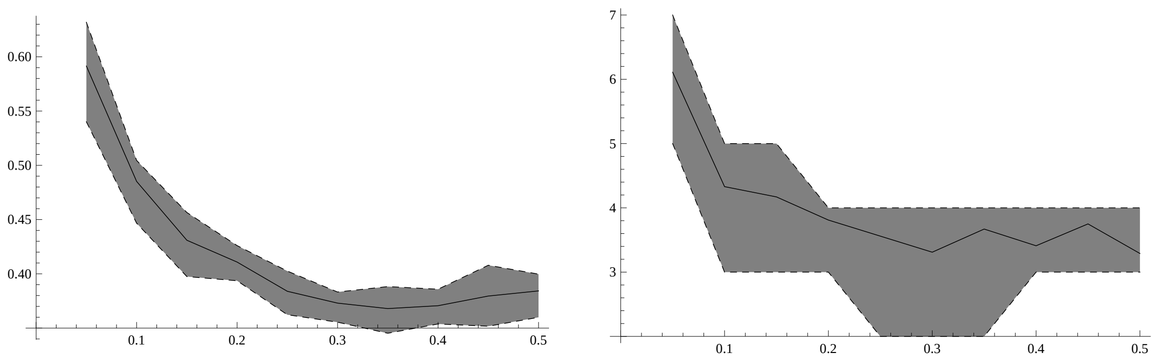
(a) Price Volatility varying α_A

(b) Sovereign Default varying α_A

Figure 6: Effects of increasing Precision of the Public Information (x-dimension)

disperse and there is no clear pattern. For higher values of α_A average price volatility decreases. This indicates that it requires a relatively high degree of precision of the domestic public signal to reduce price volatility effectively. Figure 6 represents the results. The solid lines represent the arithmetic mean across m iterations with identical paramerization and the dashed lines represent the 33$^{\text{rd}}$ and the 66$^{\text{th}}$ percentile[6].

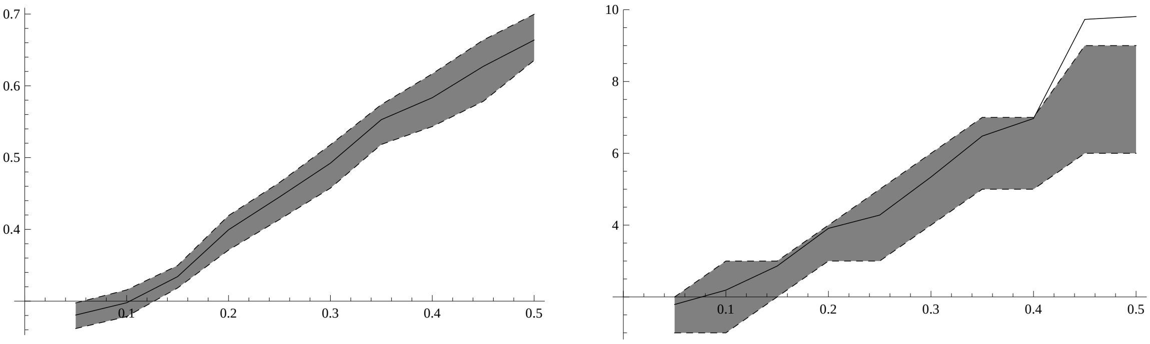
Figure 12 in the appendix indicates that effects of informational contagion through the network structure of the economy are non-monotonous. Increasing precision of the public signal first increases the spread of pessimism and decreases thereafter. Hence, effects of α_A on informational contagion based on the neighborhood are ambiguous.



(a) Price Volatility varying α_B

(b) Sovereign Default varying α_B

Figure 7: Effects of increasing Precision of the Public Information (x-dimension)



(a) Price Volatility varying β_A

(b) Sovereign Default varying β_A

Figure 8: Effects of increasing Precision of the Private Information (x-dimension)

3.2 Varying precision of the public information from the foreign country

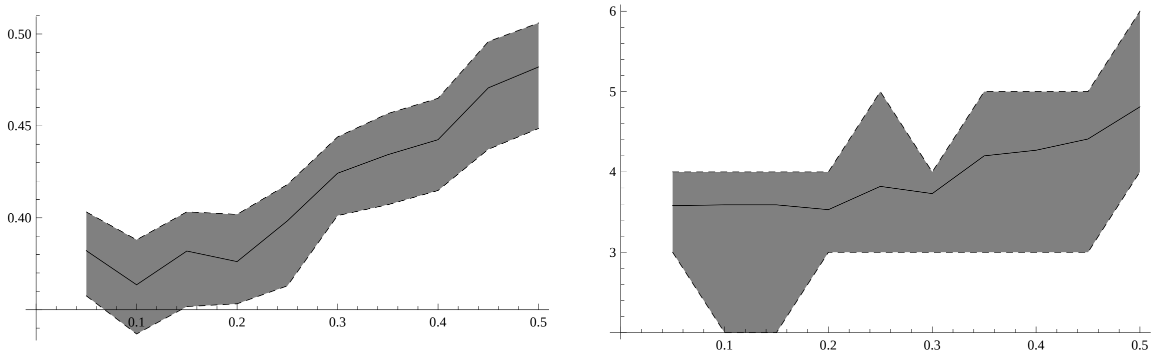
Perhaps the more interesting case is the variation of only the foreign country's parameters, since this gives us an intuition of how one country might be affected by developments across the borders given that there is no genuine domestic change. Figure 7 shows the results for $\alpha_B \in (0.05, 0.1, \ldots, 0.5)$ and $\alpha_A = 0.25$. The rest of the parameters is as in subsection 3.1. Results reaffirm that refinancing in currency unions is indeed affected by developments in fellow countries. Note that although there is no change in country A specific parameters, the degree of precision of public information in country B may alter price volatility as well as default risk by a considerable amount – in our arbitrary case both is reduced by approximately one third on average.

Figure 12 in the appendix provides evidence that neighborhood effects are of minor importance in this experiment.

3.3 Varying precision of the private information from the domestic countries

Parameterization is similar to table 1 but $\beta_A \in (0.05, 0.1, \ldots, 0.5)$ and $\alpha_{A,B}$ are held constant at 0.25. Interestingly, as β_A increases, both, price volatility as well as default risk increase (see figure 8). As the private information gets more precise, agents put more weight on the the private signal. The dispersion of the public information remains unchanged. According to the parameterization, the realization of the fundamental value θ_A might be low in some case (low realization), which, in turn, leads to low realization of the private signal x_i. In the given parameterization y_A is relatively high but higher precision of the private signal let agents

[6] Such bounds are somewhat arbitrary in any case. We decided to take 33^{rd} and the 66^{th} percentile to make it easy to identify cases where the mean is affected by outliers (i.e. the mean lies below or above the bars), which provides an intuition on the respective type of dispersion.



(a) Price Volatility varying β_B

(b) Sovereign Default varying β_B

Figure 9: Effects of increasing Precision of the Private Information (x-dimension)

increasingly disregard this information. Therefore, if the fundamental value is indeed low and precision of the private signal is relatively high, agents will be pessimistic. In this light it is not surprising that with increasing β_A, price volatility as well as incidences of sovereign default increase.

Interestingly, pessimism spreading over the population has a considerable and rather unambiguous effect when varying β_A (see figure 12 in the appendix). The higher the precision of the private signal, the higher is the probability of pessimism spreading in the population.

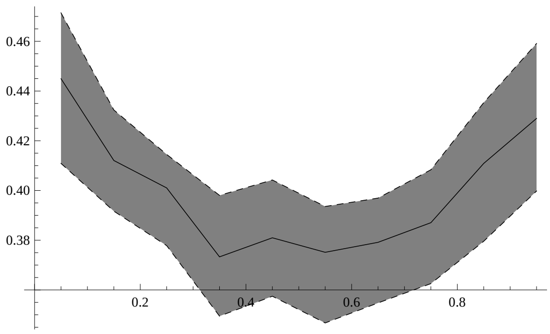
3.4 Varying precision of the private information from the foreign countries

Parameterization is similar to subsection 3.3 but now $\beta_B \in (0.05, 0.1, \ldots, 0.5)$ and β_A is fixed at 0.2. While sovereign default risk appears to be rather unaffected by changes in β_B, this is clearly not true for price volatility (results are depicted in figure 9). Interestingly, we find evidence that price volatility increases with higher precision of the private signal in the foreign country dimension. The logic is similar to the one described in subsection 3.3.

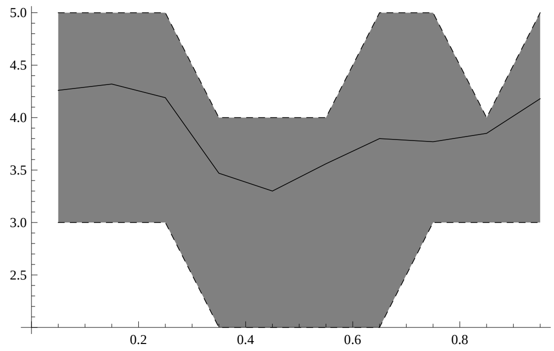
Figure 12 in the appendix provides evidence that neighborhood effects are of minor importance in this experiment.

3.5 Varying correlation of the fundamental state

Figure 10 depicts the result for $\rho_{public} \in (0.05, 0.15, \ldots, 0.95)$ for the same paramaterization than the experiments above but $\alpha_{A,B}$ are held constant at 0.25 and $\beta_{A,B}$ are held constant at 0.2. Interestingly, the default risk appears to only moderately react to changes in the correlation of the fundamental state, which makes it difficult to identify any patterns. Notably, price volatility reacts in a non-monotonous way to changes in ρ_{public}.



(a) Price Volatility varying ρ_{public}



(b) Sovereign Default varying ρ_{public}

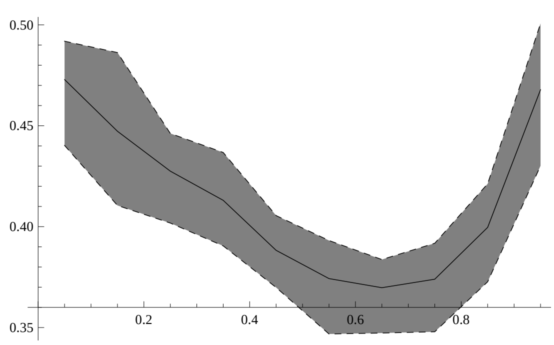
Figure 10: Effects of increasing Correlation of Fundamental States (x-dimension)

Figure 12 in the appendix presents the results for informational contagion due to the network structure of the economy. ρ_{public} is not likely to affect this kind of contagion.

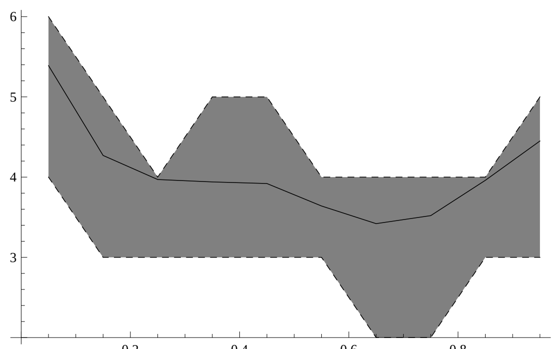
3.6 Varying correlation of the private signal

Parameterization is similar to subsection 3.5, but $\rho_{private} \in (0.05, 0.15, \ldots, 0.95)$ and ρ_{public} is held constant at 0.7 like in the previous experiments. Figure 11 provides a similar intuition than figure 10. Hence, there is an ambiguous effect on price volatility and only a relatively small effect on default risk when varying $\rho_{private}$

Similar to the previous experiment where correlation of the fundamental state is varied, figure 12 in the appendix indicates that neighborhood effects are of minor importance in this experiment.



(a) Price Volatility varying $\rho_{private}$



(b) Sovereign Default varying $\rho_{private}$

Figure 11: Effects of increasing Correlation of Private Signals (x-dimension)

4 Discussion

Note that in our model the refinancing ability of country A is exclusively depending on θ_A. But since θ_A is unobservable, agents take all relevant information into account in order to get a notion on θ_A. Since information on θ_A and θ_B is correlated, agents value information from country B.

Results about varying precision of public information in the union are rather straightforward and intuitive. Higher precision results in lower price variability and lower default risk. As long as both countries in the union are subject to healthy public finances, higher precision is benefitting for refinancing conditions.

This is not necessarily the case for the precision of the private signal. For constant $\alpha_{A,B}$ increasing precision of the private signal may increase both, price variability, and default risk when the fundamental state happens to be indeed low. Against the background of the recent developments in the context of the so called sovereign debt crisis in the Eurozone, this might be an appealing line of reasoning for adverse informational contagion in currency unions. In subsection 3.3 we depict the case of c.p. varying the precision of the private signal in the foreign country dimension and argued that price volatility increases with larger β_B. Consider the case of correlated fundamental states and correlated private information in the currency union setting. Furthermore, assume that the precision of β_B is large and θ_B happens to be relatively low. In our model such conditions affect the price of debt. This example appears particularly instructive since it is seems to be valid that bad news[7] (i.e. media coverage) about e.g. Greece affects the price of debt and default risk in e.g. Italy.[8]

A further interesting result from the numerical experiment is that the kind of informational contagion transmitted by the network structure of the economy, is not likely to originate from abroad. Only varying the precision of public and private information of the domestic country appears to affect this kind of informational contagion. Hence, "panics" triggered by the observation of the neighborhood are likely to originate in the respective country.

Concerning the correlation of the public and private signals there are two lessons one can draw from the simulations: varying correlations has ambiguous effects, and perhaps more importantly, different degrees of correlation do not affect the results fundamentally. Hence, it is not necessarily the degree of correlations driving the results for informational contagion and country risk in currency unions, but rather the fact that there *is* correlation in general.

[7]Note that this means in the case of large β_B that θ_B is low with high probability.

[8]See e.g. Mink and de Haan (2012) for a case study approach assessing the impact of news.

5 Conclusion

The agent-based approach appears to be particularly valid to study debt-roll over in currency unions. Fundamentals are essentially unobservable and hence, there is uncertainty concerning the true state of the world. Heuristics are therefore an appropriate way to describe the behaviour of economic agents.

Our model provides instructive insights on channels of informational contagion. Numerical experiments indicate that the value of informational precision is both, potentially momentous and ambiguous. Although an increase of the precision domestic public information is generally benefitting, this is not necessarily true for low levels of the informational precision because pessimism is more likely to spread. Moreover, higher precision of private information is associated with adverse effects on refinancing. Moreover, “panics” or “runs” in terms of pessimism spreading over the population are not likely to originate from abroad, but are associated with domestic factors.

The simulation approach and our model opens avenues for further research. Testing the model against stylized facts from data on government bonds from Euro members is certainly of particular interest. Moreover, the model allows for applications of laboratory experiments, which would enable us to evaluate and adjust the heuristics in the model.

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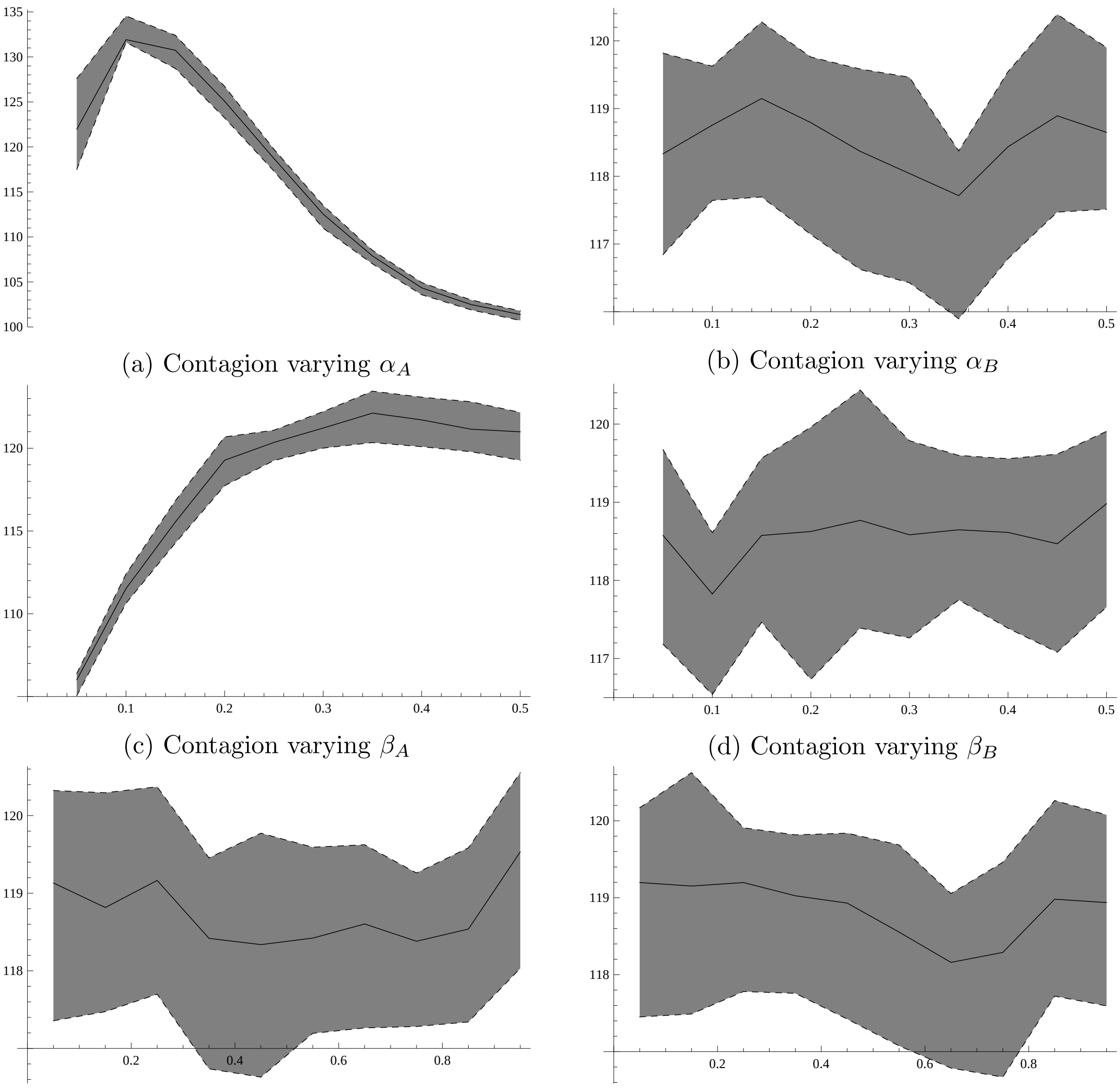
Appendix



(a) Contagion varying α_A

(b) Contagion varying α_B

(c) Contagion varying β_A

(d) Contagion varying β_B

(e) Contagion varying ρ_{public}

(f) Contagion varying $\rho_{private}$

Figure 12: Informational Contagion in the Economy